Deer Creek Reservoir Drainage

TMDL Study

Prepared By:
PSOMAS

Prepared For:
Utah Department of Environmental Quality - Division of Water Quality

Dave Wham
Project Manager

Harry Lewis Judd
Project Supervisor

March, 2002

Deer Creek Reservoir Drainage

TMDL Study

March 2002

Prepared For:

Utah Department of Environmental Quality - Division of Water Quality
Dave Wham – Project Manager
Harry Lewis Judd – Project Supervisor
288 N 1460 W
Salt Lake City, Utah 84114-4870

Prepared By:

PSOMAS
2825 E. Cottonwood Pkwy., Suite 120
Salt Lake City, UT 84121
(801) 270-5777

PSOMAS

Utah Department of Environment Quality
Division of Water Quality

Harry Judd, Project Supervisor

Dave Wham, Project Manager

PSOMAS Project Team:

David Eckhoff, Ph.D., P.E., Team Leader

Alane Boyd, P.E., Project Manager

Charles Gillette, P.E., Project Engineer

Richard King, Engineer

Table of Contents

Table of Contents (cont.)

Table of Contents (cont.)

References

Appendices

List of Tables

List of Figures

Chapter 1 Executive Summary

Deer Creek TMDL

Introduction

Deer Creek Reservoir is located in Wasatch County, Utah on the Provo River. It serves residents of both Utah and Salt Lake Counties by providing a significant amount of drinking and irrigation water, as well as being a popular recreational area. It has been identified as an impaired water body according to Utah's Year 2000 303(d) List of Waters (DWQ, 2000) because of low dissolved oxygen levels at the reservoir bottom and high surface water temperatures which impact the reservoirs fisheries. The watershed study area which drains into Deer Creek Reservoir has an area of 171,663 acres. This area is calculated for lands below Jordanelle Reservoir, and does not take into account any area draining into Jordanelle Reservoir.

Water Quality Analysis

The water quality of the reservoir was investigated to determine the level of eutrophication in the reservoir. Low dissolved oxygen is a symptom of highly eutrophic lakes. During the 1980s the reservoir had experienced high nutrient loads and had become very eutrophic. However, water quality analyses show that the reservoir has improved significantly and could now be considered a mesotrophic lake based on the average Carlson Trophic State index as shown in Figure 1-1.

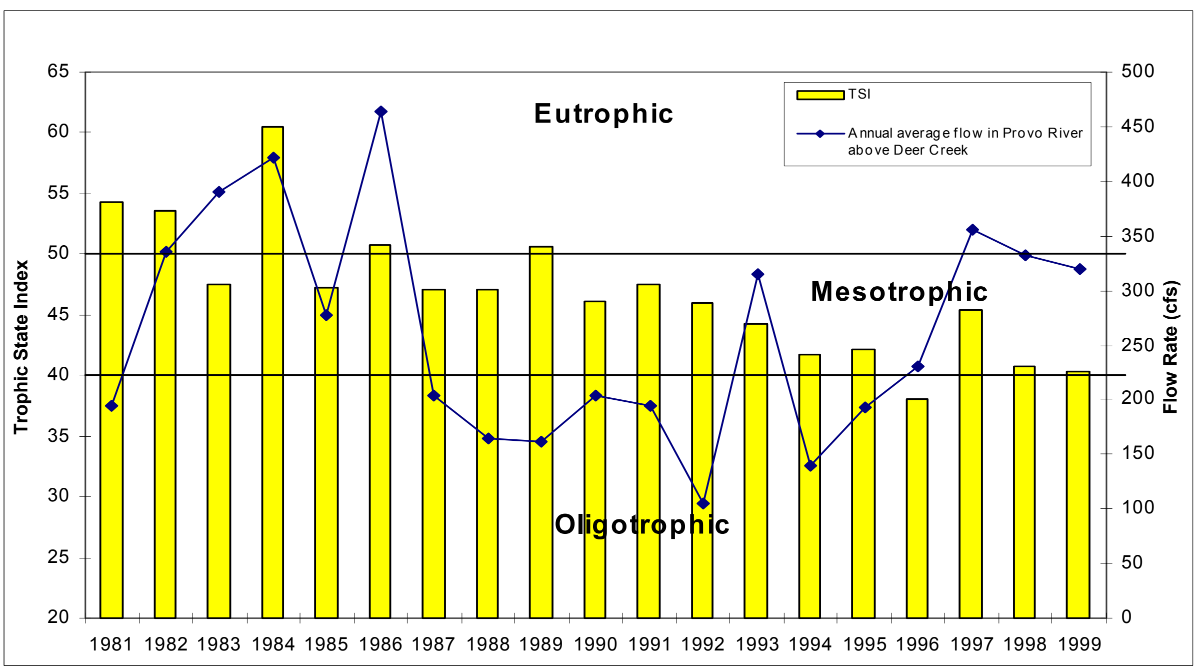


Figure 1-1: Deer Creek Reservoir Average Trophic State Index (TSI) 1981-1999

The improvements can be attributed to the focus on the watershed and efforts to reduce pollution sources. However, despite the significant improvements, low dissolved oxygen concentrations during thermal stratification is still a concern.

An analysis was conducted to determine the actual impairment on the fishery in Deer Creek Reservoir. The results of this analysis indicated that the Utah Division of Wildlife Resources has developed a healthy fishery in the reservoir. The conclusion on the impairment was that the fishery was healthy and that overall the reservoir is healthy. The analysis of information contained in this report will be the basis for a petition to delist Deer Creek Reservoir for temperature. Therefore, the focus of this Total Maximum Daily Load (TMDL) is to maintain current water quality by (1) focusing on reducing nutrient loads through current conservation plans and (2) to assure that new potential sources developed in the water shed will not increase nutrient loading. Dissolved oxygen levels in the reservoir should continue to improve, as nutrient loading remains depressed. This may be due to a lag that exists between phosphorus loading and dissolved oxygen levels. Reduction of existing phosphorus loads are still required to account for future sources and a margin of safety.

Based on the conclusion that current water quality levels should be maintained, the following endpoints shown in Table 1-1 have been assigned to this TMDL.

Table 1-1: Summary of Recommended Targets/Endpoints

Parameter	Proposed Target
Dissolved Oxygen Water Column % Impaired	<50% of column with DO <4.0 mg/l
Fish Habitat Indicator	No Fish Kills
In-lake Phosphorus Concentration	0.025 mg/l TP (Avg all depths)
In-stream Phosphorus Concentration	0.030 mg/l TP 0.020 mg/l DTP
Phosphorus Loads to Lake	15,300 kg/yr TP 9,700 kg/yr DTP 560 kg/mo TP for Aug-Oct 350 kg/mo DTP for Aug-Oct
Average TSI	40-45
Algae Biomass	5.1 ug/l Chlorophyll a 6.5×10^7 um^3/ml Biomass 3.3×10^7 um^3/ml Cyanophyta

DO=Dissolved Oxygen, TP=Total Phosphorus,
DTP=Dissolved Total Phosphorus, TSI=Carlson Trophic State Index

TMDL

Phosphorus sources in the watershed were identified for background, point and nonpoint sources. The only point source in the watershed is the Midway Fish Hatchery. The nonpoint sources were categorized as being related to urban developments or agricultural activities. Table 1-2 shows the current source loads from the watershed. The table also shows the resulting load allocation which includes an allocation for margin of safety and future point and nonpoint sources.

Table 1-2. Total Phosphorus TMDL Load Allocations

Description	Current Loads kg TP / year	Load Allocation kg TP / year	Load Reduction kg TP / year
Groundwater	2,725	2,725	
Background (Includes Jordanelle Reservoir Discharge of 2,965 kg/year)	4,225	4,225	
WLA - Current Point (Hatchery)*	560	400	160
WLA - Future Point	0	500	
LA – Agriculture	6,060	3,595	2,465
LA – Urban	1,600	1,300	300
LA - Future Nonpoint	0	900	
Total Load	**15,300**	**13,800**	**2,925**
10% Margin of Safety		1,500	
Maximum TMDL Load		**15,300**	

* Midway Fish Hatchery allocation represents net increase in total phosphorus load.
** The 15,300 kg/year represents the average load from 1996-1999. Flows during this period appear to be approximately 10% higher than the long term average flow. Even though there is an implicit margin of safety, an additional 10% explicit margin of safety takes this into account.

Recommended Projects

In order to achieve the necessary load reductions, multiple projects will be required that incorporate Best Management Practices (BMPs). The following projects are currently in process of being completed or are recommended to be completed to achieve necessary reductions.

1. *Provo River Restoration Project (PRRP)*
2. *Conversion to Sprinkler Irrigation Systems*
3. *Heber Valley Water Quality Basins*
4. *Cleanup of Potential CAFOs*
5. *Integrated Watershed Information System*
6. *Main Creek Stream Bank Restoration*
7. *Agricultural BMP Projects*
8. *Midway Fish Hatchery*
9. *Cautious Responsible Growth in Heber Valley and Jordanelle Basin*

The PRRP is currently in the process of being implemented by the Utah Reclamation Mitigation and Conservation Commission. Much of Heber Valley's irrigation system is also being converted to sprinklers through projects such as the Wasatch County Water Efficiency Project and efforts by local irrigation companies.

Chapter 2 Introduction

Deer Creek TMDL

Introduction

Waters in Utah that do not meet the water quality standards for their assigned beneficial uses are the focus of the Clean Water Act's (CWA) Section 303 (d), which requires states to identify, then develop and implement plans to improve remaining impaired waters. The Total Daily Maximum Load (TMDL) process, which identifies pollution sources and allocates maximum pollution loadings where water quality goals are not being met, is the required methodology for addressing these listed waters.

The TMDL approach targets watersheds, addressing water quality in a site-specific way tailored to local conditions and objectives. It specifies the increment of water quality improvement required, allocates responsibility for this improvement incrementally among pollution sources, and provides a framework for remedial action. The TMDL process is coordinated with other CWA programs.

In 1999 TMDLs were calculated for the Provo River above the Deer Creek watershed. These TMDLs were documented in *The Upper Provo River Water Quality Management Plan* (1999 Plan). However, at that time, Jordanelle Reservoir have not been in operation. This created a situation in which much of the analysis was based on assumptions. Since that time water quality and flow data has been gathered with the Jordanelle Reservoir in operation. It is important that this data be reviewed and incorporated into this TMDL Plan.

Additionally, the 1999 Plan only addressed the main Provo River, Main Creek, Snake Creek and Daniels Creek. The *Wasatch County Stormwater Master Plan* identifies many subwatersheds within the Provo River system. These subwatersheds need to be considered, analyzed and a TMDL calculated for some of the main waterbodies within the subwatersheds.

Deer Creek Reservoir has been identified as a priority target for the state's water quality improvement effort. Past water quality monitoring has shown that the Deer Creek Reservoir regularly exceeded state water quality criteria for total phosphorous and dissolved oxygen. As a result, the reservoir was listed on the state's 303(d) list of non-supporting waters for these constituents. Listing of a stream segment on the 303(d) requires that a TMDL be completed to address the pollutants of concern in the watershed.

The goal of this effort will be to complete a TMDL analysis aimed at restoring the beneficial uses assigned by the State to Deer Creek Reservoir through analysis of the existing situation, development of pollutant loadings that will allow restoration of the assigned beneficial uses, and development of plans to achieve these loadings, evaluated by monitoring program performance.

Location and Description

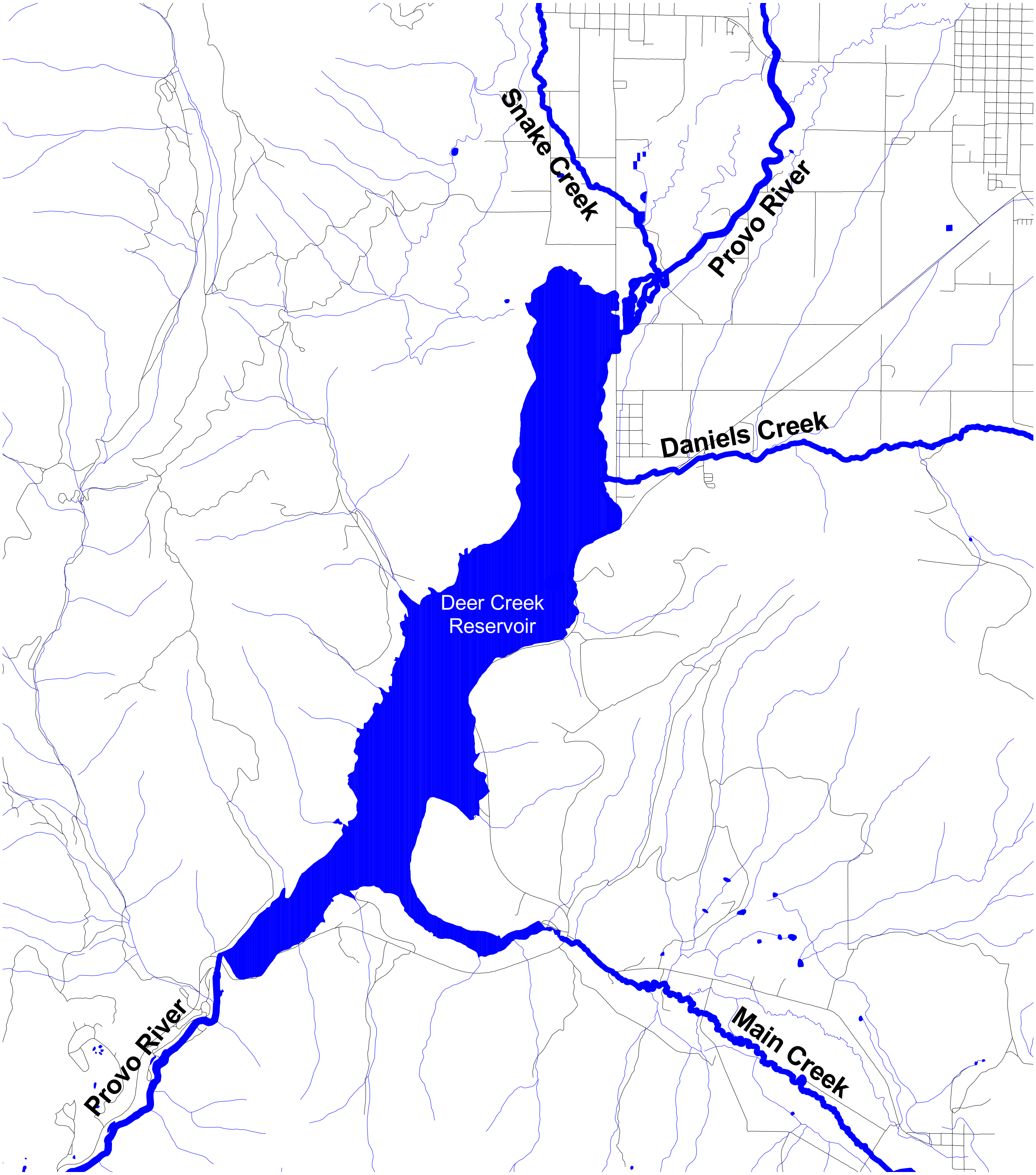
Deer Creek Reservoir is located in Wasatch County, Utah on the Provo River. It serves residents of both Utah and Salt Lake Counties, providing a significant amount of drinking and irrigation water, as well as being a popular recreational area. The reservoir has four major inflows: Provo River, Main Creek, Snake Creek, and Daniels Creek. Figure 2-1 shows the location of the reservoir and its principal inflows.

Deer Creek dam is a zoned earth-fill structure with a structural height of 235 ft. The reservoir has a capacity of 152,700 acre-ft. The outlet works and spillway have a capacity of 1,500 cfs and 12,000 cfs respectively. The dam sits on top of a limestone and sandstone foundation covered by alluvial deposits. A concrete cutoff trench was constructed to stop seepage of water through the structure.

Uses of water from Deer Creek Reservoir can be separated into three major categories: Municipal, Agricultural, and Recreational.

Municipal water users are the water districts located in Salt Lake, Utah, Wasatch and Summit Counties. These agencies provide safe drinking water to residents and industries through the region. The Central Utah Water Conservancy District (CUWCD), the Jordan Valley Water Conservancy District (JVWCD), the Metropolitan Water District of Salt Lake and Sandy (MWDSL), Metropolitan Water District of Orem City (MWDO), and the Metropolitan Water District of Provo City (MWDP) treat and distribute water from the Provo River. Good water quality is especially important to these water districts in order for them to control the expensive costs of water treatment and to provide the highest quality drinking water.

The Provo River is also a source of irrigation water for agricultural purposes. In Heber Valley there are fourteen irrigation companies that have water rights to the Provo River.



N
W
E
S

Figure 2-1
Inflows to Deer Creek Reservoir

1 0 1 2 3 Miles

The Provo River Water Users Association (PRWUA), which includes municipal water suppliers, wholesale water suppliers, and irrigation companies in Utah and Salt Lake Counties, has all rights to water storage contained in the Deer Creek Reservoir.

Jordanelle and Deer Creek Reservoirs, along with the Provo River and its tributaries, are sources of recreation for many people. State Parks are located on both the Jordanelle and Deer Creek Reservoirs. These provide basic services for thousands of recreationists that visit the two reservoirs. They also provide water skiing, swimming, boating and many more activities. These reservoirs and rivers provide excellent fishing for anglers. Water quality is important in regards to safe recreational activities and the preservation of wildlife such as birds, fish and the hosts of additional animal life common to the area.

Previous Studies and Projects

National Lake Eutrophication Study

This watershed has a long history of water quality interest by many Federal, State and local agencies, as well as the general public. Poor water quality conditions were first documented in the National Lake Eutrophication Study in 1974. Of the 27 lakes studied, Deer Creek Reservoir ranked twentieth most eutrophic. At the time of the study the reservoir was eutrophic with anaerobic conditions developing in the hypolimnion in July and persisting until September. Anaerobic conditions also often existed under the ice cover in the January through April period. Algal growth was limited by phosphoruous throughout the summer, except for localized nitrogen limitations during August.

The phosphorous loading in 1974 was determined to be 23,850 kilograms per year, including estimates of direct precipitation and immediate runoff. The reservoir outlet released a total of 15,605 kg/yr of phosphorus giving a phosphorus retention coefficient of 0.35. Based on the Vollenweider model it was determined that a 55 percent reduction in the 1975 phosphorus loading would be necessary to reduce the reservoir trophic state to borderline between eutrophic and mesotrophic. This implied a target loading of 10,730 kg/yr of total phosphorus.

208 Water Quality Study

In the 1975-76 Moutainland Association of Governments 208 Areawide Water Quality Management Study of major lakes in Summit and Wasatch counties, Deer Creek Reservoir was found to be strongly eutrophic in the shallow north end (main inflow end). Undesirable blue-green algae were dominant in this area, particularly during the heavy growth months in late summer. The deeper south end was found to be mesotrophic with the more desirable diatom algae being dominant throughout the summer. However, in the late summer the entire reservoir experienced anaerobic bottom conditions. The Larsen-Mercier model predicted an even more eutrophic condition than was actually observed in the reservoir.

At that time phosphorous loads from inflowing streams were determined to be 23,760 kg/yr. However, the 208 Study did not include estimates of additional loadings from precipitation, groundwater flow, and peripheral surface wash that would bring the total to about 27,000 kg/yr. The average annual phosphorus concentration was 0.074 mg/l based on a stream inflow of 260,500 acre-feet per year. A 50 to 60 percent phosphorus reduction was recommended to achieve a mesotrophic to slightly eutrophic condition in the reservoir. This resulted in a 1985 target loading of 14,355 kg/yr.

1984 Water Quality Management Plan

In a July 1979 letter Governor Scott Matheson committed to the State of Utah to the development of a Reservoir Management Plan for the proposed Municipal and Industrial System of the Bonneville Unit of the Central Utah Project. This action was taken in response to environmental issues raised in the Bonneville Unit Municipal and Industrial System Draft Environmental Impact Statement. The Governor's commitment was followed by action of the Bureau of Reclamation to include a reservoir management plan in the list of mitigating measures for construction of the Jordanelle Reservoir.

As a result of the Clean Lake Studies, the Deer Creek and Proposed Jordanelle Reservoir Water Quality Management Plan was prepared cooperatively by the Jordanelle Reservoir Water Quality Technical Advisory Committee (JTAC) in 1984. JTAC consists of representatives from over twenty Federal, State and local and private organizations, who are involved with water resource management within the Provo River drainage. This new management plan was considered an update to the 208 study previously discussed.

The 1984 plan documented that on average approximately 25,000 kg/yr of total phosphorus was entering Deer Creek

Reservoir on an annual basis. The plan identified goals for reducing the average phosphorus load by 11,000 kg/yr. Table 2-1 shows the goals outlined in the 1984 plan as well as an estimate of the actual reductions achieved since 1984. Many agencies and groups have spent considerable time and money on water quality, erosion control and related projects to improve water quality in Deer Creek Reservoir.

Practice	1984 Management Goal	Estimated Average Annual Reduction (kg)
Heber Valley Regional WWTP	2,600	5,000
Snake Creek Rural Clean Water Program	1,000	1,000
Construct Jordanelle Reservoir	4,800	4,800
Dairy and Feedlot Cleanup Projects	1,000	1,075
Fish Hatchery Phosphorus Removal	500	625
Other Programs	1,100	---
Total	**11,000**	**12,500**

Table 2-1:1984 Management Plan Phosphorus Reduction Goals and Estimated Reductions

In addition to reductions necessary to achieve desired conditions, the 1984 Management Plan also identified a strategy to minimize future phosphorus loads. These included:

- Storm runoff control for new developments
- No-discharge, total containment, or land application of municipal-type sewage effluents containing phosphorus.
- Enforcement of existing ordinances
- Runoff Control plans for new private developments
- Amend Wasatch County and Summit County zoning ordinances for stream bank protection.
- Implement a water quality review process for new public developments
- Upper Provo River streambank soils investigation
- Stabilize or remove Olsen-Neihart Reservoir tailings pond when Jordanelle Dam is constructed
- Stabilize Mayflower tailings ponds
- Storm runoff control around Jordanelle Reservoir
- Develop public education and awareness program
- Continued study and funding of JTAC technical team
- Encourage management boundary and buffer zone around proposed Jordanelle

Heber Valley Regional Wastewater Treatment Plant

In response to water quality concerns, the Heber Valley Special Service District (HVSSD) constructed three aerated lagoons with winter storage, chlorination and land application disposal to treat and dispose of municipal wastewater. The HVSSD facility was originally put into service for Heber City and Midway with the potential for expansion when growth in other areas made it necessary. Reductions in total phosphorus due to the HVSSD facility have been estimated at 5,000 kg/yr. The facility became operational in 1979.

In 1993 and 1994, wastewater facility plans were completed for the Jordanelle Reservoir Basin and the Twin Creeks Special Service District, respectively. Each made plans to utilize the HVSSD treatment facilities to handle the wastewater from their service areas. In this extended capacity, the HVSSD facility will prevent nutrients from entering the Jordanelle Reservoir by treating wastewater at the existing facility. Also, septic tanks have been brought off-line in the Twin Creeks areas as the sewer system has been extended into the service district.

Snake Creek Rural Clean Water Program

The objective of the Snake Creek Rural Clean Water Program was to reduce pollution from agricultural sources through the implementation of best management practices on lands south of Midway and west of Highway 113. The project was completed in 1993 and the reductions in total phosphorus from the Program have been estimated at 1,000 kg/yr.

Construction of Jordanelle Reservoir

The construction of Jordanelle Reservoir, upstream from Deer Creek Reservoir, was identified as a way to trap phosphorus from the Upper Provo River through phosphorus retention and sedimentation. The Jordanelle Dam was completed in April 1993 and was completely filled by 1996. The Jordanelle Reservoir is operated by a Selective Level Outlet Works (SLOW) Tower. This tower allows more flexibility in the operations of the reservoir. The Bureau of Reclamation and the Central Utah Water Conservancy District have completed studies to determine operational procedures that assure downstream water quality and flow targets are met. Since 1996 there has been a reduction in phosphorus loads ranging from 2200 kg/yr to 3500 kg/yr.

Clean Lakes Program

The Clean Lakes Phase I Study and the 1984 Management Plan identified dairy and feedlot operations, housing construction, development of ski resorts, agricultural return flows and stormwater as a significant source of nutrients. The implementation of BMPs was recommended to reduce the phosphorus loadings. The Deer Creek Clean Lakes Phase II Program was initiated to address these sources.

In 1994 the Mountainlands Association of Governments and the Utah Department of Environmental Quality completed the final report for the Deer Creek Reservoir Clean Lakes Phase II Study. The primary objective of Phase II was to address recommendation of the 1983 Clean Lake Phase I Study. The final report documents the measures that were recommended or implemented to reduce agricultural pollution and to educate the public about these pollution sources.

Eleven agricultural operations in the watershed participated in implementing improvements to their operations. Improvements included the construction of concrete manure bunkers, liquid waste lagoons, piping of ditches through corrals, fencing of riparian areas, fertilizer management plans, and off-stream livestock watering systems. The pubic education program involved the printing and distribution of water quality brochures to the general public and a water quality booklet for use by educators.

Wasatch County implemented planning and zoning measures to protect water quality such as sediment control from recreation areas and construction sites. The County also addressed stormwater and flood control issues.

Fish Hatchery Phosphorus Removal

The Clean Lakes Phase I Study also identified phosphorus from fish hatcheries to be a controllable source. In an effort to comply with the water quality objectives, settling ponds were constructed at the Midway Fish Hatchery and phosphorus limits were set through a Utah Pollutant Discharge Elimination System (UPDES) Permit. However, in 1989 the permit was renewed without any phosphorus limits. Through the work of JTAC members the UPDES permit issued in March of 1995 again included phosphorus limits. It has been estimated that 625 kg/yr of phosphorus has been reduced through efforts at the Midway Fish Hatchery.

Tri-Valley Watershed Plan

In 1996, the Natural Resources Conservation Service (NRCS), through the United States Department of Agriculture's Small Watershed Program (PL-566), assisted Wasatch Soil Conservation District and Wasatch County in developing a land treatment watershed plan. The plan addressed natural resource problems and opportunities within the 248,000 acre watershed.

Purposes of the Tri-Valley Watershed Project were water conservation, improved fish and wildlife habitat, and water quality. On-farm irrigation systems fulfilled the purpose of water conservation and improved fish and wildlife habitat. The on-farm systems received a priority because the conserved water would be used to enhance in-stream flows to benefit fish habitat. Some water quality improvements also were a result from decreased surface runoff and decreased deep percolation.

A detailed sediment yield study for various subwatershed areas was also completed as part of the Tri-Valley Watershed Plan. The subwatersheds with significant erosion were then targeted for further study to identify appropriate best management practices.

Chlorophyll Response Model

In 1984 the U.S. Bureau of Reclamation used data on Deer Creek Reservoir for the period 1975, and 1980 to 1983 to develop two mean summer chlorophyll a response models. These models were used to assess the impacts of changes in annual inflow total phosphorus concentrations, and annual discharge volume on the mean summer chlorophyll a concentrations in Deer Creek Reservoir.

The Chloropyll a Response Model suggest that hydrodynamics in the reservoir may be influenced by the reservoir's discharge, affecting the availability of phosphorus in the reservoir. Higher flows through the reservoir would be expected to flush nutrients in the hypolimnion, reducing the phosphorus available to algae in the fall turnover and reducing the production of algae.

The response model makes it obvious that even with a fixed target phosphorus concentration or load, variations in the natural system (i.e., weather, phosphorus retention, hydrodynamics, etc.) will cause a variable response in the production of chlorophyll, algae, and the trophic state of the reservoir.

The analysis using this model shows that if the inflow phosphorus is held to 40 ug/l, the reservoir will be mesotrophic most of the time and borderline eutrophic or worse only 10% of the time. In an average water year this target is approximately 14,000 kg/yr; however in wetter years it would be 21,000 kg/yr or 12,000 kg/yr in a drier year.

Deer Creek Water Quality Model

The Central Utah Water Conservancy District, with the support of JTAC members, in 1995 developed a predictive computer model to simulate water quality in Deer Creek Reservoir. The purpose of the mathematical model was twofold; one, to assist in a better understanding of past problems associated with algal blooms that clogged water treatment plant filters and caused taste and odor problems, and two, to guide management decisions to improve and protect water quality in Deer Creek Reservoir. CE-QUAL-W2, a two-dimensional hydrodynamic water quality model which was developed and maintained by the U.S. Army Corps of Engineers' Waterways Experiment Station, was selected to accomplish this.

The analysis to develop the model found Deer Creek Reservoir to be mesotrophic based on concentrations of total phosphorus (TP), algal chlorophyll and Secchi transparency in the surface water observed during summers of 1985 to 1994. Seasonal mean values of total nitrogen (TN) and TP suggested that the overall TN:TP ratio was approximately 20 which is the point phosphorus would be considered as the limiting nutrient for algal growth. Occasionally, the TN:TP ratio declined to around 10 in the late summer indicating that nitrogen could regulate some components of the algal community in Deer Creek.

The study found decreasing long-term trends in TP and TN concentrations in the reservoir which indicated overall success of point-source and non-point source pollution control programs in the watershed.

Wasatch County Water Efficiency Project and Daniels Replacement Project

The Wasatch County Water Efficiency Project (WCWEP) and Daniels Replacement Project (DRP) were mandated by U.S. Congress in the Central Utah Project Completion Act (CUPCA). The purpose of WCWEP was to increase the efficiency of water use in the Heber Valley by lining irrigation canals to prevent leakage and install a pressurized delivery system to facilitate conversion of flood irrigation farms to sprinkler irrigation. These improvements were meant to bolster stream flows in the Heber Valley and enable the DRP. The WCWEP enables 3,675 acres of farm land to be converted to pressure irrigation. It is estimated that 23,000 acre-feet of water will be conserved each year.

The DRP delivers water to the Daniels Irrigation Company and eliminates the previous need to divert water from the Strawberry Reservoir basin. The elimination of this transbasin diversion increases the natural inflow into Strawberry Reservoir by 2,900 acre-feet benefiting fish and fish spawning.

These projects benefit water quality by reducing the return flows from farms in the Heber Valley which are a significant source of nutrient pollution to Deer Creek Reservoir. The projects were completed in 2001 and improvements to water quality should begin to be apparent.

Deer Creek Resource Management Plan

The Deer Creek Resource Management Plan, for Federal Project Lands surrounding Deer Creek Reservoir, was initiated in 1993 by the Bureau of Reclamation. The overall goal was to develop management strategies to protect and maintain the purposes for which the Provo River Project was authorized by congress, as well as provide long-term management direction for proposed future uses.

The Plan was divided into two phases. Phase One was completed in late 1993 and consisted of researching existing planning efforts, determining plan goals and objectives, and public meetings. Phase One also included an inventory of data to address issues and outlined the procedure to accomplish Phase Two work.

Phase Two involved the development of possible alternatives for management of the resources in the project lands to insure water integrity. A modified Alternative 1 (proposed alternative) was identified as the least damaging alternative. The modification included allowing grazing on project lands east of U.S. Highway 189 as long as best management practices were implemented.

The Plan describes the activities necessary to achieve the desired future condition of the project and includes:

- Area-wide goals and objectives,
- Area-wide management requirements,
- Specific area management direction,
- Lands suited and not suited for resource use and production, and

- Monitoring and evaluation requirements.

The Deer Creek Resource Management plan was adopted in 1998.

Provo River Restoration Project

The goal of the Provo River Restoration Project (PRRP) is to restore the Provo River in Heber Valley from below Jordanelle Dam to Deer Creek Reservoir. In the past many areas of the river have been straightened for construction of flood control levees. In 1999, the Utah Reclamation Mitigation and Conservation Commission began the Provo River Restoration Project (PRRP) between Jordanelle Dam and Deer Creek Reservoir to restore the river's pattern and ecological function to a more natural condition.

The PRRP consists of constructing a multiple-thread meandering channel, reconnecting the river to existing remnants of historic secondary channels and constructing small side channels to recreate aquatic features. Existing levees are set back to create a near natural flood plain that allows the river to change course naturally. Planting and fostering streamside vegetation will provide the necessary environment for healthy fisheries. Side channels and ponds will improve fish habitat and create habitat for wetland dependent wildlife.

Utah Division of Wildlife Resources and U.S. Bureau of Reclamation in 1999 initiated the project by carving new meanders, side channels and wetland ponds in and around the Provo River from about 1.6 miles downstream of Jordanelle Dam to Highway 40. The area was revegetated and an angler access site along this reach was also improved. This work was coordinated with the Central Utah Water Conservancy District, which rebuilt diversion facilities as part of the Wasatch County Water Efficiency Project.

In the Fall, 2000, an additional 1.3 miles of the river was restored between Highway 40 and the bridge crossing on River Road in Midway. Similar to the work upstream, this river reach was taken out of a straightened, diked channel and carved into new meanders, accompanied by side channels and wetland ponds. The project along this reach is mostly complete. Other items, such as, revegetating disturbed areas, constructing additional wetland ponds, constructing two additional side-channels, and completing a new angler access site to include a restroom, resurfaced driveway and parking area, were completed in the Spring, 2001.

Annual Water Quality Implementation Reports

The 1984 Management Plan also suggested that the status of water quality in the Provo River, Deer Creek Reservoir and Jordanelle Reservoir be reported annually. Since 1984 Water Quality Implementation Reports have been prepared by Wasatch County under the direction of the Jordanelle Technical Advisory Committee. These reports accomplish the following:

- Present the results of the annual water quality sampling
- Identify exceedences of water quality parameter standards
- Identify trends in water quality
- Analyze the effectiveness of current management practices, and
- Recommend action for further progress towards water quality improvement.

Water Body Description

As part of the TMDL study, a discussion of the impairments caused by the pollutants is required. Through more than 20 years of study the State of Utah Division of Water Quality and the JTAC agencies have gathered and analyzed data on Deer Creek Reservoir and the watershed. The reservoir is a dynamic system with many characteristics similar to other western reservoirs. The following section describes the knowledge gleaned from the past years of study.

Watershed

The watershed which drains into Deer Creek Reservoir has an area of 171,663 acres. This area is calculated for lands below Jordanelle Reservoir, and does not take into account any area draining into Jordanelle Reservoir. The study watershed has been divided into four sub-watersheds. These sub-watersheds have been delineated at each of the four major inflows to the reservoir at the location where they enter the reservoir. Table 2-2 shows the area contributing to runoff for each of these inflows.

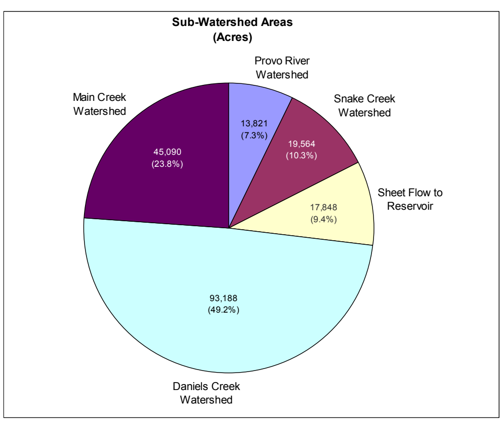


Figure 2-2: Sub-Watershed Areas

Sub-Watershed	Area (acres)
Provo River	13,821
Snake Creek	19,564
Main Creek	45,090
Daniels Creek	93,188
Total	171,663

Table 2-2: Sub-Watershed Areas

The boundaries of each of these sub-watersheds and how they contribute to flow into the reservoir are shown in Figure 4-7.

Table 2-3 below gives information on Deer Creek and Jordanelle Reservoirs.

	Deer Creek Reservoir	Jordanelle Reservoir
Surface Area	2,683 Acres	2,500 Acres
Maximum	2,786 Acres	
Low Season		2,097 Acres
Capacity	152,700 acft	320,000 acft
Mean Depth	60.5 feet	102 feet
Maximum Depth	137 feet	281 feet
Spillway Elevation	5417 feet	6166 feet
Average Annual Inflow (1993-1999)	360 cfs	283 cfs
Outlet Location	25 feet from bottom	Selective level outlets
Annual Precipitation	20 inches	17 inches

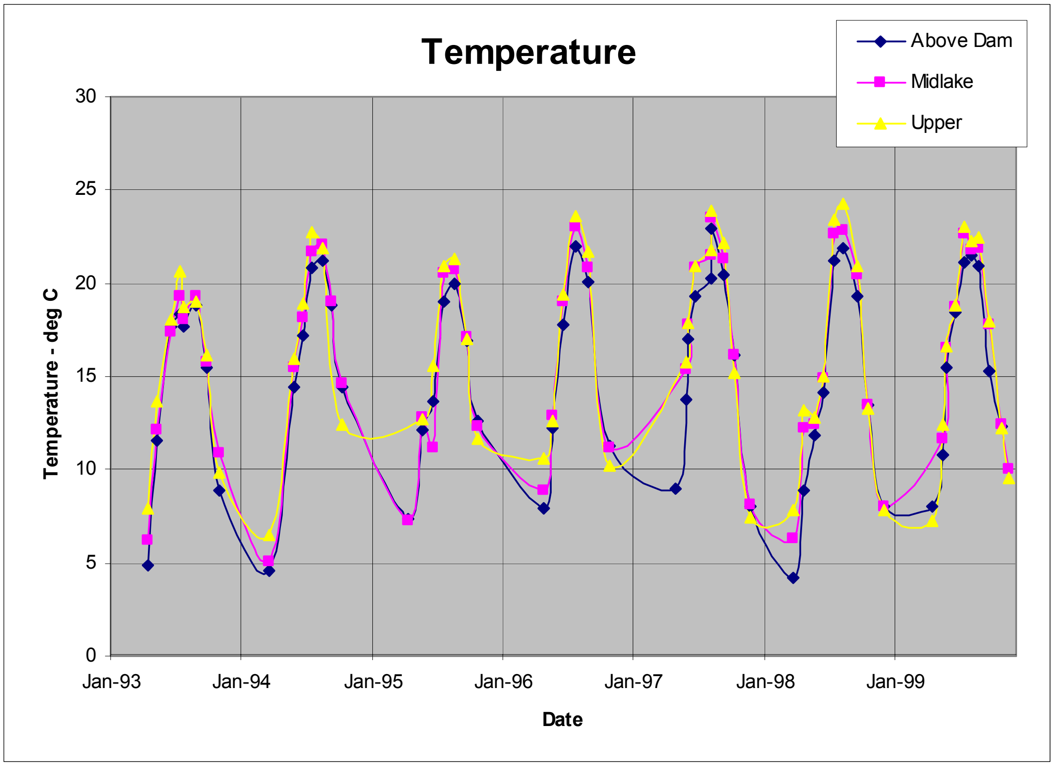
Table 2-3: Deer Creek Reservoir and Jordanelle Reservoir Characteristics

Thermal Stratification Cycle

The thermal stratification cycle in Deer Creek Reservoir is typical for lakes and reservoirs in Northern Utah. As the temperatures begin to increase in Deer Creek during the summer the reservoir begins to stratify into multiple layers of varying temperatures. The cause of stratification being the natural physical properties of water to become less dense with an increase in temperature. Stratification of Deer Creek Reservoir is evident by the middle of July and continues through September. The surface temperatures during these months commonly exceed 20 deg C while the hypolimnion temperatures rarely exceed 15 deg C. Figure 2-3 shows the surface water temperatures in the Reservoir. Figure 2-4 shows the stratification cycle for 1999. The reservoir will exceed the 20 deg C threshold to depths of up to 10 meters. In the upper end of the reservoir where depths are less than 10 meters, the temperature may remain above 20 deg C throughout the entire water column.

In October, as air temperatures decrease and begin to cool the surface temperatures, the reservoir mixes through a convection process, an event commonly known as turnover. The reservoir remains in a fully mixed state until surface temperatures approach freezing and a reverse stratification occurs. This state continues as long as the surface temperatures remain above 4 deg C.

Figure 2-3: Deer Creek Reservoir surface water temperatures from 1993 to 1999



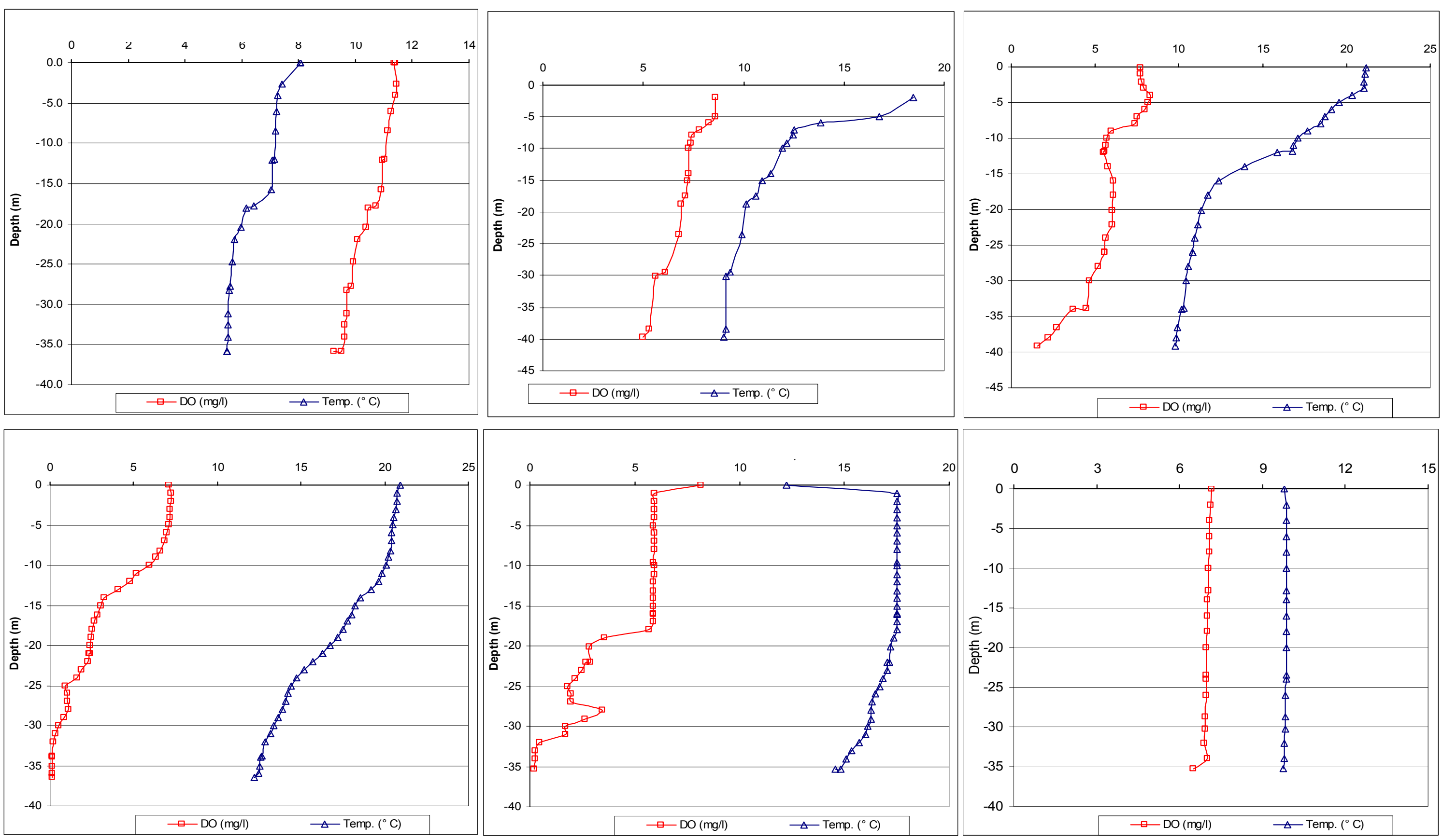


Figure 2-4: Temperature and DO Profiles for 1999

Dissolved Oxygen

As shown in Figure 2-4, the dissolved oxygen levels in the reservoir are directly related to the stratification cycle. As the reservoir becomes stratified and mixing between layers ceases, the dissolved oxygen levels begin to become depleted from natural biological and chemical processes. Eventually in the deeper portions of the reservoir the oxygen levels will become completely depleted, or anoxic. At this point only anaerobic processes continue and the water can build up substances known to cause taste and odor problems. In the deep waters of Deer Creek Reservoir near the dam embankment, approximately 65% of the water column at worst case during the year will have DO concentrations less than 4.0 mg/l, the threshold value used by the State to assess beneficial use support; and approximately 45% of the water column will be below 2.0 mg/l. The State has determined a impairment exists to the reservoir fishery because more than 50% of the column is below 4.0 mg/l during at least part of the year.

Figure 2-5 shows the depths of water with dissolved oxygen levels below 2.0 mg/l since 1986.

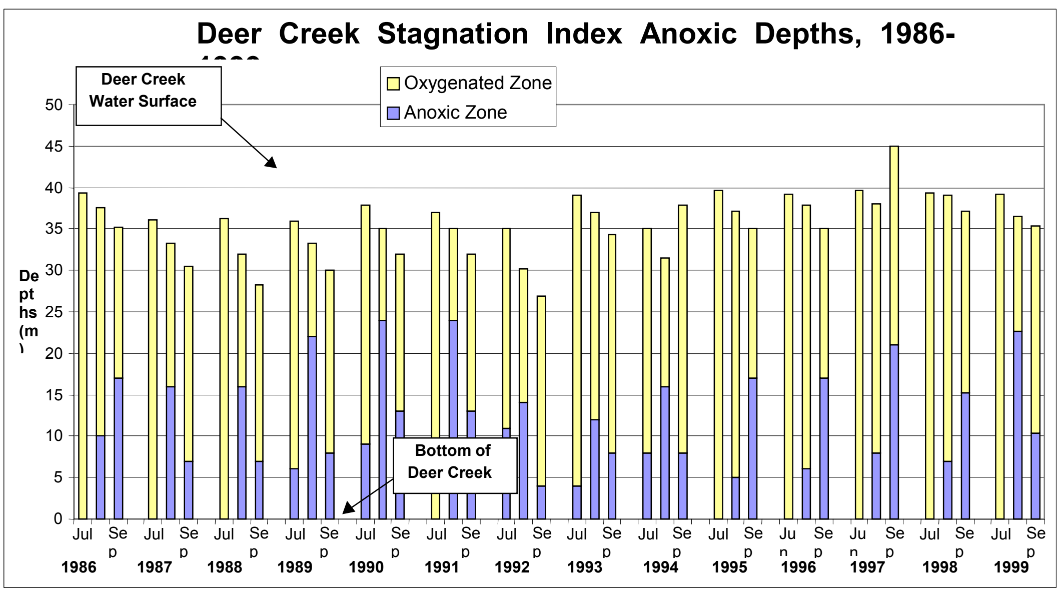


Figure 2-5: Deer Creek Stagnation Index Anoxic (<2.0 mg/l DO) Depths 1986-1999.

Trophic State

The dissolved oxygen levels in the reservoir are considered to be related to the trophic state of the reservoir. Trophic state is a classification of reservoir health based on the level of biological activity and growth. Lakes and reservoirs are generally classified into one of three categories: eutrophic, an overabundance of nutrients and biological growth; mesotrophic, a medium level of nutrients and biological growth; and oligotrophic, a lack of nutrients and biological growth.

Eutrophic lakes have impaired water quality since increased amounts of nutrients can spawn the growth of significant amounts of algae. Algae in high production can form blooms (visible floating mats of algae) on the surface of the reservoir which reduces aesthetics. Blue-green algae, cyanophyta, are a particular problem because of toxins that are produced and released into the water which can be harmful for drinking. When the algae begins to die, it sinks to the bottom of the reservoir and begins to aerobically decay until oxygen is depleted.

The trophic state of Deer Creek Reservoir has been monitored since 1981 using equations proposed by Carlson (1977) called the Trophic State Index (TSI). The average TSI is calculated using total phosphorus concentration, chlorophyll-a concentration, and Secchi depths throughout the months of May to September. The following equations are used:

$$TSI = 60 - 14.41 \ln [\text{ Secchi disk (meters) }]$$
$$TSI = 9.81 \ln [\text{ Chlorophyll a } (\mu g/L)] + 30.$$
$$TSI = 14.42 \ln [\text{ Total phosphorus } (\mu g/L)] + 4.15$$

Figure 2-6 shows the TSI values of Deer Creek Reservoir since 1981 plotted with average flow. In the early 1980's, the reservoir was eutrophic, but has been steadily improving since the focus on water quality improvement in the reservoir became heightened. The improvements can be attributed to reductions in phosphorus outputs. A significant portion of these reductions can be attributed to construction of the HVSSD wastewater treatment facility, agricultural sources improving operations, dairy operations having decreased in number in the Heber Valley, and the Jordanelle Reservoir serving to retain a significant portion of phosphorus. The reservoir is no longer eutrophic, but rather is mesotrophic and very borderline oligotrophic. However, despite the improvements in trophic state, the dissolved oxygen levels may still be a concern.

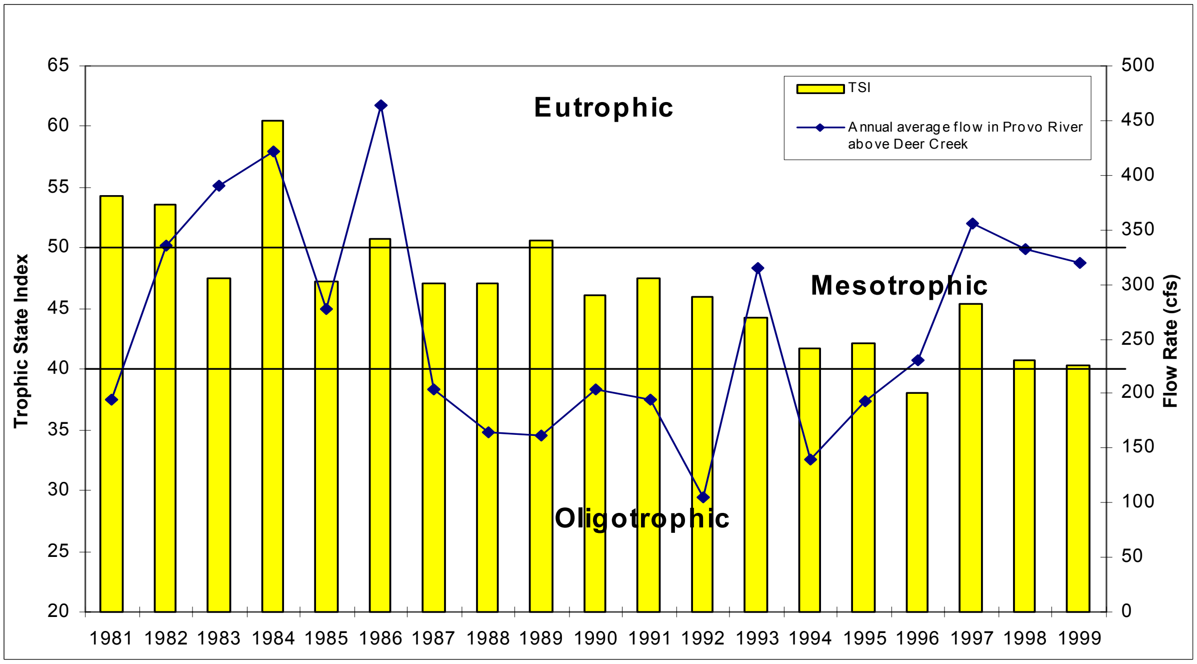


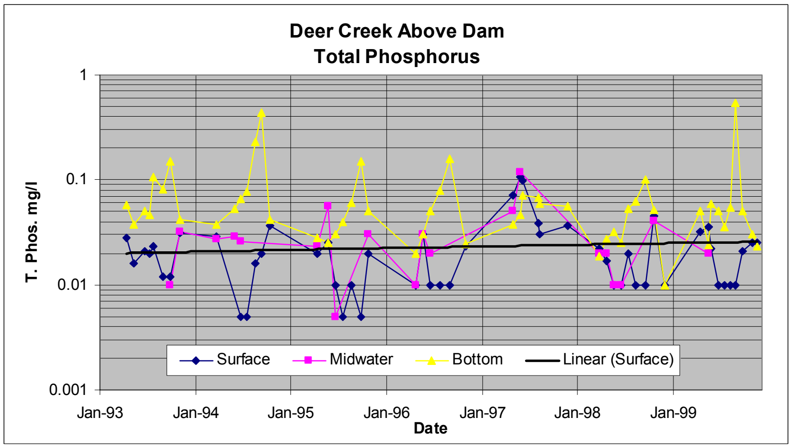
Figure 2-6: Deer Creek Reservoir Average Trophic State Index (TSI) 1981-1999

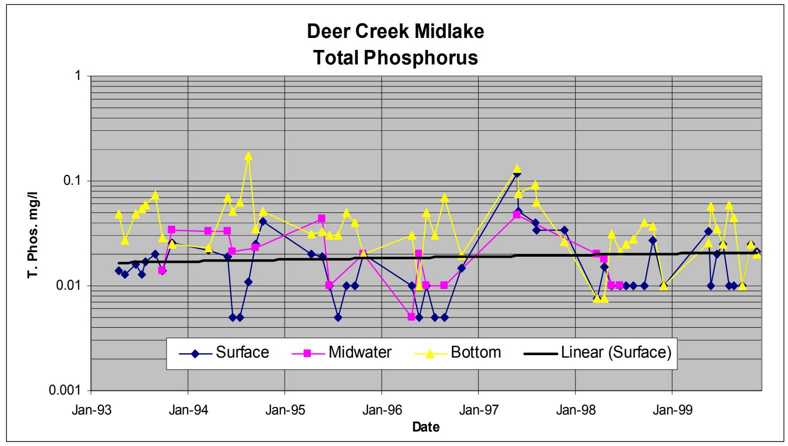
Phosphorus Analysis

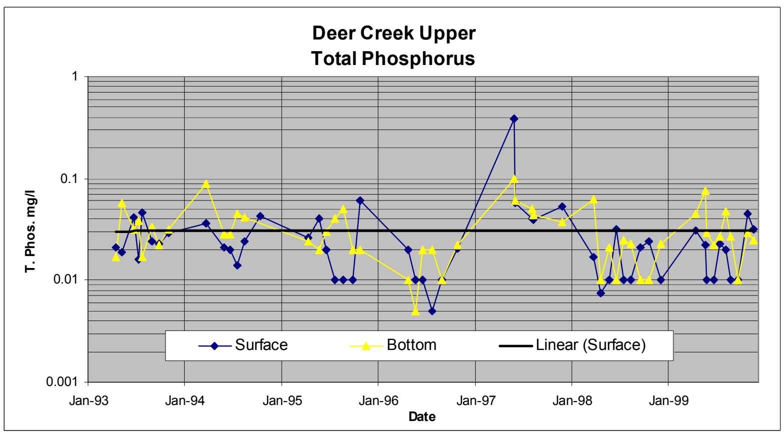
The growth of algal communities in Deer Creek Reservoir are generally considered to be limited by phosphorus since nitrogen to phosphorus ratios average at approximately 11. Occasionally, the system as a whole may be considered to be nitrogen limited since the N:P ratio at times will drop to levels of approximately 1.0, but this is an infrequent event and is even more tempered by the fact that the blue-green algae can metabolize nitrogen from the air as well as the water. Regardless, phosphorus has always been the nutrient of concern for this watershed; it is considered to be a more controllable pollutant.

Total Phosphorus levels in Deer Creek Reservoir during 1993 to 1996 are shown in Figure 2-7. The graphs show the cyclical pattern of phosphorus in the reservoir that follow from the effects of thermal stratification. As the reservoir stratifies, phosphorus levels decrease in the surface layer and increase in the bottom layer. Decreased phosphorus levels in the surface are explained by settling of particulate phosphorus and the consumption of dissolved phosphorus by algae which will eventually settle as well. Meanwhile the bottom layers show increased levels due to dissolved oxygen depletion which leads to a release of phosphorus from sediments. At turnover in October, the reservoir mixes and the phosphorus levels become homogeneous throughout the reservoir. The mix increases the levels of surface phosphorus providing for potential algae growth spurts immediately after turnover. Algae blooms have been reported in October and November.

Figure 2-7: Total Phosphorus Levels in Deer Creek Reservoir at Sampling Locations







The phosphorus levels in the reservoir can be correlated to phosphorus levels in the streams. There are four major stream inputs to Deer Creek Reservoir that are monitored which are, listed in order of importance: Provo River, Snake Creek, Main Creek and Daniels Creek. Table 2-4 shows the phosphorus and total suspended solids that are discharged into Deer Creek Reservoir from 1993-1999. The period from 1996-1999 represents the flow regime and pollutant inputs resulting after the completion and normal operation of the Jordanelle Reservoir. Figure 2-8 shows the comparative contributions from the four streams to the total input of phosphorus and flow. These graphs show that Provo River contributes 75% of the flow yet only 69% of the phosphorus load. Main Creek on the other hand contributes 8% of the flow and 17% of the phosphorus load. Figure 2-9 shows the Dissolved Total Phosphorus and Total Phosphorus concentrations in the four major contributing streams.

	1993	1994	1995	1996	1997	1998	1999	Average
Provo River above Deer Creek, STORET 591363								
Weighted Average Flow (cfs)	314	138	198	262	303	332	319	**267**
TP Weighted Average (mg/l)	0.077	0.040	0.060	0.047	-	0.026	0.065	**0.052**
TP Annual Load (kg/yr)	21,671	4,975	10,472	10,866	-	7,681	18,551	**12,369**
DTP Weighted Average (mg/l)	-	-	0.025	0.025	-	0.009	0.018	**0.019**
DTP Annual Load (kg/yr)	-	-	4,478	5,773	-	2,591	5,253	**4,524**
TSS Weighted Average (mg/l)	24.2	7.7	27.1	11.2	18.6	8.7	27.6	**17.9**
TSS Annual Load (kg/yr)	6,778,611	944,936	4,774,856	2,629,371	5,025,665	2,586,511	7,856,242	**4,370,884**
Snake Creek above Deer Creek, STORET 591016								
Weighted Average Flow (cfs)	45	38	50	54	48	57	43	**48**
TP Weighted Average (mg/l)	0.057	0.058	0.061	0.038	-	0.017	0.037	**0.045**
TP Annual Load (kg/yr)	2,259	1,934	2,690	1,860	-	873	1,416	**1,839**
DTP Weighted Average (mg/l)	-	-	0.029	0.023	-	0.009	0.013	**0.019**
DTP Annual Load (kg/yr)	-	-	1,270	1,134	-	476	502	**846**
TSS Weighted Average (mg/l)	5.4	11.0	14.0	8.7	10.1	10.1	10.9	**10.0**
TSS Annual Load (kg/yr)	213,742	369,582	616,915	421,925	431,283	507,661	423,365	**426,353**
Daniels Creek above Deer Creek, STORET 591352								
Weighted Average Flow (cfs)	24	8	18	14	22	19	22	**18**
TP Weighted Average (mg/l)	0.300	0.104	0.103	0.082	-	0.067	0.066	**0.120**
TP Annual Load (kg/yr)	6,517	702	1,645	1,047	-	1,160	1,281	**2,059**
DTP Weighted Average (mg/l)	-	-	0.046	0.049	-	0.030	0.044	**0.042**
DTP Annual Load (kg/yr)	-	-	732	625	-	513	854	**681**
TSS Weighted Average (mg/l)	241.7	36.4	86.7	62.9	90.3	37.8	28.1	**83.4**
TSS Annual Load (kg/yr)	5,257,412	247,102	1,390,923	801,933	1,801,933	651,235	549,040	**1,528,511**
Main Creek above Deer Creek, STORET 591346								
Weighted Average Flow (cfs)	23	11	28	65	30	23	16	**28**
TP Weighted Average (mg/l)	0.128	0.046	0.137	0.125	-	0.058	0.067	**0.093**
TP Annual Load (kg/yr)	2,570	437	3,452	7,154	-	1,183	977	**2,629**
DTP Weighted Average (mg/l)	-	-	0.038	0.099	-	0.030	0.035	**0.050**
DTP Annual Load (kg/yr)	-	-	964	5,669	-	605	511	**1,937**
TSS Weighted Average (mg/l)	106.1	25.7	108.7	19.9	139.5	45.4	68.8	**73.5**
TSS Annual Load (kg/yr)	2,136,137	243,025	2,750,898	1,146,639	3,727,492	926,538	1,005,716	**1,705,207**
Total Combined Loads								
Weighted Average Flow (cfs)	406	194	293	395	403	431	400	**360**
TP Weighted Average (mg/l)	0.091	0.047	0.070	0.059	-	0.028	0.062	**0.060**
TP Annual Load (kg/yr)	33,018	8,048	18,259	20,927	-	10,898	22,225	**18,896**
DTP Weighted Average (mg/l)	-	-	0.028	0.037	-	0.011	0.020	**0.024**
DTP Annual Load (kg/yr)	-	-	7,443	13,201	-	4,186	7,120	**7,987**
TSS Weighted Average (mg/l)	39.7	10.4	36.4	14.2	30.5	12.1	27.5	**24.4**
TSS Annual Load (kg/yr)	14,385,902	1,804,646	9,533,591	4,999,868	10,986,373	4,671,944	9,834,363	**8,030,955**

Table 2-4: Stream inputs of Phosphorus and Total Suspended Solids to Deer Creek Reservoir 1993-1999.

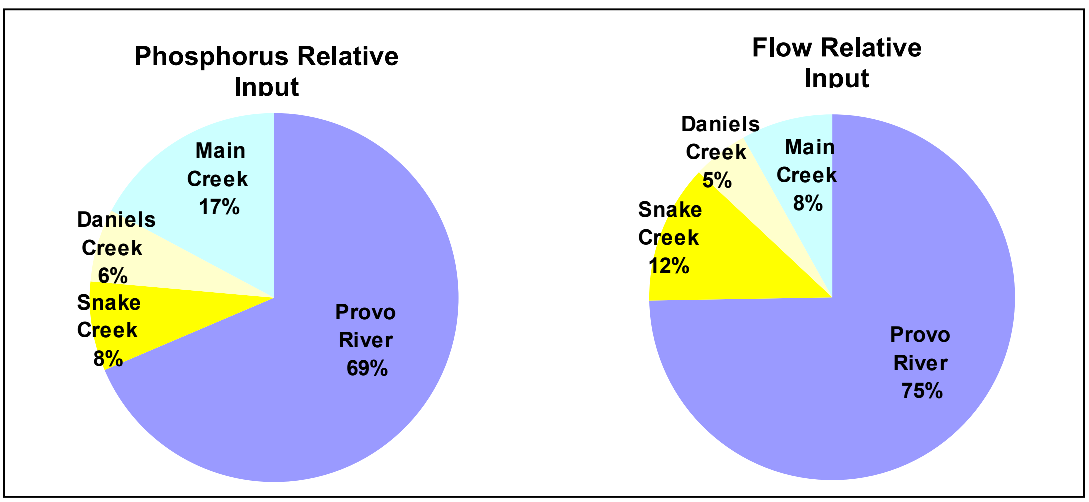
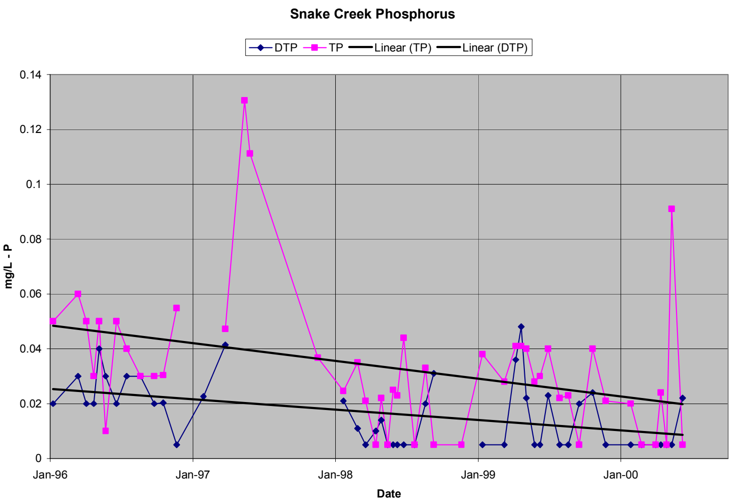
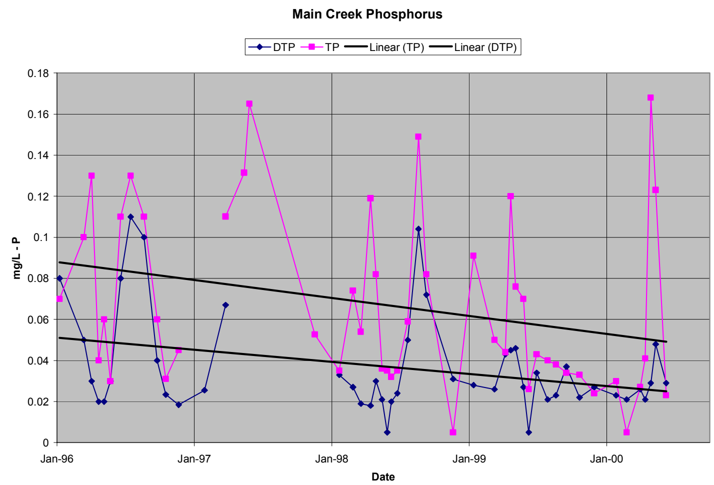
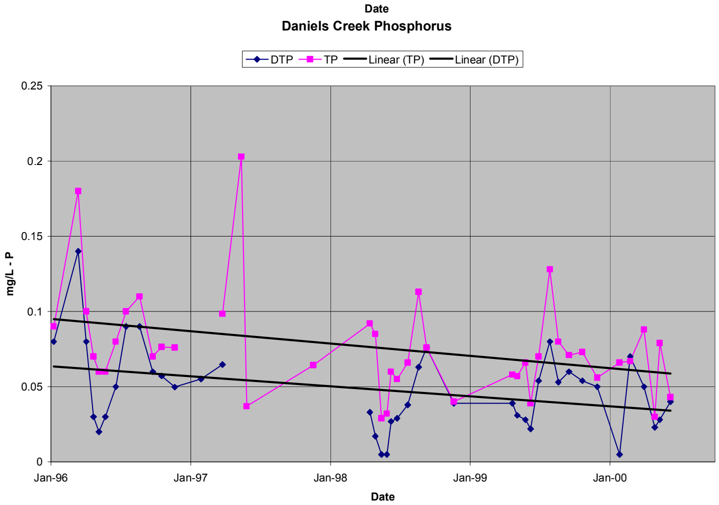


Figure 2-8: Average Contribution of Phosphorus and Flows to Deer Creek Reservoir since operation of Jordanelle Reservoir 1996-1999.







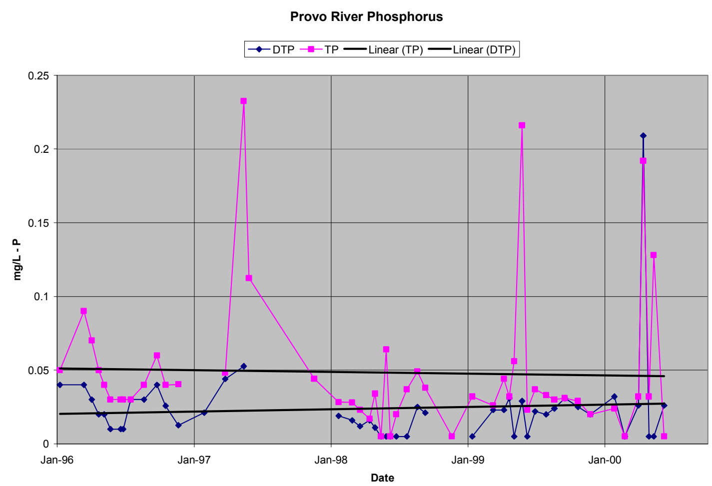


Figure 2-9: Phosphorus Concentrations in Provo River, Snake Creek, Daniels Creek and Main Creek.

Chapter 3 Water Quality Analysis

Deer Creek TMDL

Introduction

Deer Creek Reservoir is a vital source of water to Utah and Salt Lake Counties, and a prime Wasatch County recreational destination. It has been identified as an impaired water body according to Utah's Year 2000 303(d) List of Waters (DWQ, 2000) because of low dissolved oxygen levels at the reservoir bottom and high surface water temperatures which impact the reservoirs fisheries. This chapter discusses the water quality standards compared with monitoring and the targets and endpoints that are recommended from the analysis.

Beneficial Uses

Each stream and reservoir in the State of Utah is classified according to its beneficial uses. The classifications are used to determine the required standards for water quality parameters. The classifications of Deer Creek Reservoir per Utah Administrative Code R317-2 Standards of Quality for Waters of the State are defined as:

Class 1C: Protected for domestic purposes with prior treatment processes as required by Utah Department of Health.
Class 2A: Protected for primary contact recreation such as swimming.
Class 2B: Protected for secondary contact recreation such as boating, wading and similar uses.
Class 3A: Protected for cold water species of game fish and other cold water aquatic life, including the necessary aquatic organisms in the food chain.
Class 4: Protected for agricultural uses including stock watering and irrigation of crops.

Water Quality Monitoring Program

The Jordanelle Technical Advisory Committee (JTAC) has been reviewing monitoring data in watershed since 1984. JTAC is a watershed coordination group representing over twenty federal, state, local and private agencies. JTAC receives monetary and in-kind support from drinking water suppliers in Utah and Salt Lake County as well as the State and Federal governments.

JTAC currently coordinates the monitoring program that takes nearly 600 samples annually at 45 locations in Provo River watershed rivers and streams and Jordanelle and Deer Creek Reservoirs (Psomas, 2000). The samples are sent to the Utah State Laboratory to be analyzed and the results are reported through the U.S. Environmental Protection Agency's (EPA) STORET (STOrage and

RETrieval) database.

For this TMDL analysis, data from January 1996 through July 2000 was used for most analyses since this is representative of the flow and pollution regime since operation of the Jordanelle Reservoir. A few analyses extend to 1993 to help better identify the water quality trends of the watershed. It was not part of the scope of this study to analyze data in the Jordanelle Reservoir basin.

Table 3-1 shows the STORET monitoring locations where water quality data was available. Figure 3-1 shows the location of each of these sites.

Table 3-1: Water Quality Monitoring Sites

STORET Number	Description
499687	Little Deer Ck Ab Cnfl / Provo River
499713	Midway FH Comp of Two Outfalls
499719	Midway FH Inflow Composite
499725	Spring Ck Ab Cnfl / Provo R Nr Heber
499733	Provo R At Jordanelle On US40 Xing
591002	Lower Charleston Cnl Ab Cnfl / Daniels Ck
591016	Snake Ck Ab Cnfl/ Provo R At USBOR Guage
591027	Sagebrush-Spring Ck Cnl At US189 Xing
591045	Snake Ck Ab WMSP Golf Course Near Ranger's House.
591321	Provo River Bl Deer Creek Res
591322	Deer Creek Res Ab Dam 01
591323	Deer Creek Res Midlake 02
591324	Deer Creek Res Upper End 03
591345	Deer Creek Res Midlake Up Wallsberg Bay Off Creek Inlet 08
591346	Main Ck Ab Deer Ck Res At US 189 Xing
591352	Daniels Creek Ab Deer Creek Res
591354	Daniels Creek At First Diversion
591355	Daniels Ck At Whiskey Springs
591363	Provo River Ab Cnfl/ Snake Ck At McKeller Bridge

While data were obtained for all listed sampling stations, not all of them had sufficient data to be used for calculating loads. Some sites only have measurements for one or two years while some have data for the entire period. These sites with minimal data will be used to better understand small sub-watersheds in an effort to better identify point and non-point sources.

Where applicable, flow data was obtained from USGS stream gauges located within the study area. At locations without USGS continuous gauges, flows were measured by field crews. Flow from these gauging stations is considered to be more accurate and at a higher resolution than those recorded by field crews.

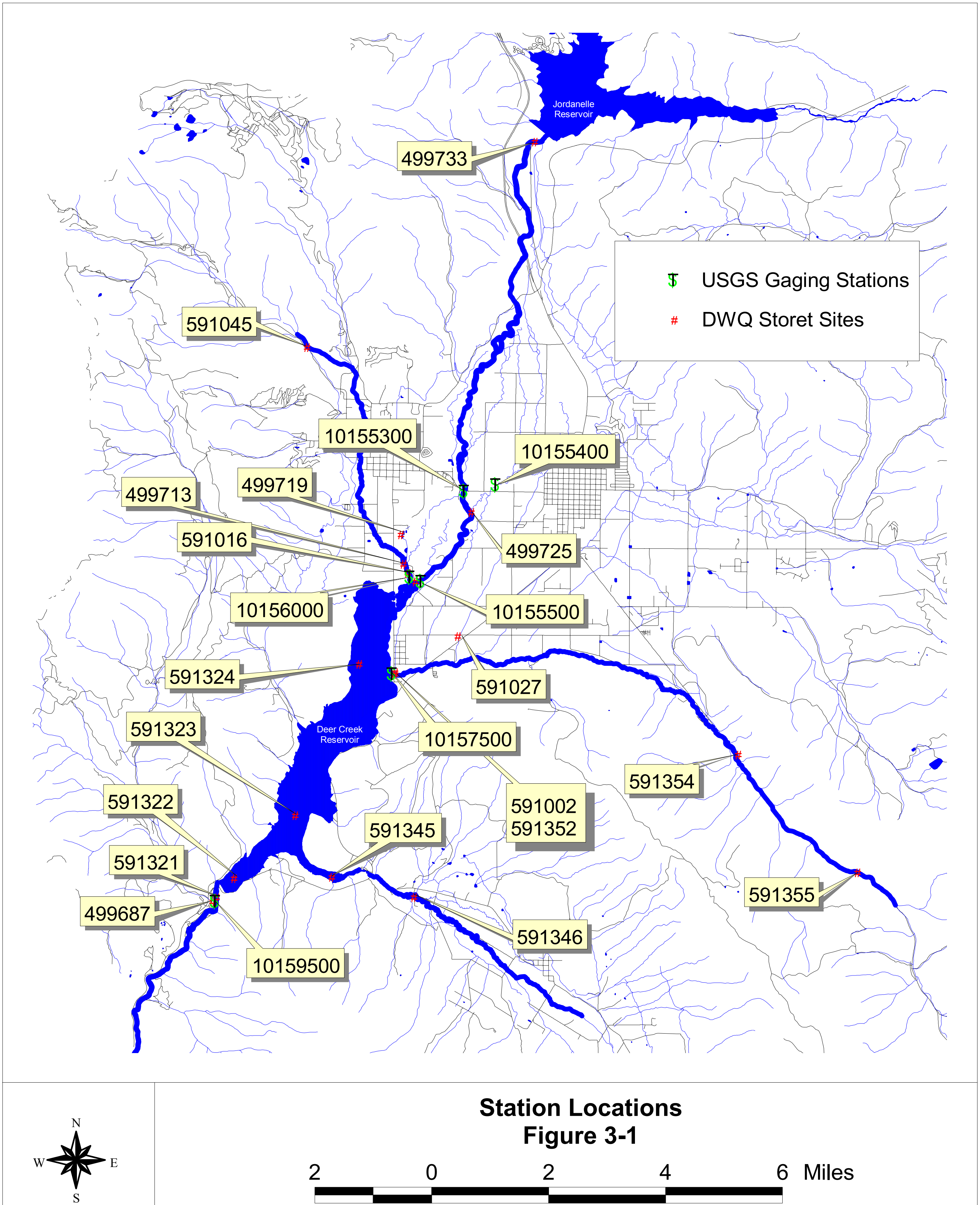
USGS data is recorded continuously which is much more often than water quality samples are taken. When loading calculations are performed, USGS flows will be used where appropriate. Table 3-2 shows the USGS gaging stations located within the study area as well as which Storet sites will use flow data for each gaging station. Figure 3-1 shows where these sites are located.

Table 3-2: USGS Flow Gaging Stations

Station	Description	Used for STORET Site
10155300	Provo River Near Midway	Not Used
10155400	Spring Creek Near Heber City	499725
10155500	Provo River Near Charleston	591363
10156000	Snake Creek Near Charleston	591016
10157500	Daniels Creek At Charleston	591352
10159500	Provo River Below Deer Creek Dam	591321

Additional flow data was obtained for the release from Jordanelle Reservoir and the Timpanogos Canal Diversion respectively from the U.S. Bureau of Reclamation (USBR) and the Utah Division of Water Rights. These flows are used to calculate the flow at STORET 499733 Provo River below Jordanelle Dam which is located downstream of the dam and the diversion. The flow at this station is calculated as the diversion flow subtracted from the Jordanelle release. Appendix G contains a tabulation of the flow data obtained from the USGS and the Division of Water Rights.

In addition to Utah DWQ's water quality data obtained through EPA's STORET system, temperature and dissolved oxygen data were obtained at different depths at Deer Creek and Jordanelle reservoirs. These data were gathered as part of the JTAC monitoring program by Central Utah Water Conservancy District at several locations within each reservoir. Profiles for temperature and dissolved oxygen are included in Appendix F for the year 2000.



Station Locations
Figure 3-1

Data Distribution Analysis

To address the question of whether the values reported are reasonable, a data distribution analysis was performed. This analysis determines the number of samples which lie within one, two, or three standard deviations from the mean. The number of samples which lie outside of this range is also included. Appendix D shows the results of this analysis for the five-year period of data. The results show that a majority of values, 78 percent, lie within one standard deviation from the mean. Eighteen percent lie between one and two standard deviations, and four percent lie greater than two standard deviations from the mean.

Appendix E contains a tabulation of the water quality data obtained for the eight constituents of interest. It also shows highlighted values where the measured values exceed the state standards and indicator values, if applicable. Simple statistics such as minimum, maximum, average, number, and standard deviation are also shown. High concentrations of total and dissolved phosphorus are a concern in this area. No other constituents have concentrations which consistently exceed state indicator values.

As a result of this data analysis procedure, and after discussion with DWQ, all data falling outside of three standard deviations from the mean were excluded from this TMDL study. All of the data, however, is included in the appendices mentioned previously in this section. Also, in 1997 there was a problem with the quality testing of a large number of phosphorus samples. As a result, the state has removed these values from its database. During this year, only a few reliable samples remained. As a result, phosphorus values were not used for 1997.

Reservoir Impairment Analysis

Applicable Utah Water Quality Impairment Criteria

Utah's 303(d) List shows Deer Creek Reservoir is impaired for dissolved oxygen and temperature. The list identified the basis of dissolved oxygen impairment as follows:

> Exceedence criteria for dissolved oxygen have been defined using the one-day minimum dissolved oxygen concentration of 4.0 mg/L. In addition a wider latitude in percentages has been allowed associated with dissolved oxygen. When the concentration is above 4.0 mg/L for greater than 50% of the water column depth a fully supporting status is assigned. When 25-50% of the water column is above 4.0 mg/L, it is designated as

partial supporting and when less than 25% of the water column exceeds the 4.0 mg/L criteria, it is designated as not supporting its defined beneficial use. (DWQ, 2000)

Exceedence criteria for temperature is based on the 3A beneficial use limit of 20 deg C which has been identified as the indication of a fishery stressor.

Analysis of Fishery Impairment

The identified impairment of the cold water fishery by the 303(d) is based solely on the reservoir data compared to State standards. An investigation of the status of the fishery was conducted to determine the validity of the fishery impairment.

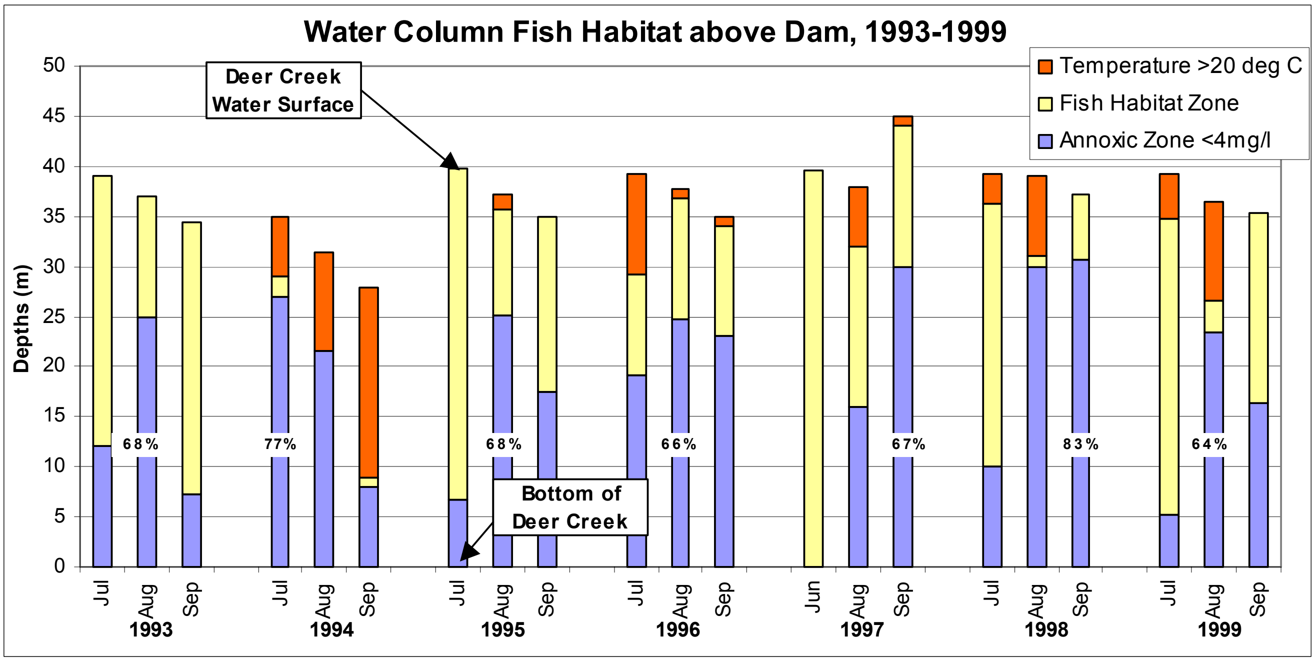
The water column data during the critical months of stratification (July, August, September) were analyzed at the deepest portion of the lake near the dam and at midlake to determine the portion of epilimnion which exceeds 20 deg C in temperature and the portion of the hypolimnion which has dissolved oxygen levels below 4.0 mg/l. This data is presented in Figure 3-2.

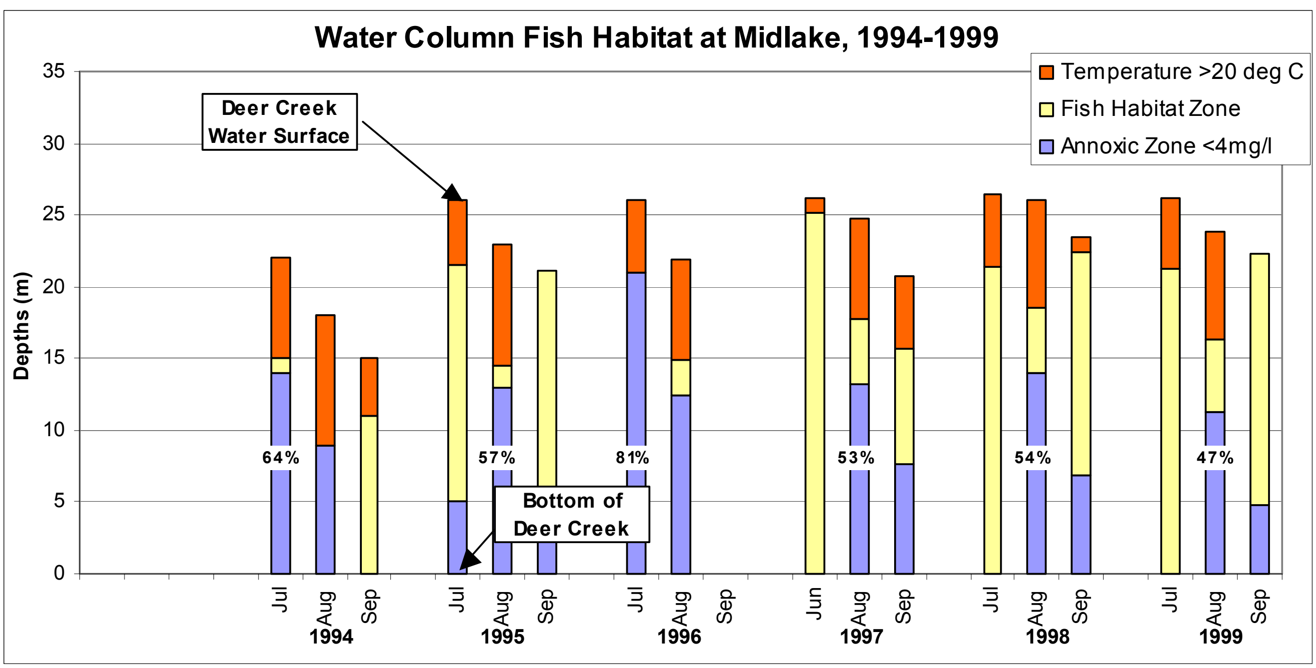
As can be observed in this figure, on average – during the month of greatest stratification – approximately 70% of the water column is below the 4.0 mg/l DO threshold showing the justification of the non-support determination. The figure also shows that high temperatures can penetrate as low as 10 meters into the water column significantly shrinking the fish habitat envelope, thus justifying the non-support determination for temperature. During 1994 in August, the combination of DO and Temperature impairments appear to completely eliminated the envelope in both monitoring locations for a short period of time. Other years show that when the envelope was as small as one or two meters in one of the locations that the other location had at least a 5-meter envelope.

In an effort to better understand the Deer Creek fishery, fisheries data was obtained from the Utah Division of Wildlife Resources (DWR), which has conducted fish surveys since 1993. The fishery data is shown in Figure 3-3 which was adapted from reports prepared by Don Wiley and Charlie Thompsen(2000) of the Division.

An attempt was made to correlate the fishery data in Figure 3-3 to the fish habitat data in Figure 3-2, to see if decreases in fish populations corresponded to water column impairments. As can be observed, the correlations are not apparent. The reports show the establishment of an excellent trout, walleye and perch fishery. Rainbow trout have recovered from extremely low numbers during 1993 and 1994 to a stabilized healthy population. The improvements are the result of reduced walleye predation on the trout with DWR planting of larger adolescent fish. During this period of time, no fish kills have been reported and angler catch rates have improved. The strength of the fishery seems to indicate that the current water quality conditions are conducive to fish survival.

Figure 3-2: Water Column Fish Habitat in Deer Creek Reservoir 1993-1999.





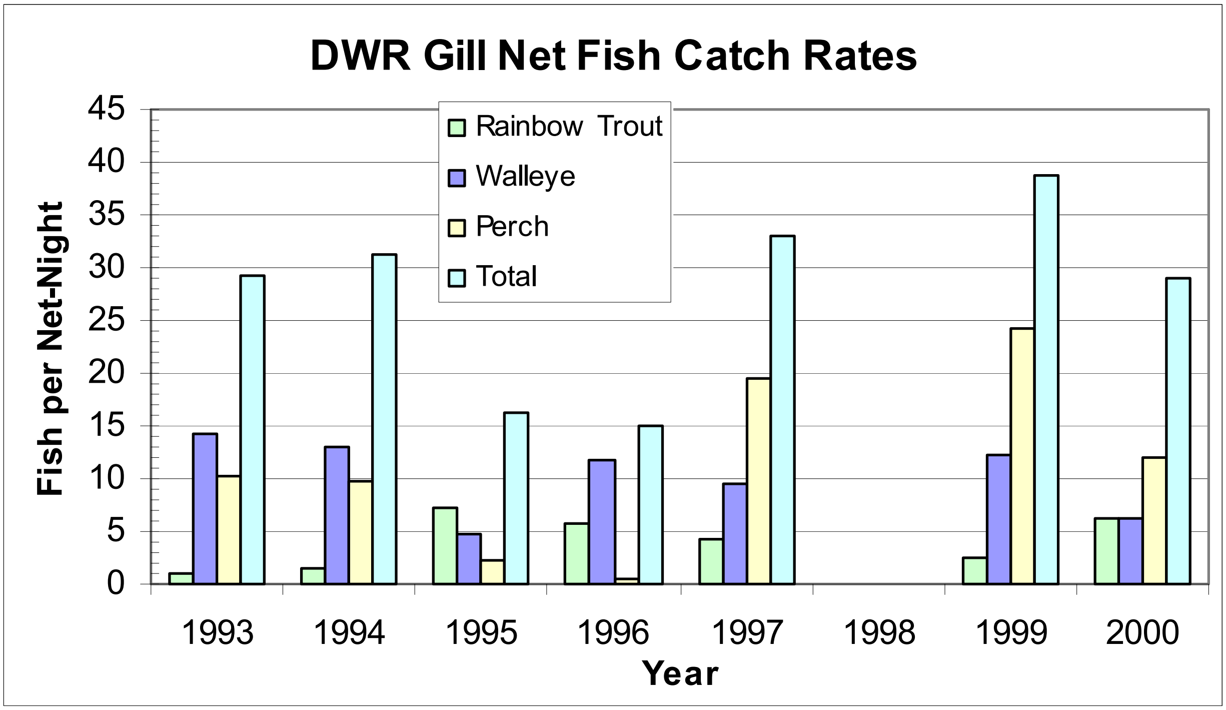


Figure 3-3: Utah Division of Wildlife Resources Gill Net Catch Rates 1993-2000.
(Data source: Wiley and Thompsen, 2000)

CONCLUSIONS ON FISHERY IMPAIRMENT

The DO and temperature data would tend to indicate limited fish habitat, however, the healthy fish population observed by DWR seems to indicate the opposite. The best conclusion that can be drawn from this information is that while there are areas in the reservoir where fish populations are likely stressed during the months of deep stratification, stressors are not fatal. It appears that other areas exist providing adequate habitat during the critical period. In addition, the high temperature penetration in the epilimnion often only exceeded the 20 deg C standard by one or two degrees while the hypolimnion DO depletion generally decreases gradually with depth where hardy fish may be capable to survive below the habitat envelope in waters of 3-4 mg/l DO.

Another explanation for the healthy fish population is that, except for 1994, it appeared that when the fish habitat envelope was squeezed in one portion of the lake that the other location had a more reasonable envelope. For example, in 1995 and 1996 the midlake location indicated a stressed fish habitat while the above dam location indicated a much better habitat, and in 1998 and 1999 vice versa. Fish populations may be migrating during summer months of stratification away from stressing habitats into localized pockets of improved habitat throughout the reservoir or even into the stream channels.

TEMPERATURE DELISTING

It is recommended that Deer Creek Reservoir be delisted from the 303(d) list as impaired for temperature. This recommendation is given for the various reasons, recognizing that the surface temperatures in Deer Creek exceeds state guidelines for a Class 1A cold water fishery during the summer months.

The primary reason for delisting is that our analysis has determined that the source of temperature impairment is not induced by human activities. The primary source of heat in the reservoir is solar radiation and natural environmental factors. The most significant inflow to Deer Creek is Provo River. The upstream Jordanelle Reservoir has the ability to control water temperature in Provo River through selective level outlet works (SLOW) withdrawal.

Figure 3-4 shows the temperatures in Provo River during optimized operation of Jordanelle during 1996. As shown, the temperatures of the river entering Jordanelle Reservoir above Hailstone during the critical months of July and August are two to six degrees (Celsius) higher than the temperatures of water being released below the dam. Before the construction of Jordanelle, these higher temperature waters would continue to increase in temperature through the three to four mile stretch of river now inundated by Jordanelle Reservoir and the 10-mile stretch from the dam location to Deer Creek Reservoir.

Figure 3-5 shows the diurnal and average temperatures in Provo River just before it discharges into Deer Creek Reservoir. The maximum temperatures represent the peak day temperatures where solar radiation causes rises in temperature through the 10-mile stretch between Jordanelle Dam and Deer Creek Reservoir. The minimum temperature is the night temperature which closely reflects the temperature of water discharged from Jordanelle since solar radiation is not present. This data indicates how temperature reductions in the SLOW are currently maximized.

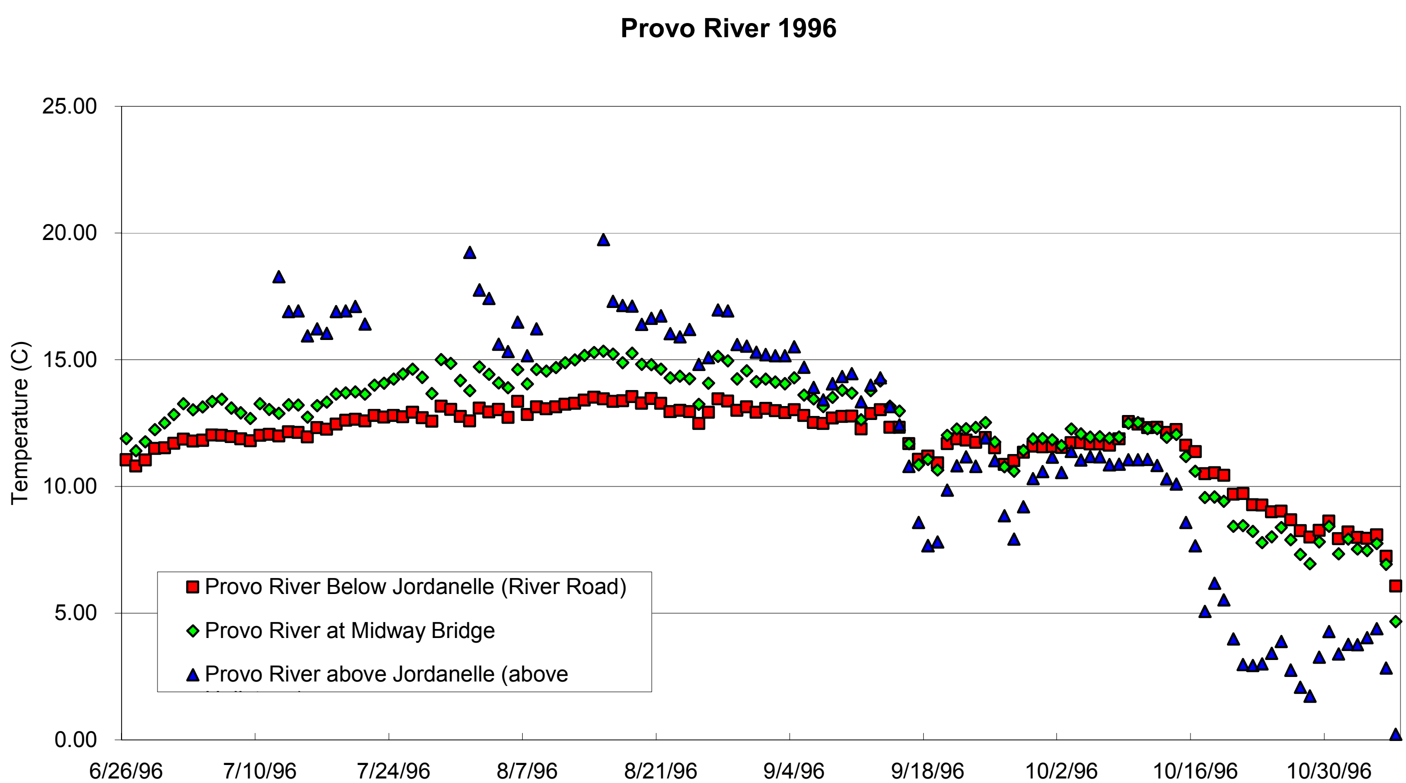


Figure 3-4: Provo River Water Temperatures July to October 1996.

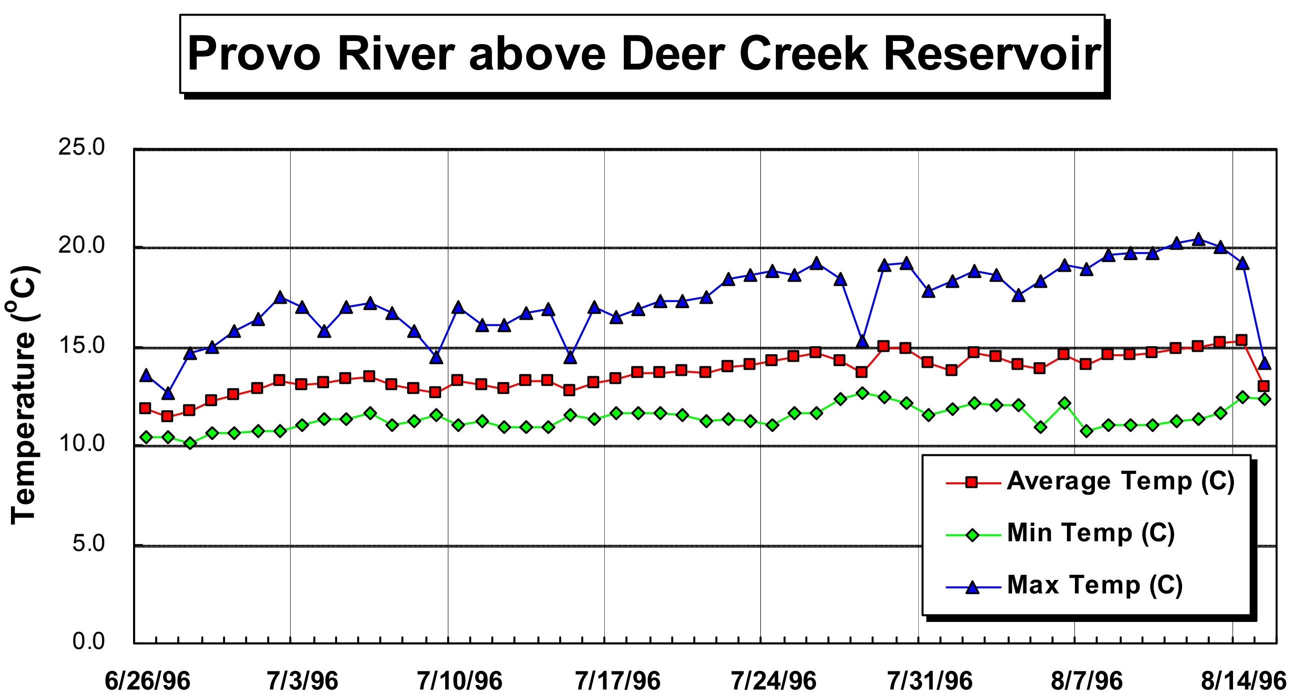


Figure 3-5 Provo River Temperatures Discharging to Deer Creek Reservoir July to August 1996.

Other secondary reasons for delisting are the strength of the fishery and the lack of other reasonable management practices to reduce temperatures.

OTHER POSSIBLE IMPAIRMENTS

Since Deer Creek Reservoir is a vital source of drinking water to Utah and Salt Lake Counties, the maintenance of water quality is tremendously important for the health of the communities and the reduction of water treatment costs. The effects of eutrophication, which impact the fishery, also impact drinking water, specifically, eutrophication can lead to taste and odor problems due to anoxic waters and toxins produced by algae.

By numeric standards criteria, the State has designated that Deer Creek Reservoir is fully supporting of the drinking water beneficial use. However, an incident occurred in January 2001 where treatment facilities that use the Salt Lake Aqueduct (Orem Water Treatment Plant and Little Cottonwood Treatment Plant) had a taste and odor incident. Once the problem was detected, the taste and odor was removed, at a large expense, with powdered activated carbon.

Research of the problem showed that the likely cause was a substance called Geosmin, which can be produced by algae. Algae blooms were observed during November 2000, which may indicate that a surge in algae production after turnover may have helped cause the incident. Also, it is likely that the taste and odor problem is due to low flows and high draw down which seems to be consistent with past taste and odor events during the 1970s and 1980s.

One event does not indicate that the reservoir is impaired for drinking water use, however, it does signify that the reservoir is very sensitive to seasonal swings in water quality.

Endpoint/Target Analysis

Introduction

This section covers the analysis that was done to determine the water quality targets and endpoints that will guide load reductions and watershed management practices. EPA guidelines on targets and endpoints define that they must restore beneficial use and be achievable. As part of the Endpoint and Target Analysis, the following tools were used:

- Phosphorus Reservoir Budget
- Vollenwieder Loading Plots
- Predictive Computer Modeling
- TSI Analysis

Phosphorus Budget

A phosphorus mass balance can be performed to determine the amount of phosphorus deposited in Deer Creek Reservoir since the inputs and outputs have been monitored as well as in-lake concentrations. The mass balance equation shown below was used for this analysis.

Eq 3-1
$V\,dp/dt = W - Qp - k_s V p$

Eq 3-2
$p = W/(Q+k_sV)$

p = Reservoir TP concentration (mg/m^3)
W = TP Load Input (mg/yr)
Q = Flow (m^3/yr) (average = 360 cfs or 3.2×10^8 m^3/yr)
V = Reservoir Volume (m^3) (average = 1.59×10^8 m^3)
k_s = 1st order settling constant (yr^{-1})

The results of the mass balance equation applied to Deer Creek from 1993-2000 is shown in Table 3-3. The equation uses a first order rate constant (k_s) to approximate the rate of phosphorus deposition in the reservoir. The results of the data show that the phosphorus settling rate constant in the reservoir has varied from –0.8 to 4.7 $year^{-1}$ with an average value of 2.9 $year^{-1}$. The negative values are confusing but may not be entirely inaccurate since retained phosphorus in the bottom sediments can be resuspended when the dissolved oxygen levels become depleted.

Table 3-3. Deer Creek Reservoir Phosphorus Budget Calculation 1993-1999.

Year	TP Load In W kg/yr-P	TP Load Out O kg/yr-P	TP Conc. p mg/L-P	Res. Volume V m^3	In Lake TP Load p*V kg-P	TP Load Deposited L kg/yr-P	k_s L/V/p 1/yr
1993	36142	12999	0.058	1.43E+08	8305	23143	2.787
1994	11173	10331	0.048	1.32E+08	6325	-1138	-0.180
1995	21384	8887	0.026	1.42E+08	3701	9873	2.668
1996	24052	8098	0.022	1.53E+08	3358	15611	4.649
1997*	19037	9135	0.021	1.56E+08	3271	9815	3.001
1998	14022	10171	0.020	1.68E+08	3369	3950	1.172
1999	25350	12299	0.032	1.58E+08	5056	14738	2.915
Average 96,98,99	21141		0.024	1.59E+08			2.912

*1997 phosphorus data was approximated and not used to calculate averages

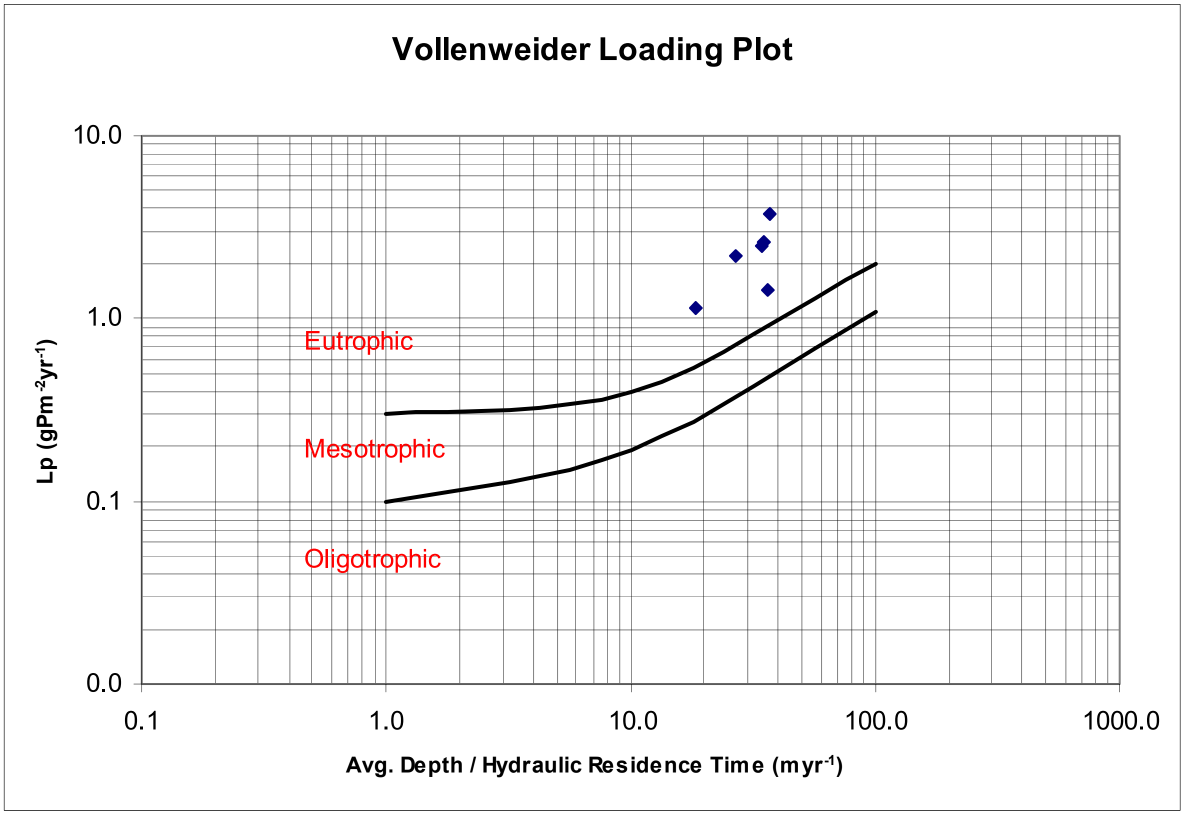
Using the average rate constant and a targeted in-lake concentration we can target an amount of phosphorus load that may be considered acceptable. The targeted in lake concentration that has been used in the past for Deer Creek Reservoir, and is the state indicator value, is 0.025 mg/l. Using the average rate constant, this corresponds to an input load of 20,600 kg. This corresponds to a in-stream concentration of 0.047 mg/l for a year of average total stream inflow (407 cfs from 96-99). Current average inflow concentration is 0.05 mg/l corresponding to an average reservoir phosphorus input load of 21,100 kg.

Vollenweider Plots

Vollenweider (1976) identified a method of determining trophic status based on areal phosphorus loading, average depth, and reservoir hydraulic residence time. As shown in Figure 3-5, the areal phosphorus loading in units of grams/meter2/year is plotted on the vertical axis and the average depth/ hydraulic residence time is plotted on the horizontal axis of a log-log plot. The two plotted curves show the approximate boundaries between eutrophic, mesotrophic, and oligotrophic as observed by Vollenweider.

As shown in Figure 3-5, the plot predicts Deer Creek Reservoir to be eutrophic with areal loads ranging from 1.2 to 3.7 g/m2/yr. According to this method, areal phosphorus loading should be decreased to 0.90 g/m2/yr to achieve mesotrophic status. This would correspond to an annual phosphorus input load of 8,700 kg/yr, which is a stream concentration of 0.027 mg/l at the average flow. These plots do not appear to correlate to the Deer Creek Reservoir system, since observed conditions in the reservoir more likely represent a mesotrophic classification.

Figure 3-6: Vollenwieder Loading Plots for Deer Creek Reservoir 1993-1999



Year	Q cfs	TP Load kg-P/yr	A m^2	V m^3	H m	DT yr	H/DT m/yr	Lp gP/m^2yr
1993	406	36142	9712500	1.43E+08	14.7	0.40	37	3.7
1994	195	11173	9712500	1.32E+08	13.5	0.76	18	1.2
1995	294	21384	9712500	1.42E+08	14.6	0.54	27	2.2
1996	385	24052	9712500	1.53E+08	15.7	0.44	35	2.5
1997	403		9712500	1.56E+08	16.0	0.43		
1998	431	14022	9712500	1.68E+08	17.3	0.44	40	1.4
1999	400	25350	9712500	1.58E+08	16.2	0.44	37	2.6

Predictive Modeling

The Central Utah Water Conservancy District in 1995 developed a predictive computer model to simulate water quality in Deer Creek Reservoir. The model was developed in CE-QUAL-W2, a two-dimensional hydrodynamic water quality model which was developed and maintained by the U.S. Army Corps of Engineers' Waterways Experiment Station.

The model was used to determine the cause and effect relationships between phosphorus and the dissolved oxygen impairment and to validate whether the 0.04 mg/l indicator value should be continued. Three scenarios were assembled to simulate stream loading conditions of with average concentrations of 0.03, 0.04 and 0.05 mg/l. The actual concentrations for the input were varied based on seasonal patterns which indicate a increase in flow and total phosphorus during spring runoff.

Figure 3-6 shows the model results of the three scenarios on the dissolved oxygen water column in the critical month of August.

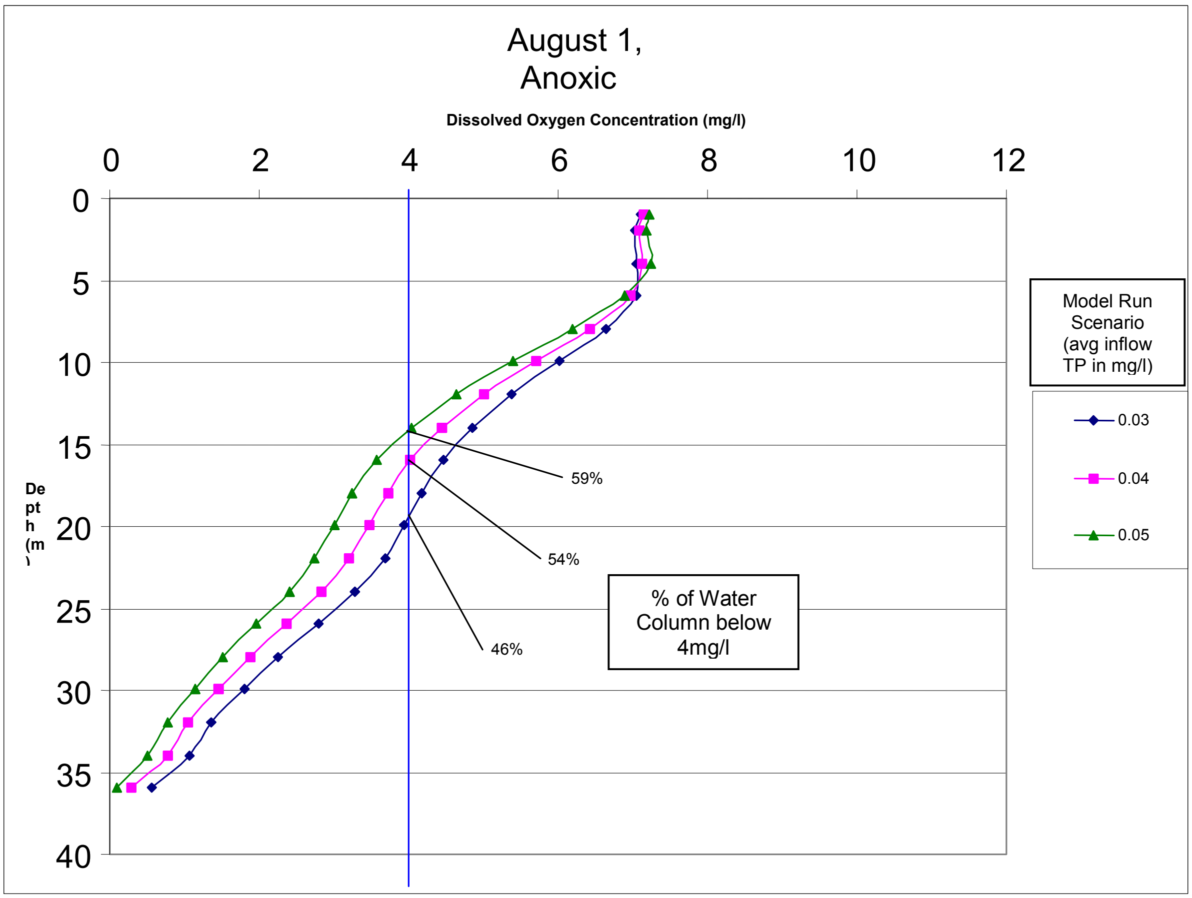


Figure 3-7. Predictive Model Results on Dissolved Oxygen Water Column

The 0.03, 0.04, and 0.05 mg/l total phosphorus scenarios show low dissolved oxygen levels in 46%, 54%, and 59% of the water column. The model seems to indicate that to achieve a state where 50% of the water column has adequate D.O. levels, the in-stream concentrations would need to be approximately 0.035 mg/l.

Current water column DO depletions in the reservoir reach on average 70% (during the month of greatest stratification) of the water column with an average current stream concentration at 0.03 mg/l. It is believed that the discrepancy between the model and the current conditions is caused due to a lagging of the reservoir response to improved conditions. The organics that have been deposited in the reservoir bottom sediments in the past from eras of poorer water quality may be continuing to consume oxygen. Even though current water quality showed an impeded eutrophication, they will likely cause continued depletion of the dissolved oxygen during stratification until these organics have been digested completely.

Trophic State Index

Chapter 2 documents the improvements to Deer Creek Reservoir based on the Carlson Trophic State Index (TSI). Figure 2-6 shows how the reservoir has improved, based on TSI, from a eutrophic to a mesotrophic reservoir over the period of the last 20 years. The current TSI values range between 40 to 45, which indicates a beneficial balance of productivity. This is consistent with where Deer Creek Reservoir should be maintained.

Algae Biomass Analysis

Algae samples have been collected in Deer Creek Reservoir since the 1970's. Dr. Sam Rushforth, a research biologist, of Utah Valley State College has been JTAC's consultant on algae productivity. Each year he prepares an annual assessment of algae biomass. Recently he completed an analysis to study the time series from 1971 to 1999 (Rushforth et al., 2001). Conclusions of this study which are significant to this TMDL analysis are as follows:

1. The most remarkable aspect of this data set is the decrease in total phytoplankton biomass (biovolume) from the 1971-1980 study period. This decrease in total biomass has been nearly two orders of magnitude. This biomass reduction is likely due to phosphorus control efforts conducted in the 1980s.
2. Every phytoplankton division has decreased substantially in biomass except Chrysophyta. The increase in Chrysophyta biomass has been negligible.
3. Deer Creek Reservoir has shown a substantial increase in phytoplankton community diversity through the study period.
4. Deer Creek Reservoir is a diatom-dominated ecosystem. Diatom dominance has dimininished during the past 15 years but continues to the present.
5. Cyanophyta have increased in relative density in the reservoir but, more important, have decreased

in biomass. The noxious Aphanizonmenon flos-aquae and Anabaena spiroides var. crassa have decreased substantially while Microcystis incerta increased in biomass.

6. Blooms of cyanobaceria occurred during some fall months of the 19990s that approached biomass levels seen for cyanophyte "blooms" in the 1970s. It is important to continue monitoring Deer Creek Reservoir to follow changes in cyanophytes in the future. In particular, it seems important to develop an operating plan for Jordanelle Reservoir to help reduce cyanobacteria populations during fall months. Furthermore, take autumn "blooms" of cyanobacteria indicate the need to locate and limit nutrient sources during this period.

Figures 3-8 shows the current levels of major algae types in Deer Creek Reservoir based on Rushforths analyses. As shown, low biomass has been recorded from 1990 to 1998. It is believed that the endpoint should reflect a maintenance of these conditions. The average biomass during this period is approximately 6.5×10^7 um^3/ml. Since cyanophytes are the largest concern of the four algae categories, it is recommended that an endpoint be established such that cyanophyte comprise of less than half the total biomass or 3.3×10^7 um^3/ml.

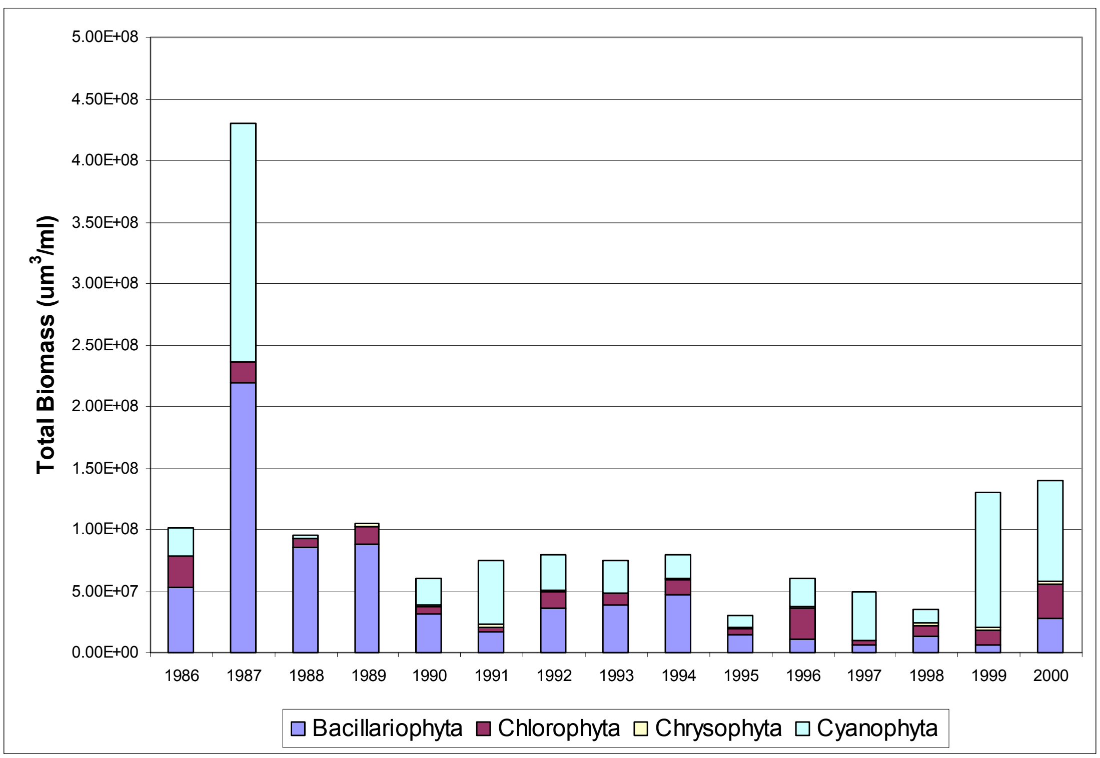


Figure 3-8. Total Biomass of all divisions from total plankton samples in Deer Creek Reservoir, 1986-2000. (Source: Rushforth and Sinclair, 2001)

Endpoint/Target Recommendations and Conclusions

The results of the analyses seem to indicate a fairly healthy reservoir that can be classified as a stable mesotrophic system. Compared to the 1980's, the reservoir has improved dramatically from a eutrophic status. All trophic indicator parameters have improved since then such as algae biomass, Secchi depth, phosphorus concentrations (as evidenced by TSI improvements in Figure 2-6), and oxygen depletion (see Figure 2-5). Many of these improvements are related to clean-up programs and water quality improvement projects.

The water quality history of the reservoir highlights the sensitivity of the reservoir and the need to be aware of the potential impacts of phosphorus loading. **The current health of the reservoir, however, indicates that major improvements are not needed, but instead, the reservoir needs a management plan that stresses protection and maintenance of the current water quality conditions, especially as Wasatch County continues to experience large growth in the Heber Valley and Jordanelle Basin.** There is a general consensus among the water quality specialists in JTAC that this should be the management direction for the reservoir.

Following this concept, the endpoints and targets that are recommended in this study are maintenance of current loading levels. However, as is discussed in Chapter 4, loading reductions will be necessary to accommodate a margin of safety and future loading sources. Table 3-4 summarizes the recommended endpoints.

Table 3-4: Summary of Recommended Targets/Endpoints

Parameter	Current (Avg. for 96-99)	Proposed Target	Notes
Dissolved Oxygen Water Column % Impaired	65% of column with DO <4.0mg/l	<50% of column with DO <4.0mg/l	Further studies may be conducted to determine fish habitat in Deer Creek Reservoir during stratified months and endpoint adjusted accordingly.
Fish Habitat Indicator	No Fish Kills have been reported	No Fish Kills	
In-lake Phosphorus Concentration	0.025 mg/l TP	0.025 mg/l TP (Avg all depths)	Annual average of all measurements at all depths.
In-stream Phosphorus Concentration	0.030 mg/l TP 0.015 mg/l DTP	0.030 mg/l TP 0.015 mg/l DTP	Annual average flow weighted concentration.
Phosphorus Loads to Lake	15,300 kg/yr TP 9,700 kg/yr DTP	15,300 kg/yr TP 9,700 kg/yr DTP 560 kg/mo TP for Aug-Oct 350 kg/mo DTP for Aug-Oct	
Average TSI	42.1	40-45	Average of Phosphorus, Secchi Depth and Chlorophyll a TSI for samples taken in May through September.
Algae Biomass	5.1 ug/l Chlorophyll a $6.5x10^7$ um^3/ml Biomass $3.3x10^7$ um^3/ml Cyanophyta	5.1 ug/l Chlorophyll a $6.5x10^7$ um^3/ml Biomass $3.3x10^7$ um^3/ml Cyanophyta	

Chapter 4 Source Assessment

Deer Creek TMDL

Introduction

The previous chapter has identified the linkage between phosphorus pollution and the dissolved oxygen impairment in Deer Creek Reservoir through computer modeling. As part of the TMDL process, the amount of pollution coming from nonpoint sources, point sources, and natural sources must be identified. Responsible parties can then be targeted and reductions can be determined in order to meet applicable water quality standards. This chapter of the report identifies those sources within the Deer Creek watershed that have been found to contribute a significant portion of the pollution that has caused water quality degradation.

Existing Local Conditions

The local conditions of the watershed affect the amount of phosphorus which is loaded into the system. This section briefly describes soil erosion hazards, land use patterns, and the hydrology of Heber Valley canal system.

SOIL EROSION HAZARD

As identified in the 1999 Upper Provo River Water Quality Management Plan, phosphorus in the Provo River System is tied to sediments in the form particulate phosphorus (Psomas, 1999), therefore, erosion is one of the major sources of phosphorus into the reservoir. Also, one of the concerns with any reservoir is the amount of sediment entering which can significantly reduce the amount of water storage. Data from the soil survey of the Heber Valley, from the U.S. Natural Resource Conservation Service, provides a detailed description of the soils in the study area including the erosion hazard. Figure 4-1 is a map of the erosion hazard for the watershed based on this data.

It is evident that the erosion hazard is closely linked to the topography of the area as shown in Figure 4-2. Areas with steep slopes in the mountainous regions are shown to have a high risk of erosion but soils in the valley where slopes are gradual are shown to have a much lower risk of erosion. Farming practices, however, can increase the risk of erosion in the valley since soils are worked loose and made more susceptible to erosion. Then irrigation practices provide increased mobility of soils since the frequent use of flood irrigation will contribute to soil losses. Conversion of the areas to pressurized sprinkler from the Wasatch County Water Efficiency Project and Midway Irrigation Project is likely to reduce erosion.

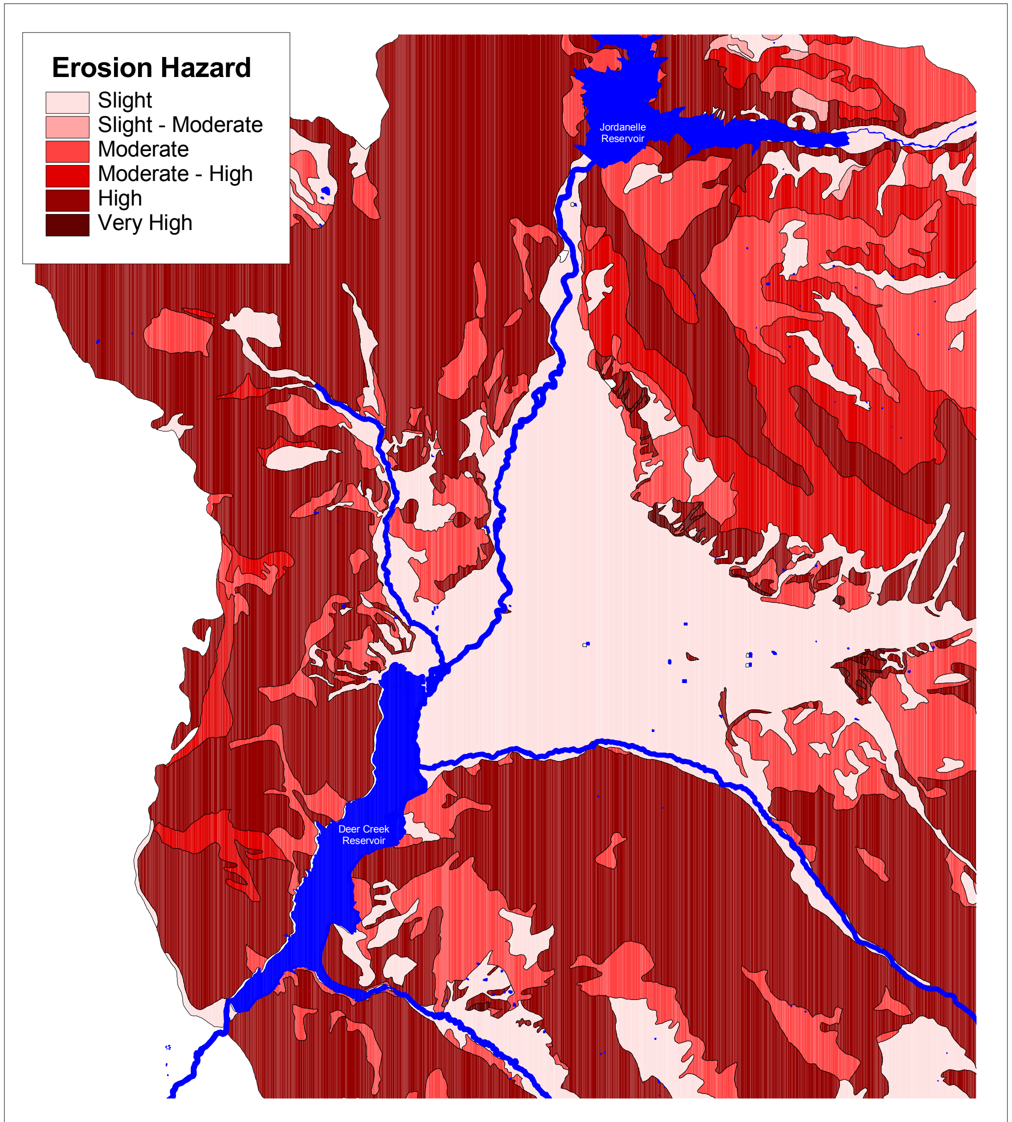


Figure 4-1
Erosion Hazard

2 0 2 4 Miles

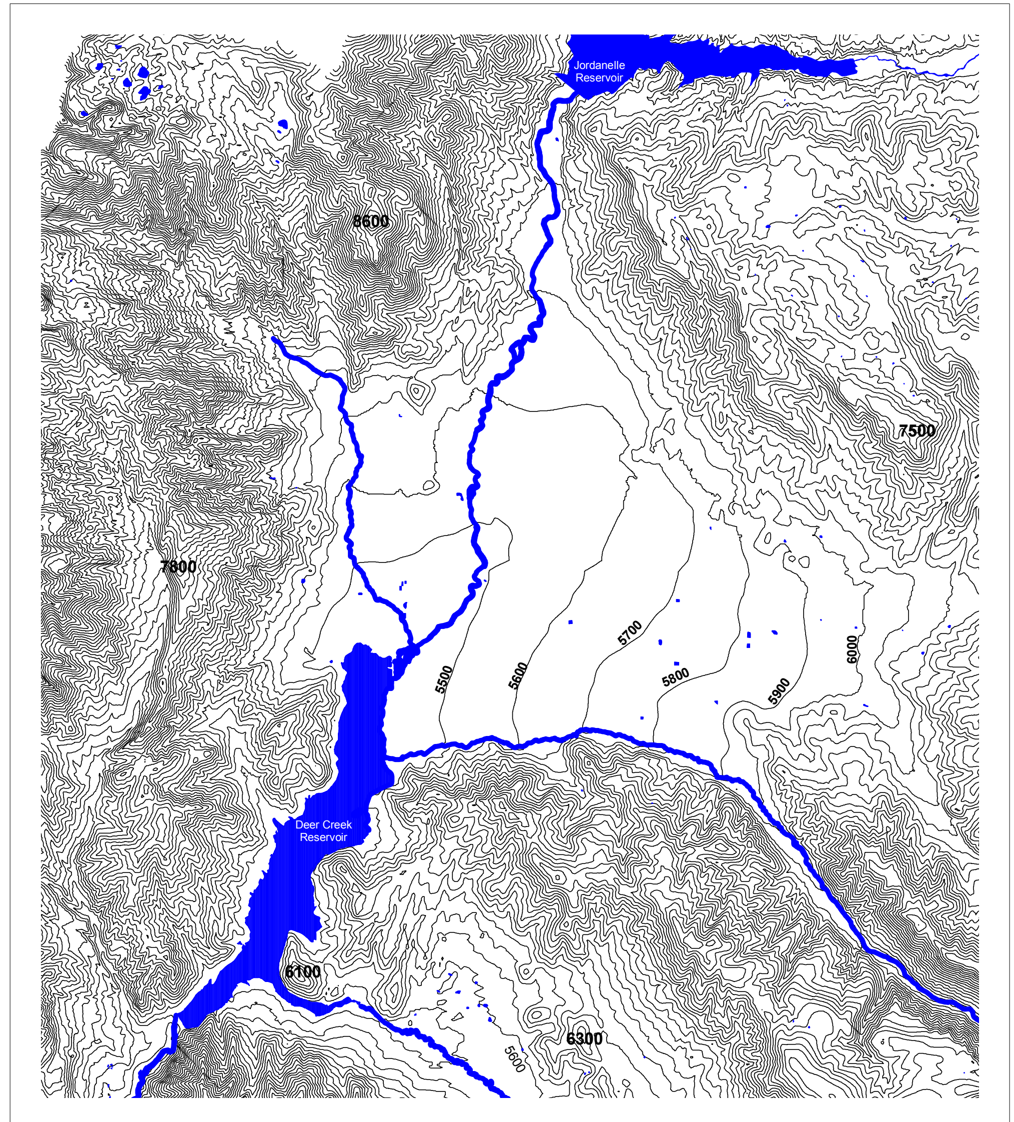


Figure 4-2
Topography - 100 ft Contours

2 0 2 4 Miles

LAND USE AND OWNERSHIP

The land use of the watershed can be generally characterized by Figure 4-3, where municipal boundaries indicate residential and urban areas while outer disturbed areas are more agricultural. The mountainous regions are generally characterized as native although there are impacts from small residential developments, light grazing, and multiple public and private roads. Using these assumptions the watershed is 85% Native rangeland, 12% agricultural and 3% urban-residential as shown in Figure 4-4. Many new developments outside of the municipal boundaries can generally be considered residential areas, however, the densities of these developments are mostly low and, for the purposes of pollutant source evaluation, can be lumped together with the adjacent agricultural areas.

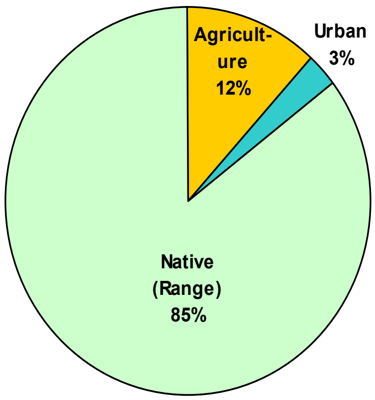


Figure 4-4. Land Use in Deer Creek Reservoir Watershed

As shown in Figure 4-5, the majority of the watershed is privately owned property including a significant portion of the mountainous regions. Some of the public property includes Wasatch Mountain State Park in the Snake Creek Drainage, Uinta National Forest in Daniels Creek and Main Creek Drainage, and other smaller scattered parcels of land owned by the State of Utah. U.S. Bureau of Land Management, and the U.S. Bureau of Reclamation.

HEBER VALLEY HYDROLOGY

The hydrology of Heber Valley is very complex due to the alterations that have been made to natural drainages with the construction of supply irrigation canals. Figure 4-6 shows the multiple canals which convey water from north to south while the natural drainages of Spring Creek, Lake Creek and Daniels Creek advance from east to west. Many of the crossing points of natural drainages and canals have diversion structures which allow for drainage to travel in multiple directions which may cause runoff to be conveyed to Daniels Creek or Provo River.

The Flood Control Channel is one of the routes that will intermittently convey water from Lake Creek and Center Creek to the Provo River. At other times, the Flood Control Channel will be dry because canals are diverting water to Daniels Creek. This pattern will change with the implementation of pressure irrigation. It is anticipated that pressure irrigation systems will significant reduce flows in most canals and Daniels Creek which should reduce phosphorus load as well. The assessment of current sources, however, is analyzed with respect to historic use of the irrigation canals since the data set does not include impacts from pressure irrigation.

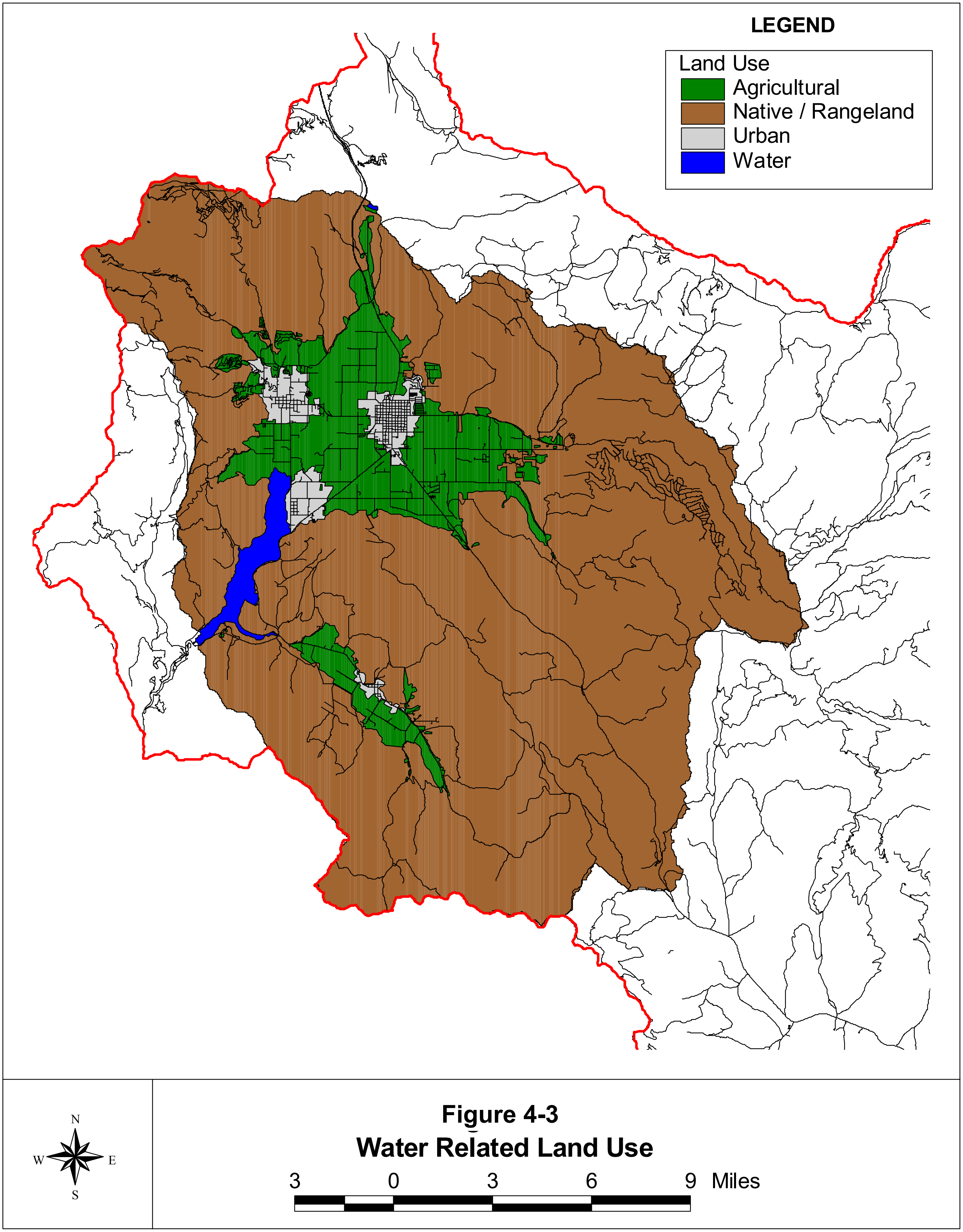


Figure 4-3
Water Related Land Use

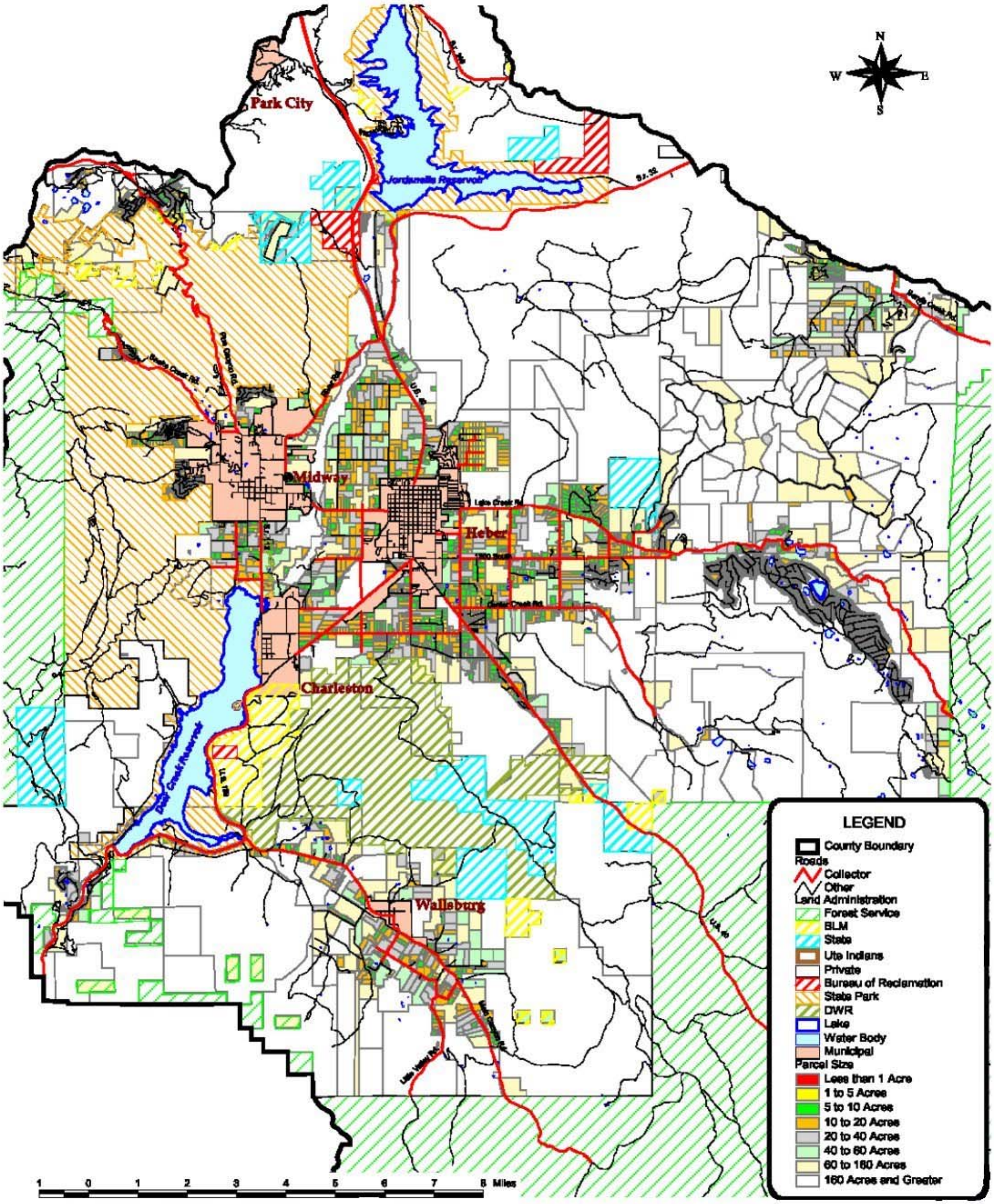


Figure 4-5
Wasatch County Ownership
(Source: Wasatch County General Plan, Wasatch County 2001)

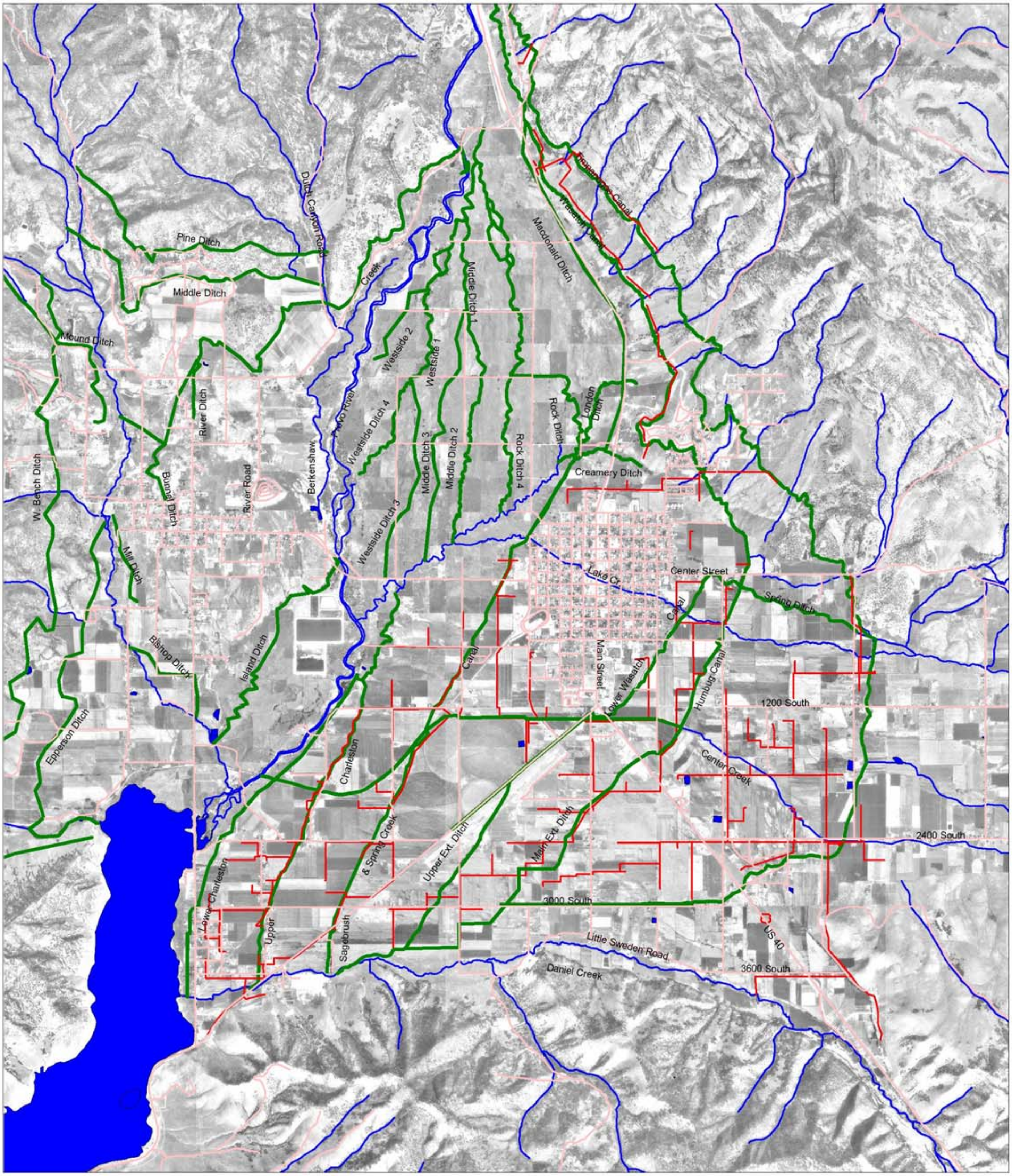


Figure 4-6
Heber Valley Canals and Streams

PSOMAS

Roads
Ditches
Lakes
WCWEP & DRP
Canals
Streams

N
W E
S

SCALE 1" = 1 MILE

Subwatershed Phosphorus Loads

As has been discussed Deer Creek Reservoir has four main stream inflows: Provo River, Main Creek, Snake Creek, and Daniels Creek. The phosphorus loads from these streams have been calculated and are shown in Table 4-1.

Past practices from previous water quality studies (Psomas, 2000) on the Deer Creek Reservoir have included a groundwater contribution approximated at 2,725 kg per year based on an approximated groundwater flow into the reservoir of 61 cfs and an approximated concentration of 0.04 mg/l. The same practice has been applied to determine the groundwater phosphorus contribution however, some past groundwater sampling may indicate that groundwater concentrations, at least in the deeper aquifers, is at a lower concentration.

In addition to the groundwater load, past practices in previous water quality studies estimate an additional 400 kg per year (Psomas, 2000) for storm flush from the subwatershed that surrounds Deer Creek Reservoir not draining into any of the four main stream inflows which are monitored. This value is also based on practices from previous water qualities studies.

SUBWATERSHED DELINEATION

For the purposes of identifying nonpoint sources the basin has been divided into six subwatersheds as shown in Figure 4-7. A single subwatershed has been identified for Main Creek (46,000 ac), Daniels Creek (92,700 ac), and Snake Creek (19,900 ac). The Provo River has been divided into two subwatersheds, one for the main channel (12,400 ac) and the other for a significant tributary called Spring Creek (2,100 ac), which drains high intensity grazing area in the Heber Valley called the North Fields. The last watershed is the area surrounding Deer Creek Reservoir identified at the area that drains directly to the reservoir (16,400 ac).

The Daniels Creek Watershed is shown to be the largest draining the majority of the east Heber Valley. This is due to canal diversions which cutoff flow from the foothills of the valley and convey water southward towards Daniels Creek. Lake Creek, which is a stream emerging from the canyon in the northeast corner of the valley, is assumed to flow into Daniels Creek due to diversions. However, during higher flows, much of Lake Creek is routed through the Flood Control Channel that discharges into the Provo River. Because of these temporary changes in flow patterns the water quality in Provo River cannot be

	1996	1997	1998	1999	Average 96-99
Provo River above Deer Creek, STORET 591363					
Weighted Average Flow (cfs)	244	340	333	355	**318**
TP Weighted Average (mg/l)	0.040	-	0.020	0.030	**0.030**
TP Annual Load (kg/yr)	9,131	-	7,108	10,109	**8,783**
DTP Weighted Average (mg/l)	0.020	-	0.010	0.020	**0.017**
DTP Annual Load (kg/yr)	4,652	-	2,986	6,053	**4,564**
TSS Weighted Average (mg/l)	10.9	11.3	8.7	11.4	**10.6**
TSS Annual Load (kg/yr)	2,379,786	3,402,450	2,583,525	3,603,574	**2,992,334**
Spring Creek at Provo River, STORET 499725					
Weighted Average Flow (cfs)	-	25	35	13	**24**
TP Weighted Average (mg/l)	-	-	0.054	0.113	**0.084**
TP Annual Load (kg/yr)	-	-	1,671	1,282	**1,477**
DTP Weighted Average (mg/l)	-	-	0.031	0.055	**0.043**
DTP Annual Load (kg/yr)	-	-	969	630	**800**
TSS Weighted Average (mg/l)	-	28.3	15.9	62.5	**35.6**
TSS Annual Load (kg/yr)	-	634,393	496,794	712,786	**614,658**
Snake Creek above Deer Creek, STORET 591016					
Weighted Average Flow (cfs)	49	54	57	56	**54**
TP Weighted Average (mg/l)	0.040	-	0.010	0.030	**0.027**
TP Annual Load (kg/yr)	1,839	-	695	1,420	**1,318**
DTP Weighted Average (mg/l)	0.020	-	0.020	0.010	**0.017**
DTP Annual Load (kg/yr)	890	-	820	508	**739**
TSS Weighted Average (mg/l)	10.2	8.9	10.1	8.6	**9.4**
TSS Annual Load (kg/yr)	443,120	422,764	510,229	424,702	**450,204**
Daniels Creek above Deer Creek, STORET 591352					
Weighted Average Flow (cfs)	10	22	17	21	**18**
TP Weighted Average (mg/l)	0.080	-	0.060	0.070	**0.070**
TP Annual Load (kg/yr)	687	-	991	1,208	**962**
DTP Weighted Average (mg/l)	0.040	-	0.030	0.040	**0.037**
DTP Annual Load (kg/yr)	380	-	450	770	**533**
TSS Weighted Average (mg/l)	70.0	71.9	36.9	42.9	**55.4**
TSS Annual Load (kg/yr)	633,595	1,400,162	574,090	786,242	**848,522**
Main Creek above Deer Creek, STORET 591346					
Weighted Average Flow (cfs)	20	25	25	20	**22**
TP Weighted Average (mg/l)	0.070	-	0.050	0.060	**0.060**
TP Annual Load (kg/yr)	1,256	-	1,161	978	**1,132**
DTP Weighted Average (mg/l)	0.040	-	0.030	0.030	**0.033**
DTP Annual Load (kg/yr)	669	-	634	511	**605**
TSS Weighted Average (mg/l)	47.7	93.0	41.9	57.6	**60.0**
TSS Annual Load (kg/yr)	854,295	2,085,235	925,058	1,004,109	**1,217,174**
Total Combined Loads					
Weighted Average Flow (cfs)	323	441	432	451	**412**
TP Weighted Average (mg/l)	0.036	-	0.021	0.027	**0.028**
TP Annual Load (kg/yr)	12,913	-	9,955	13,715	**12,195**
DTP Weighted Average (mg/l)	0.018	-	0.010	0.016	**0.015**
DTP Annual Load (kg/yr)	6,592	-	4,890	7,842	**6,441**
TSS Weighted Average (mg/l)	11.98	14.89	9.55	11.59	**12.0**
TSS Annual Load (kg/yr)	4,310,796	7,310,611	4,592,902	5,818,627	**5,508,234**
Groundwater					
Approximated Flow (cfs)	61	61	61	61	**61**
TP Approximation (mg/l)	0.040	0.040	0.040	0.040	**0.040**
TP Approx. Load (kg/yr)	2,725	2,725	2,725	2,725	**2,725**
Storm Flush					
TP Approx. Load (kg/yr)	400	400	400	400	**400**
Total Load to Deer Creek					
Weighted Average Flow (cfs)	384	502	493	512	**473**
TP Weighted Average (mg/l)	0.037		0.024	0.030	**0.030**
TP Annual Load (kg/yr)	16,038	-	13,080	16,840	**15,319**
Provo River Below Deer Creek, STORET 591346					
Weighted Average Flow (cfs)	358	406	462	371	**399**
TP Weighted Average (mg/l)	0.025	-	0.025	0.037	**0.029**
TP Annual Load (kg/yr)	8,099	-	10,171	12,299	**10,190**
DTP Weighted Average (mg/l)	0.021	-	0.014	0.022	**0.019**
DTP Annual Load (kg/yr)	6,711	-	5,603	7,219	**6,511**
TSS Weighted Average (mg/l)	0.5	0.9	1.1	1.5	**1.0**
TSS Annual Load (kg/yr)	164,330	324,265	443,813	495,506	**356,979**

Table 4-1. – Summary Phosphorus Loading to Deer Creek Reservoir 1996-1999 and averages.

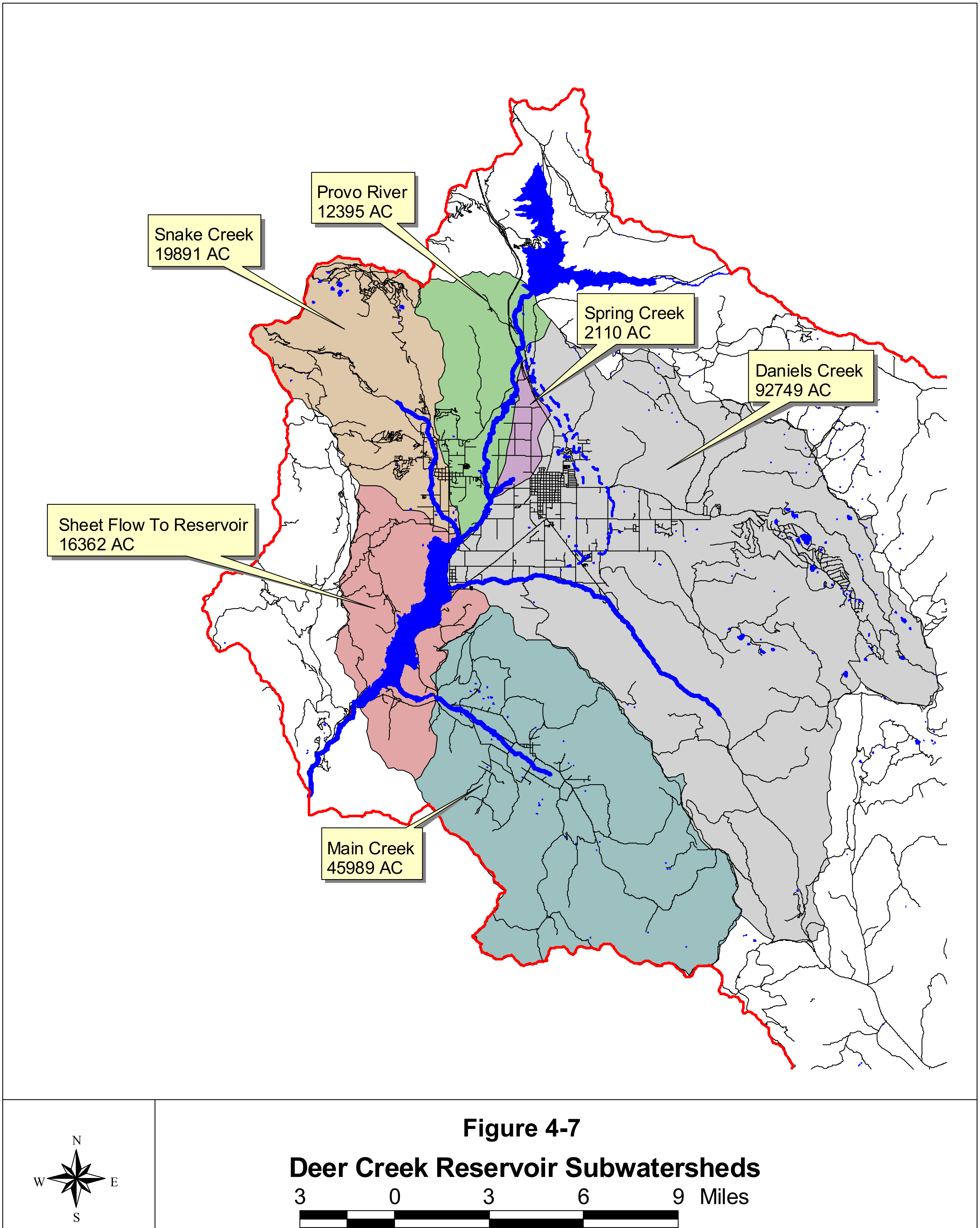


Figure 4-7

Deer Creek Reservoir Subwatersheds

attributed only to the land use within the boundary shown in Figure 4-7. Therefore to determine nonpoint source loadings, Provo River, Spring Creek and Daniels Creek subwatersheds are considered as one subwatershed.

PROVO RIVER AND SPRING CREEK SUBWATERSHED MONITORING

Table 4-2 shows the sampling sites used to evaluate the Provo River watershed and the availability of data for these STORETs. The annual average loading for this inflow is given in Table 4-3.

Table 4-2 Data Availability for Provo River

Storet	Description	Data Availability
499725	Spring Creek Above Provo River	1996 – 2000
591363	Provo River Above Snake Creek	1996 – 2000
499733	Provo River at Jordanelle Dam	1996 – 2000

Table 4-3 Average Annual Pollutant Load in Provo River

		Total Phosphorus	Dissolved Total Phosphorus	Total Suspended Solids	Volume
Storet	Location	Load (kg/yr)	Load (kg/yr)	Load (kg/yr)	(ac-ft)
499725	Spring Creek Above Provo River	1,660	957	579,101	15,095
591363	Provo River Above Snake Creek	8,783	4,564	2,936,841	224,322
499733	Provo River at Jordanelle Dam	3,057	1,148	0	225,605

As demonstrated, the Provo River accumulates a significant amount of phosphorus as passes through the Heber Valley from non-point sources. The release from Jordanelle Dam constitutes 35 percent of the load of total phosphorus and 25 percent of the load of dissolved total phosphorus into this subwatershed. Spring Creek contributes about 20 percent of each of the loads calculated.

SNAKE CREEK SUBWATERSHED MONITORING

Table 4-4 shows the sampling sites used to evaluate the Snake Creek watershed and availability of data for these STORETs. The annual average loading for this inflow are given in Table 4-5.

Table 4-4 Data Availability for Snake Creek

Storet	Description	Data Availability
499713	Midway FH Comp of Two Outfalls	1996 – 2000
499719	Midway FH Inflow Composite	1996 – 2000 (Total Phos. Only)
591016	Snake Creek Above Provo River	1996 – 2000
591045	Snake Creek Above Golf Course	End of 1999 – 2000

Table 4-5 Average Annual Pollutant Load in Snake Creek

		Total Phosphorus	Dissolved Total Phosphorus	Total Suspended Solids	Volume
Storet	Description	Load (kg/yr)	Load (kg/yr)	Load (kg/yr)	(ac-ft)
499713	Midway FH Comp of Two Outfalls	789	942	13,210	56,188
499719	Midway FH Inflow Composite	232	N/A	N/A	6,570
591016	Snake Creek Above Provo River	1,318	1,398	450,204	155,240

The fish hatchery average net increase in loading from the state monitoring is 557 kg per year which represents approximately 42 percent of the load of total phosphorus into Snake Creek, but is not a significant source of suspended solids. Solids are most likely the result of erosion occurring on Snake Creek upstream of the fish hatchery.

DANIELS CREEK SUBWATERSHED MONITORING

Table 4-6 shows the sampling sites used to evaluate the Daniels Creek watershed and the availability of data for these STORETs.

Table 4-6 Data Availability for Daniels Creek

Storet	Description	Data Availability
591002	Lower Charleston Canal Above Daniels Creek	1996 – 1997
591352	Daniels Creek Above Deer Creek Res.	1996 – 2000
591027	Sagebrush-Spring Creek Canal	1996 – 1997
591354	Daniels Creek At First Diversion	1996
591355	Daniels Creek At Whiskey Springs	Last half of 1999 – 2000

The only time period where good data exists for most of the locations is the last half of 1996. Loads were calculated for this year to identify sources of total load at all of the above stations except 591355. Table 4-7 shows the results of these loading calculations.

Sagebrush-Spring Creek contributes 55 percent of the load of total phosphorus and 77 percent of the load of dissolved total phosphorus to this subwatershed. While a significant load occurs in Daniels Creek upstream of Sagebrush-Spring Creek, this load does not arrive at the reservoir due to several diversions which occur in this area. This reach of Daniels Creek does, however, significantly affect the suspended solids load, contributing 74 percent of the total.

Table 4-7 Pollutant Load in Daniels Creek (Last half of 1996)

		Total Phosphorus	Dissolved Total Phosphorus	Total Suspended Solids	Volume
Storet	**Description**	**Load (kg)**	**Load (kg)**	**Load (kg)**	**(ac-ft)**
591002	Lower Charleston Canal @ Daniels Crk	79	61	2,532	734
591027	Sagebrush-Spring Creek Canal	150	141	15,214	1,002
591352	Daniels Creek At First Diversion	269	183	65,953	1,936
591354	Daniels Creek At Whiskey Springs	205	58	48,098	7,557

MAIN CREEK SUBWATERSHED MONITORING

The Main Creek watershed only has one STORET, 591346, which is currently used to measure water quality. This is the same station that is used previously, designated as “Main Creek”. Figure 3-1 shows the location of this sampling site.

Nonpoint Source Analysis

Nonpoint sources are those which are considered to discharge to a river system at no one particular point. This section describes the nonpoint sources of the watershed which have been divided into the following categories: background, agricultural and urban.

BACKGROUND SOURCE

Background sources are those sources which are considered to be natural and not influenced by presence of human activities. This is often associated with naturally occurring erosion and dissolution of phosphorus, as well as natural atmospheric deposition.

For this TMDL, background sources for each of the major inflows to the reservoir were determined by evaluating data from the most upstream monitoring station available in each sub-watershed. This generally is the monitoring site that is least affected by human land use, draining the relatively undisturbed canyon areas.

For Snake Creek, station 591045 located above the golf course was used to determine background concentrations. For Daniels Creek, station 591355 located at Whiskey Springs was used. For the Provo River, the release from Jordanelle Dam, station 499733, was used. There are no monitoring stations located high in the Main Creek sub-watershed. Therefore an interpretation was made from Daniels Creek as the nearest neighboring drainage area. The result of this analysis is shown in Table 4-8 and 4-9.

Table 4-8 Background Concentrations of Contaminants

Sub-Watershed	Total Phosphorus (mg/l)	Dissolved Total Phosphorus (mg/l)	Total Suspended Solids (mg/l)
Provo River	0.01	0.00	0.0
Snake Creek	0.01	0.00	0.1
Daniels Creek	0.02	0.00	6.2
Main Creek	No Data (Assumed to match Daniels Creek)		

Table 4-9 Background Phosphorus Loads

Sub-Watershed	1998 Average Flow cfs	Background TP Concentration mg/l	Background TP Load kg/yr
Provo River	332	0.01	2965
Snake Creek	57	0.01	509
Daniels Creek	19	0.02	339
Main Creek	23	0.02	411
Total			4224

Having calculated the loads at each of these background points, the next step was to look at each of these points individually. This will aid in determining the sources of high pollutant loads and allow a more detailed analysis of each sub-watershed.

This TMDL analysis assumes that the Jordanelle Reservoir will maintain phosphorus discharges at current levels as a background source. It is paramount to the health of Deer Creek Reservoir that these current discharges do not increase. It is not the scope of this analysis to identify pollution sources in the watershed above Jordanelle Reservoir, however, it is known that future land use plans in this watershed identify residential, commercial and recreational developments which could potentially increase phosphorus inputs. JTAC should work with local officials to ensure that such developments will not increase phosphorus loads to the water system.

PROVO RIVER SOURCE IDENTIFICATION STUDY

Large increases in phosphorus loads between Jordanelle and Deer Creek have been evident each year. As part of this TMDL study, a one-day intensive monitoring on the Provo River between Jordanelle Reservoir and Deer Creek was conducted on May 9, 2001. This study was conducted to determine the general location of increased phosphorus loads along the Provo River in the Heber Valley. Several samples were taken on five locations along the Provo River along with eight other locations of discharging ditches and springs found near the Provo River.

Figure 4-8 shows a map of the area, the locations that were sampled and the results of the study. As shown, the in-channel concentrations of TP were consistently low throughout four of the five Provo River monitoring locations, indicating that the majority of phosphorus loading in Provo River occurs south of the Midway Road crossing (Highway U-113). In this area it is apparent that Spring Creek is one of the major contributors of phosphorus. But it was also recognized that many of the springs that emerge from the ground within the flood plain of the Provo River also contributed significant phosphorus concentrations from shallow groundwater sources. These sources are likely heavily influenced from agricultural activities as well as some septic systems. The concentrations from those springs ranged between 0.07 to 0.17 mg/l.

Ditches that discharged into the Provo River were also shown to be high in phosphorus. Casper Ditch had a TP concentration of 0.17 mg/l. Investigations along this ditch showed that agricultural practices allowed animals to water within the ditch itself certainly contributing to the high concentrations. Also the source water of this ditch was effluent from a drain in the bottom of the Heber Valley WWTP lagoons. Samples from the drain were shown to have a TP concentration of 0.08 mg/l.

ESTIMATION OF NONPOINT SOURCES

Nonpoint sources in the watershed have been simplified into two categories: agriculture and urban based on the land uses identified in Figure 4-3. An analysis was performed on the data to determine the loading coefficients from these two sources. Literature has indicated that phosphorus loading coefficients from urban and agriculture land uses as shown in Table 4-10 may have a broad range depending on site parameters and land management.

Table 4-10 Literature Values of Land Use TP Load Coefficients (Chapra, 1997, p.531)

	Urban	**Agriculture**	**Forest**
TP Load Coeff. (kg/ac/yr)	1 0.04 – 4.0	0.5 0.04 – 2.0	0.4 0.004 – 0.36

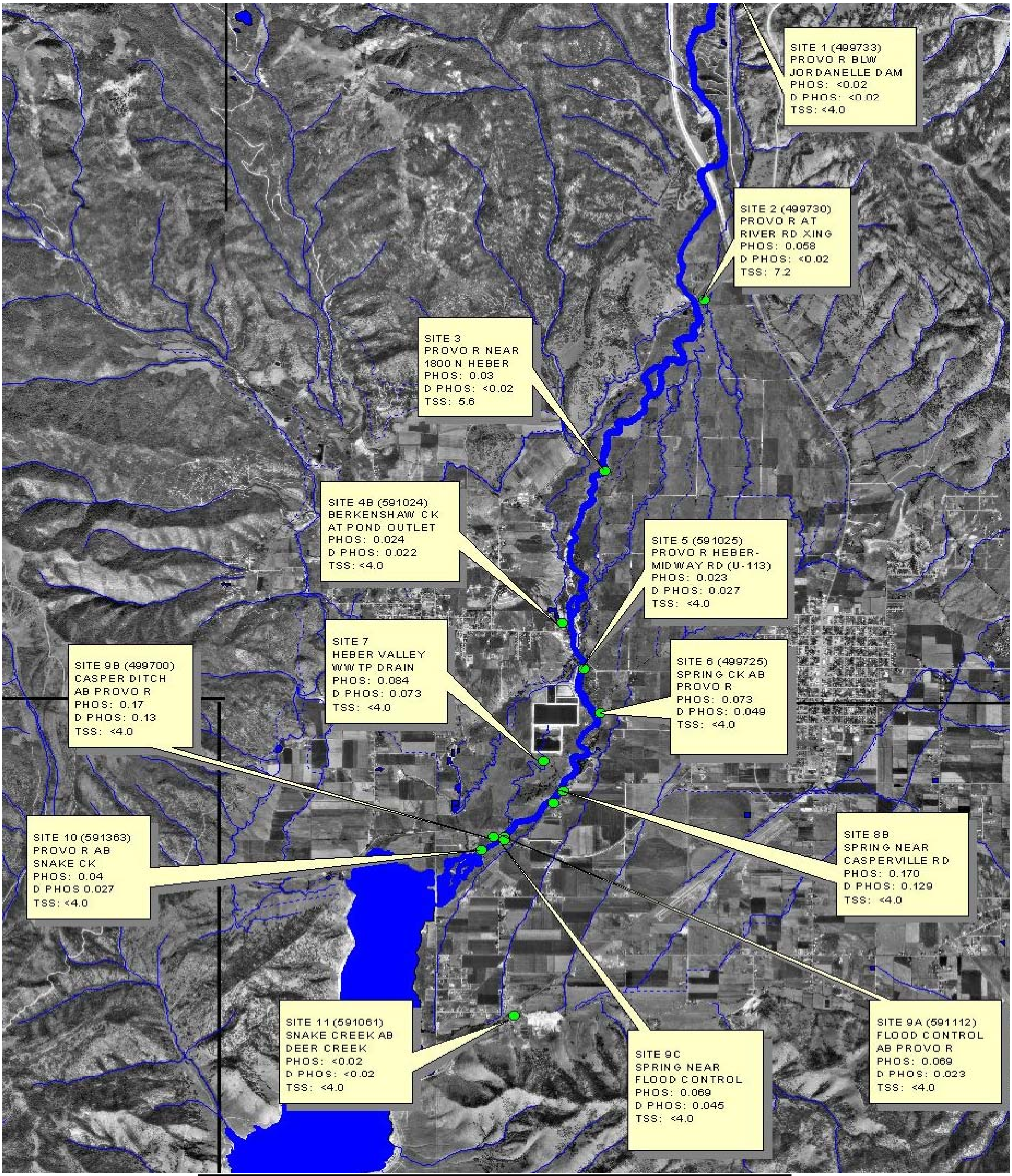


Figure 4-8. Provo River Corridor One-Day (May 9, 2001) Intensive Monitoring Results

In this analysis the background analysis helped to determine the load coefficients for the native areas. This analysis showed that an average loading coefficient for the native lands could be estimated at 0.01 kg/acre/year.

Next an effort was made to determine the loading coefficients for urban and agricultural sources. The Spring Creek subwatershed was used for this purpose since the drainage is more than 90% agriculture lands which are used primarily for grazing. The TP loading coefficient for this subwatershed was approximately 0.6 kg/acre/year. Even though this loading coefficient nearly matches the literature values, it is relatively high as compared to other agricultural areas in the watershed. It was apparent that this value could not be applied to all agricultural land use in the entire watershed to represent total phosphorus loadings from agriculture. Rather a lower coefficient would be necessary to better represent actual TP loads. Literature generally shows that urban sources contribute at a higher rate than agricultural sources (Chapra, 1997), however, the analysis of the Spring Creek drainage shows that agriculture is likely as significant or more significant than urban runoff. Therefore, it was assumed that for the purpose of this analysis that the loading coefficients for urban and agricultural sources would be equivalent. This is justified since in the Deer Creek watershed many of the areas termed agricultural have many residential aspects and many areas identified as urban have many agricultural aspects.

An iterative analysis, as shown in Table 4-11, was performed and it was determined that 0.25 kg/acre/year best estimated the contributions of TP from agriculture and urban areas. In order to remove the confusion due to hydrology within the complex drainages of the Provo River, Spring Creek and Daniels Creek subwatersheds, the three subwatersheds were combined for this analysis.

Table 4-11. Analysis of TP Loading Coefficients.

	Agriculture			Native			Urban			Pre-dicted	1996-99	
	Area	TP Coeff.	TP Load	Area	TP Coeff.	TP Load	Area	TP Coeff.	TP Load	TP Load	Average TP Load	% Error
Watershed	ac	kg/ac/yr	kg/yr	ac	kg/ac/yr	kg/yr	ac	kg/ac/yr	kg/yr	kg/yr	kg/yr	
Entire Watershed	22503	0.25	5626	145985	0.01	1460	4629	0.25	1157.25	8243	8673	-5.0%
Main Creek	3083	0.25	771	42592	0.01	426	314	0.25	78.5	1275	1132	12.6%
Snake Creek	1782	0.25	446	17280	0.01	173	828	0.25	207	825	761*	8.4%
Provo,Daniels,Spring	17638	0.25	4410	86113	0.01	861	3487	0.25	871.75	6142	6780**	-9.4%

* The value shown does not reflect discharges from Midway Fish Hatchery (557 kg TP / year, compare to Table 4-1).
** The value shown does not reflect discharges from Jordanelle Reservoir (2965 kg TP / year, compare to Table 4-1).

The coefficients are calibrated to the average loading during 1996 and 1999 as shown in the last three columns of Table 4-11. The predicted load calculated using the loading coefficient are within 15% of the average 1996-1999 loading.

This analysis allows a determination of relative contributions from nonpoint sources. As shown in Figure 4-9, nonpoint sources in the watershed could be characterized 18% urban/residential, 68% agriculture, and 14% native. The characterizations change slightly per subwatershed as shown where urban sources have higher relative contributions in Snake Creek and Main Creek.

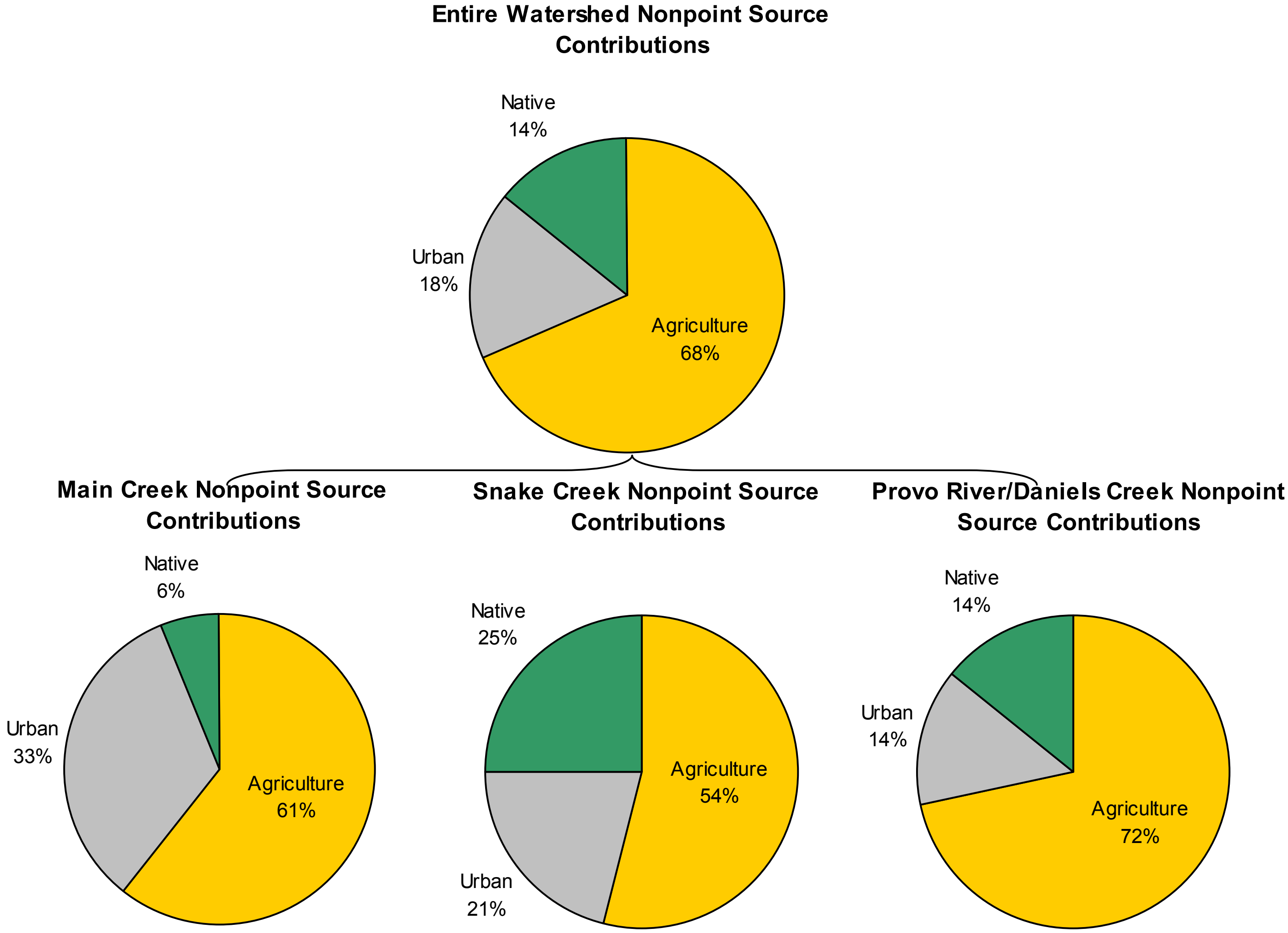


Figure 4-9 Summary of Nonpoint Source Relative Contributions per subwatershed.

AGRICULTURE SOURCES

The Heber Valley and Round Valley (Main Creek Subwatershed) have significant portion of lands dedicated to agricultural practices such as grazing, animal feeding, crop production, etc. Currently over 20,000 acres or 12% of the watershed is dedicated to agriculture. This number could be considered to be even larger when considering the low density grazing that occurs in the mountainous areas of the watershed which have been considered as native areas for this analysis.

The 1997 Census of Agriculture conducted by the Utah Agriculture Statistics Service of the U.S. Department of Agriculture shows the agriculture statistics for Wasatch County. The 1997 data showed that of 16,600 acres of cropland in Wasatch County that 15,400 acres were irrigated and 9,300 acres were harvested. The majority of cropland produced alfalfa or other type of silage with 8,400 acres.

The data also indicated that there were 9,389 cattle and calves in the County of which 2,651 were beef cows and 1,484 were milk cows. The other significant animal operations were sheep and lambs of which there were 16,417 animals in the County.

ANIMAL FEEDING OPERATIONS

As part of the Utah Strategy on Animal Feeding Operations (AFOs) and Confined Animal Feeding Operations (CAFOs), an assessment of farms in Wasatch County has been completed by members of the Utah Association of Conservation Districts (UACD). As a result, 52 dairies and feedlots were assessed in the County. The assessment identified that 47 of the 52 feedlots do not pose a water quality hazard.

The other five feedlots were identified as potential CAFOs due to the proximity to a stream or canal and observed conditions and practices that potentially create a water quality hazard. Two of the operations are dairies and the remaining three were cattle operations. The Utah Strategy is that AFOs and CAFOs prepare a Comprehensive Nutrient Management Plan (CNMP) to address the water quality hazard and essentially become a non-discharging facility. If these facilities do not address the water quality issues through a CNMP, then they will be designated as CAFOs by the State and be required to obtain a UPDES discharge permit.

URBAN SOURCES

There are four cities and towns in the watershed: Heber, Midway, Charleston and Wallsburg. These four areas represent the majority of areas with land use identified as urban. It is important to note that many of these areas contain development with large lots with many agricultural practices mixed throughout. Heber City is the largest city with a population of 7,291 (Census 2000). It also has the largest amount of high density development with a total average density of 3.3 residents per acre. The City of Midway has a population of 2,121. This area is much lower in density than Heber with an average density of 1.0 residents per acre. The town of Charleston has a population of 378 and an average density of 0.35 residents per acre. The town of Wallsburg in Round Valley adjacent to Main Creek is the smallest residential community with a population of 274 and an average density of 0.85 residents per acre.

Heber City currently has five discharge locations for storm water runoff. The primary discharges are to the Spring Creek-Sagebrush Canal which travels from north to south on the west side of the City of Heber (See Figure 4-6). There are four discharge points along this canal. The discharged water now currently is conveyed southward to Daniels Creek. The other discharge is located at approximately 1300 South and U.S. Highway 40 which discharges into the Flood Control channel from a small development east of the discharge point.

The City of Midway has no centralized storm drain system. The current drainage patterns are based on small ditches that can be found on the side of most roads. There is very little curb and gutter in the city. The ditches that are used for drainage have, in the past, also been used for irrigation. However, many of these ditches are no longer used for this purpose with the conversion of much of the Midway Irrigation Company to pressurized irrigation systems. The storm water runoff from the city is conveyed partially to the Provo River and partially to Snake Creek.

The town of Charleston is similar to Midway and relies on ditches which line the roads for storm water conveyance. Most runoff is discharged into the Lower Charleston Canal, which travels from north to south on the west side of Charleston and discharges into Daniels Creek.

The town of Wallsburg is located in the Round Valley adjacent to Main Creek. The residential area is encompassed in an area of 0.5 square miles. The runoff drains directly to Main Creek through roadside ditches.

OTHER POTENTIAL SOURCES

There are many other potential sources that are neither related to urban land use or agriculture. The Heber Valley Special Service District (HVSSD) waste water treatment plant (WWTP) and septic systems in the county are addressed in the next two subsections.

HEBER VALLEY WWTP

The Heber Valley WWTP is a total containment lagoon and land application facility which currently has an average day capacity of 3.6 million gallons per day (MGD) and can service approximately 6,000 connections. It has just recently completed an expansion from 2.5 MGD. Some of the water is used for reuse in the irrigation of alfalfa fields near the treatment plant. The plant currently supports 4,450 connections (Scott Wright, Personal Comunication. 2002).

The lagoons are located between Heber and Midway adjacent to the Provo River posing a potential concern to water quality. The intensive monitoring of the Provo River indicated that the majority of increased phosphorus loads occurred in the area of the treatment lagoons. It appeared that the lagoons had been leaking and potentially polluting the Provo River system. The HVSSD announced in 2001 that a leak had been detected in one pond when a drain pipe was found through excavations made during its plant expansion process. The drain pipe has since been plugged and will likely contribute to reduced nutrient loads to the Provo River. However, this problem should be monitored in the future.

The HVSSD reuse project is an efficient use of water which would otherwise be lost to evaporation, however, the irrigation with the water allows nutrients to be added to these fields. It is important that appropriate nutrient management be applied so that over fertilization of these fields does not occur.

SEPTIC SYSTEMS

Septic systems are commonly used by individual residences to dispose of sewer wastes throughout the Deer Creek Reservoir watershed. Septic systems have a potential to pollute the shallow groundwater aquifer with increased levels of nutrients, which may eventually impact surface waters. Currently, septic tank densities are limited by Wasatch County Code to 1 acre per tank.

Wasatch County, according to county health officials, has approximately 2,500 septic systems and new systems are being installed at a rate of 200 to 300 systems per year (Phil Wright, pers. comm., 2002). A septic system study performed in 1994 (HA&L) showed that the County previously had approximately 1,900 systems. According to the 1994 study, 20% of the systems (388 systems) are located in the Timber Lakes region in the Lake Creek drainage, 7% (131 systems) near Center Creek, 6% (121 systems) in Charleston, and 9% (175 systems) along Main Creek.

The town of Charleston and the Timber Lakes residential region both recently rejected proposals to install sewer lines which would eliminate the septic systems and convey the water to the HVSSD treatment lagoons.

Properly functioning septic systems that are maintained can be effective at treating residential sewer waste. However, improper site selection can cause water quality problems in surface waters. Wasatch County Health Department has the responsibility to oversee the installation of new systems and check that they are properly sited, installed, and maintained. Also the County Health Department is responsible to inspect existing systems and find problems. For the protection of water quality, sewer systems are preferred over septic systems.

GOLF COURSES

There is two golf courses in the Heber Valley, both of which are located in the Snake Creek subwatershed. One is the Wasatch Mountain State Park Golf Course which comprises of 36-holes, owned and operated by the Utah Division of State Parks. The other is owned and operated by the Homestead Resort Golf and comprises of 18-holes. Golf courses are generally water quality concern due to the large use of fertilizers and pesticides. Currently this golf course does not appear to significantly impact the reservoir since Snake Creek does not have elevated nutrient levels. However, there is a concern as the valley continues to develop and additional golf courses are planned.

Point Source Analysis

Point sources are defined as those sources which consist of a single discharge to the stream system. There is only one point source identified in the watershed which is the Midway Fish Hatchery in the Snake Creek drainage.

MIDWAY FISH HATCHERY

The Midway Fish Hatchery is owned and operated by the State of Utah Division of Wildlife Resources (UDWR). It is the State's largest fish hatchery producing 180,000 lbs of fish per year, mainly rainbow trout. The hatchery is an important resource to the UDWR to help maintain healthy trout fisheries throughout the State. The Midway Fish Hatchery is located south of Midway and discharges into Snake Creek.

The fishery is a source of phosphorus as the fish are fed with foods that inevitably contain phosphorus. Fish excretion which contain high concentrations of phosphorus are then discharged into the waters. The Midway Fish Hatchery has a system of settling ponds to help reduce the amount of contaminants that are discharged. The hatchery has a UPDES (Utah Pollutant Discharge Elimination System) Permit which was renewed on March 10, 2000 and is valid through February 28, 2005. Effluent limits include TSS maximum concentration of 25 mg/l, TSS maximum daily loading of 1398 lbs/day, pH range of 6.5 to 9.0, and maximum net increase of total phosphorus of 626 kg/yr. The permit requires the hatchery to monitor the influent springs and the effluent for the determination of net increase of total phosphorus.

The results of the monitoring as reported in a monthly Discharge Monitoring Report (DMR) indicated that for 1998 the net increase of phosphorus measured was 190 kg/year, well below its allowed load in the permit. The 1998 STORET data as collected independently by DWQ shows a discrepancy where the net increase is calculated to be 707 kg/year. The discrepancy is a concern, but may be due to sampling and/or laboratory errors. As shown in Table 4-5, the STORET data shows that the average TP annual load at the effluent of the Fish Hatchery from 1996 to 1999 is 789 kg per year with the maximum annual load of 890 kg during 1998. These loads have improved from the late 1980s and early 1990s before the treatment ponds had been installed. The Fish Hatchery's average net increase, based on STORET data, during 1996 to 1999 is 557 kg/year. This is below the current limits in the UPDES permit.

The hatchery is currently considering using a cleaner source of water, such as a deep-water well, rather than the current springs which are impacted by agricultural nonpoint sources.

OTHER POTENTIAL POINT SOURCES

There are no other regulated point sources in the watershed. However, as mentioned previously there have been five potential CAFOs identified in the watershed. These potential CAFOs may be regulated by the State in the future as non-discharging point sources.

Future Sources

The Heber Valley is currently experiencing large growth with various new developments planned throughout. Development is expected to occur continuously for the next several years as many agricultural lands are being converted into residential developments. The development of agricultural lands may, however, actually reduce phosphorus loadings, especially if areas of intense agricultural activities are included such as those in the North Fields. However, there are many areas, especially in mountainous regions where currently native conditions are planned to be converted to residential. Development in these areas has the most potential to negatively impact the water quality in the basin since the areas are currently contributing relatively smaller phosphorus loads. It will be important that Wasatch County planners carefully watch developments in these areas and ensure that proper best management practices for development are followed.

In addition to future growth in the Heber Valley, it is important to note that growth in the Jordanelle Basin even though it is outside of the scope of this study. One of the assumptions of this report is that phosphorus discharges from the Jordanelle Reservoir will remain constant at 0.01 mg/l as a background source of phosphorus. There are various future development plans in the Jordanelle Basin which include residential, commercial, and recreational land uses which could potentially degrade water quality. Wasatch County, with the help of JTAC, should ensure that this growth proceeds forward cautiously with water quality control measures.

Other future sources are also related to development with the need of future sewer services. There is a potential for additional septic systems in the Heber Valley as growth continues. The Heber Valley Special Service District WWTP currently has the capacity to service the Heber Valley for approximately 5 to 10 years without expansion. The Wasatch County's draft general plan (Wasatch County, 2001) recommends that in the future the District install a mechanical plant for treatment, which may add an additional point source to the Provo River.

Additionally, the Jordanelle Special Service District is in need of a wastewater treatment plant and has discussed the possibility of placing one in the Heber Valley. The construction of any mechanical treatment plants must include advanced wastewater treatment, which removes phosphorus to low concentrations and minimizes the potential impact to the reservoir.

Future point sources must not degrade the water quality in Deer Creek Reservoir. As discussed in Chapter 2, the 1984 Management Plan, which was an update of the 208 Water Quality Plan, stipulated that no new discharges should be permitted in the watershed. In order to permit a new point source in the watershed, this stipulation would need to be modified. Modification of the 208 would require approval from the Mountainland Association of

Governments.

In addition, Utah Administrative Code R317-2-12-3, designates the Provo River Watershed as a High Quality Waters - Category 3. This designation requires State approvals before any new discharges. A discharge permitee must show that:

1. There shall be achieved all statutory and regulatory requirements for all new and existing point sources and there shall be achieved all required cost-effective and reasonable best management practices for nonpoint source control in the immediate area of the discharge,
2. There are no reasonable non-degrading or less degrading alternatives to the discharge (based on information provided by the discharger)
3. The proposed activity has economic and social importance, and
4. Water quality standards will not be violated by the discharge.

It may be feasible, in the future, to set up a pollution trading system to account for additional point sources. This system could have point sources help fund best management practice projects in the basin. This would reduce a nonpoint source load such that a point source could receive a pollution credit and there would be no net increase of pollution.

Chapter 5 TMDL

Deer Creek TMDL

Introduction

The Total Maximum Daily Load (TMDL) is a method mandated by the Federal Government in the Clean Water Act to determine the maximum amount of contaminants that a water body can support and remain healthy. This chapter discusses in detail the TMDL that is being established for Deer Creek Reservoir to control the water quality problems that have been explained in Chapter 3. This chapter reviews how water quality determined endpoints will be achieved and maintained through actual load reductions of the sources.

Endpoints

Endpoints have been determined from the analysis described in Chapter 3 and are shown in Table 5-1. There are seven endpoints identified for water column dissolved oxygen (DO), fish kill monitoring, in-lake phosphorus, in-stream phosphorus, phosphorus loading, average trophic state index (TSI), and algae biomass concentrations.

Table 5-1: Summary of Recommended Targets/Endpoints

Parameter	Proposed Target
Dissolved Oxygen Water Column % Impaired	<50% of column with DO <4.0 mg/l
Fish Habitat Indicator	No Fish Kills
In-lake Phosphorus Concentration	0.025 mg/l TP (Avg all depths)
In-stream Phosphorus Concentration	0.030 mg/l TP 0.025 mg/l DTP
Phosphorus Loads to Lake	15,300 kg/yr TP 9,700 kg/yr DTP 560 kg/mo TP for Aug-Oct 350 kg/mo DTP for Aug-Oct
Average TSI	40-45
Algae Biomass	5.1 ug/l Chlorophyll a 6.5×10^7 um^3/ml Biomass 3.3×10^7 um^3/ml Cyanophyta

DO=Dissolved Oxygen, TP=Total Phosphorus,
DTP=Dissolved Total Phosphorus, TSI=Carlson Trophic State Index

Upon attainment of these defined endpoints the reservoir should be designated as meeting its defined beneficial uses. Current data indicate several of these endpoints have already been achieved; an exception is dissolved oxygen in the water column. It is expected that improvements to dissolved oxygen will occur, as current phosphorus levels remain depressed, assuming a lag between DO response and low algae production. This assumption is based on reservoir modeling and current literature citing the correlation between reservoir productivity and depressed DO concentrations. The main purpose of these endpoints is to ensure that the current water quality conditions that have been achieved in the reservoir will be maintained into perpetuity through the reduction of additional phosphorus, which provides a margin of safety and an allocation for future sources.

Critical Conditions & Seasonality

The health of the system must be maintained at all times. Certain periods are more sensitive to pollutant loadings than others. The critical period generally occurs during the low flow periods of the year. Flows into the Deer Creek Reservoir are variable and partially dependent on irrigation patterns and water releases from the Jordanelle Reservoir. Table 5-2 shows the average monthly flows as determined by the USGS for each of the three main tributaries in the Heber Valley.

Table 5-2 USGS Average Monthly Flows in Heber Valley Streams (cubic feet per second)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Provo River (USGS 10155500)	129	141	166	156	639	592	180	89	92	94	121	121
Snake Creek (USGS 10156000)	43	43	46	46	55	59	45	41	42	47	48	45
Daniels Creek (USGS 10157500)	3.1	3.2	2.9	15	64	38	8.5	11	8.4	6.2	4.5	3.4

The table shows that the low flows, particularly in the Provo River, occur during the months of August through October which has been designated as the critical period for this reservoir. Daniels Creek shows its low flow period occurs more in the winter months but is still significantly depressed during the August to October Period. Although Main Creek does not have USGS flow meter station, its flow patterns are similar to Daniels Creek.

Sensitivity analysis with the Deer Creek Reservoir CE-QUAL-W2 model has shown that increased phosphorus loads during this late summer period is more sensitive than increased loads in the winter periods. It is important that loads during these months remain at or below the 0.03 mg/l TP endpoint value. With combined stream flows of approximately 150 cfs, the monthly allowable TP load from the streams would be 330 kg per month. With an inclusion of TP loads from groundwater and direct flows into the reservoir the monthly TMDL during these critical months should be approximately 560 kg per month.

Dissolved Oxygen-Phosphorus Linkage

In a review of scientific literature, Carpenter et al. (1998), have shown that nonpoint sources of phosphorus have lead to eutrophic conditions for many lakes and reservoirs across the country. One consequence of eutrophication is oxygen depletions caused by decomposition of algae and aquatic plants. They also document that a reduction in nutrients will eventually lead to the reversal of eutrophication and attainment of their designated beneficial uses, the rates of recovery are variable among lakes and reservoirs. This supports this document's viewpoint that decreased nutrient loads at the watershed level will result in improved oxygen levels, although this process takes a significant amount of time (5-15 years).

In Lake Erie, heavy loadings of phosphorus have impacted the lake severely. Monitoring and research from the 1960's has shown that large mats of decaying algae were responsible for depressed DO levels and large fish kills. Programs to reduce nutrients into the lake have resulted in a downward trend of phosphorus concentrations and oxygen depletion rates since monitoring began in the 1970's. The trend of oxygen depletion has lagged behind that of P reduction, but this was expected (USEPA, 2001)

Nurnberg (1995, 1995a, 1996, 1997) developed a model that quantified duration (days) and extent of lake oxygen depletion, referred to as an anoxic factor (AF). This model showed that AF is positively correlated with average annual total phosphorus (TP) concentrations. Nurnberg (1996) developed several regression models that show nutrients (P and N) control all trophic state indicators related to oxygen and phytoplankton in lakes and reservoirs. These models were developed from water quality characteristics using a suite of North American lakes. The Division of Water Quality has calculated morphometric parameters such as surface area (A_o), mean depth (z), and the ratio of mean depth to surface area ($z/A_o^{0.5}$) for Deer Creek Reservoir. The results show that these parameters are within the range of lakes used by Nurnberg. We expect that Nurnberg's empirical nutrient-oxygen relationship holds true for these reservoirs, and the prescribed BMPs will reduce external loading of nutrients to the reservoirs, resulting in reduced algae blooms and an increase in dissolved oxygen levels over time.

In addition, as described in Chapter 3, water quality modeling of Deer Creek Reservoir was performed using an existing CE-QUAL-W2 model calibrated by the Central

Utah Water Conservancy District. As shown in Figure 3-7, if phosphorus levels are reduced to 0.03 mg/l, the model predicts that approximately 46% of the water column would have DO levels less than 4.0 mg/l which would meet the endpoint of the reservoir.

Load Allocations

The TMDL load allocation assigns loads to all sources including point, nonpoint and background sources. In addition, a margin of safety is included to account for the uncertainty and ensure that water quality standards are maintained.

Current Loads

Table 5-3 and Figure 5-1 show the current loads for each of the sources that have been determined in Chapter 4. These loads add to be approximately 15,300 kilograms per year and represent the estimated average loading into Deer Creek Reservoir from 1996 to 1999.

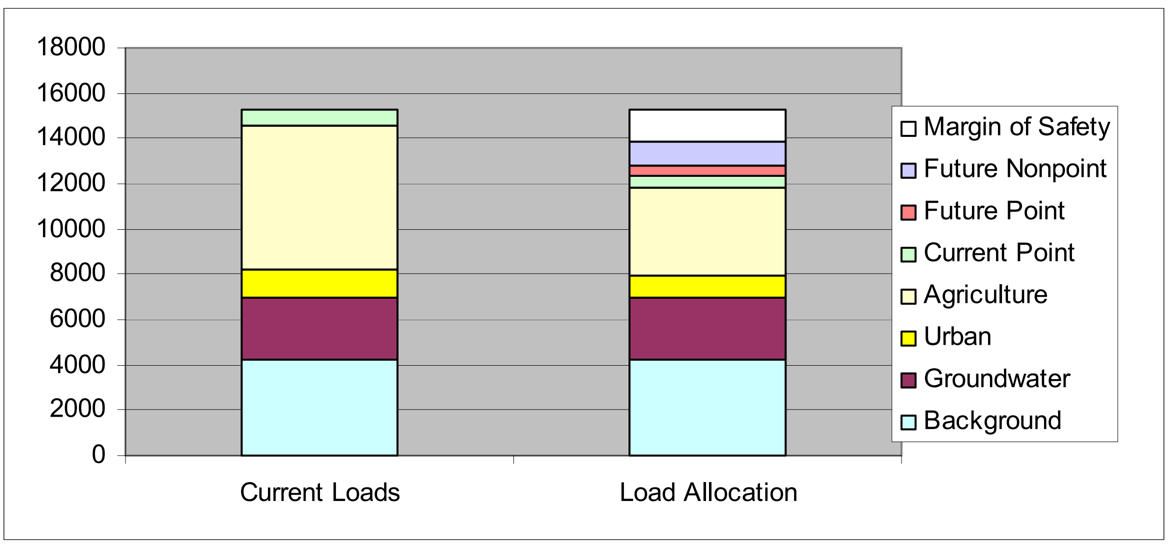


Figure 5-1. Bar Chart of Current Loads Compared to Future Load Allocation.

Table 5-3. Total Phosphorus TMDL Load Allocations

Description	Current Loads kg TP / year	Load Allocation kg TP / year	Load Reduction kg TP / year
Groundwater	2,725	2,725	
Background (Includes Jordanelle Reservoir Discharge of 2,965 kg/year)	4,225	4,225	
WLA - Current Point (Hatchery)*	560	400	160
WLA - Future Point	0	500	
LA – Agriculture	6,060	3,595	2,465
LA – Urban	1,600	1,300	300
LA - Future Nonpoint	0	900	
Total Load	**15,300**	**13,800**	**2,925**
10% Margin of Safety		1,500	
Maximum TMDL Load		**15,300**	

* Midway Fish Hatchery allocation represents net increase in total phosphorus load.
** The 15,300 kg/year represents the average load from 1996-1999. Flows during this period appear to be approximately 10% higher than the long term average flow. Even though there is an implicit margin of safety, an additional 10% explicit margin of safety takes this into account.

Reductions will be required from current point and nonpoint sources so that future growth and margin of safety can be accommodated within the total load allocation. The reductions are shown in Table 5-3 which will require the current point source Midway Fish Hatchery to reduce TP loads from 560 kg/year to 400 kg/year of net increase. Urban and agricultural nonpoint source discharges will also require an approximate 300 kg and 2,465 kg per year reduction in TP loads, respectively.

Background Sources

Background sources including groundwater impacts were assumed to remain constant at current levels. This includes discharges from the Jordanelle Reservoir, which should be operated such that the total phosphorus discharges remain at 2,965 kg per year which is an equivalent concentration of 0.01 mg/l TP at an average flow. The Bureau of Reclamation and Central Utah Water Conservancy District are responsible for the control of phosphorus from the Jordanelle Reservoir since they operate the selective level outlet works (SLOW) on the dam. The other background sources are discussed in more detail in Chapter 4.

This TMDL analysis assumes that the Jordanelle Reservoir will maintain phosphorus discharges at current levels as a background source. It is paramount to the water quality health of Deer Creek Reservoir that these current discharges do not increase. It is not the scope of this analysis to identify pollution sources in the watershed above Jordanelle Reservoir, however, it is known that future land use plans in this watershed identify residential, commercial and recreational developments which could potentially increase phosphorus inputs. JTAC should work with local officials to ensure that such developments will not increase phosphorus loads to the water system.

Waste Load Allocations

Waste load allocations (WLAs) are given to point sources to determine future allowable loads which will maintain the water quality standards as identified in the TMDL. One point source is currently located within the watershed which is the Midway Fish Hatchery. The hatchery currently is meeting its permit limitations which is 626 kg/year of a net increase in total phosphorus. The new WLA allocation will require that the hatchery reduce its net increase TP loads to 400 kg/year. Its current loads are estimated at 560 kg/year based on STORET data. It is estimated that the reduction will be able to be accomplished through the maintenance of the current water treatment system.

An allocation for future point sources has been included to allow for potential construction of a waste water treatment plant for the Jordanelle Special Service District and the potential for the Heber Valley Special Service District to convert to mechanical treatment in the future.

Load Allocations

Load allocations (LAs) are given to nonpoint sources to identify discharge requirement to maintain the water quality standards identified in this TMDL report. Load allocations were identified for agricultural, urban and future nonpoint sources.

The agricultural LA was reduced from the current TP loading of 6,060 kg per year to 3,595. This reduction should be achieved through the implementation of a Comprehensive Nutrient Management Plan (CNMP) for each of the five potential CAFOs identified by the Utah Association of Conservation Districts (UACD) assessment. The UACD should ensure that these CNMPs are completed and then implemented. The UACD should also work with the owners of cattle pastures in the North Fields and those farms which are within 1000 feet of the Provo River south of Midway Road (U-113) to reduce stock watering within springs and canals that drain into the Provo River. The completion of the Provo River Restoration Project and the Wasatch County Water Efficiency Project should also contribute significantly to reduce agricultural loads.

The urban LA was reduced from the current estimated TP loading of 1,600 kg/year to 1,300 kg/year. This reduction should be accomplished from implementation of the Wasatch County Stormwater Management Plan (Psomas, 2000b) which identifies storm water quality wet ponds which would treat runoff from the Heber Valley before discharge into the Provo River.

Future LAs were assigned for the anticipated future growth that will continue to occur. Growth will have its impact on water quality as areas that were previously native are converted to residential neighborhoods such as those areas in the mountainous regions of the watershed. Wasatch County is responsible to ensure that growth does not significantly increase pollution to the water system.

Margin of Safety

The margin of safety for this TMDL is both implicit and explicit. The explicit margin of safety is meant to adjust the TMDL to reflect the long term average flows since the study period (1996 to 1999) appears to have flows 10% to15% higher than the normalized long term average. The implicit margin of safety is based on the reservoir modeling discussed in the endpoint analysis in Chapter 3 (see Figure 3-6). The modeling predicted that dissolved oxygen standards would be obtained with stream inflow levels of 0.035 mg/l. However, the TMDL endpoint has been set at 0.030 mg/l based on a non-degradation policy which provides a 15% implicit margin of safety. An additional implicit margin of safety is based on the conservative estimate that groundwater inflow has a phosphorus concentration of 0.04 mg/l.

Public Process

The TMDL of Deer Creek Reservoir has a potential to affect many people including those in Wasatch County which will be implementing BMPs and those in Utah and Salt Lake County which rely on good water quality in Deer Creek Reservoir for drinking water. The requirements for a TMDL indicate that the public should be involved at an appropriate levels before any approval of the TMDL report. One of the main tools used to institute a public process on this TMDL was the Jordanelle Reservoir Water Quality Technical Advisory Committee or JTAC. JTAC was formed in 1981 by Utah Governor Scott Matheson, because of eutrophication evidences in the Deer Creek Reservoir and for the purpose of developing a reservoir management plan for Deer Creek Reservoir and the then future Jordanelle

Reservoir. JTAC was created with the representation of over twenty federal, state, local agencies, and private companies.

JTAC meets on a quarterly basis to discuss the issues of the watershed. The JTAC meetings and contact with individual JTAC members have provided valuable insight for the creation of this TMDL. The TMDL has been reviewed by many JTAC members and comments have been incorporated.

Additionally, the TMDL report was available for the general public to review and comment. The comment period was advertised in the Deseret News together with the Salt Lake Tribune on March 5, 2002 and the period extended to March 28, 2002. The document was made available on the Internet at:

http://www.deq.state.ut.us/EQWQ/TMDL/TMDL_WEB.HTM

No comments were received.

Chapter 6 Project Implementation

Deer Creek TMDL

Introduction

To achieve the TMDL goals and endpoints it will be necessary to begin to implement various watershed restoration projects. This chapter identifies the recommended projects for the Deer Creek Reservoir watershed and discusses prioritization of projects, estimated costs, implementation, and potential funding sources. Some of the projects listed in the recommendations are those which are either in the process of being completed or have recently been completed, but water quality improvements have not been realized yet in the data.

Recommended Projects

As discussed in Chapter 5, in order to achieve the necessary load reductions, multiple restoration projects will be required that incorporate Best Management Practices (BMPs). The following projects are currently in process of being completed or are recommended to be completed as part of the TMDL implementation.

1. *Provo River Restoration Project (PRRP)*
2. *Conversion to Sprinkler Irrigation Systems*
3. *Heber Valley Water Quality Basins*
4. *Cleanup of Potential CAFOs*
5. *Integrated Watershed Information System*
6. *Main Creek Stream Bank Restoration*
7. *Agricultural BMP Projects*
8. *Midway Fish Hatchery*
9. *Cautious Responsible Growth in Heber Valley and Jordanelle Basin*

BMP Analysis

This section analyzes each of the recommended BMPs, describing the purpose, benefits, estimated pollutant reductions, project costs, and responsible party.

Provo River Restoration Project

The goal of the Provo River Restoration Project (PRRP) is to restore the Provo River in Heber Valley below Jordanelle Dam to Deer Creek Reservoir which in the 1940's and 50's was straightened for the purpose of flood control. The Utah Reclamation Mitigation and Conservation

Commission (URMCC) is implementing the PRRP to restore the river pattern and ecological function to a more natural condition.

Restoration will be achieved by constructing a multiple-thread meandering channel, reconnecting the river to existing remnants of historic secondary channels and constructing small side channels to recreate aquatic features. Existing levees will be set back to create a near natural flood plain that will allow the river to change course naturally.

The URMCC started the project at the base of Jordanelle Reservoir in 1999 and has since completed the first three miles, approximately, of the ten mile stretch. The water quality improvements from the project should be significant since larger water quality buffer zones will be created, better vegetated river banks should help reduce erosion, and increased wetlands in the riparian zone should reduce nutrients. The Environmental Impact Statement (EIS) (URMCC 1997) identified that a phosphorus reduction of 465 kg per year may be a result of the restoration project. The EIS identified that the cost of the project is estimated at $14,351,000 for construction costs and $9,730,000 for land acquisition costs.

Conversion to Pressurized Irrigation

Flood irrigation is known to contribute to water quality degradation in the Heber Valley since return flows are generally laden with high concentrations of nutrients. Many areas in the Heber valley are currently in process of converting irrigation canal systems to pressurized sprinkler systems. The Wasatch County Water Efficiency Project (WCWEP) in conjunction with the Tri-Valley Watershed Project has recently been completed as part of the federally funded Central Utah Project. The goal of the WCWEP is to increase the efficiency of water use through sprinkler irrigation systems in the Heber Valley. The WCWEP project will convert 3,675 acres of irrigated farm land. Central Utah Water Conservancy District is responsible for the project management of WCWEP which installed the main distribution laterals. The Natural Resources Conservation Service is responsible to help on-farm conversion through the Tri-Valley Watershed Project.

Midway Irrigation Company, which irrigates approximately 3,500 acres, has recently installed the first phase of a pressurized irrigation system and has plans to convert the entire system in the near future. These efforts should help improve the water quality in Snake Creek and Provo River.

It is recommended that the Federal, State, Local Agencies and irrigation companies continue to work together to increase pressurized irrigation throughout the valley.

Heber Valley Water Quality Basins

The Heber Valley Storm Water Management Plan (Psomas, 2000) identifies the location for four water quality basins to improve the water quality from agriculture return flows and storm water runoff from agriculture and urban areas. The basins are planned on Spring Creek near the Provo River, the Flood Control Channel near the Provo River, Daniels Creek near Deer Creek Reservoir, and Snake Creek near Deer Creek Reservoir.

The costs of construction of these basins are estimated at approximately $2 million and it is anticipated that total phosphorus loads could be reduced by as much as 1000 kg per year. It is recommended that these basins be constructed by Wasatch County.

Potential CAFO Cleanup

The Utah Association of Conservation Districts (UACD) have assessed that five feedlots (which have been identified as potential problems) having unacceptable conditions impacting water quality.

These potential CAFOs (Confined Animal Feeding Operations) should develop a Comprehensive Nutrient Management Plan (CNMP), which should be implemented to eliminate the movement of wastes into waterways thereby protecting water quality. The CNMP should address manure handling, storage and disposal, storm water runoff, composting, nutrient management, soil testing, feed management, and any other issues that are relevant to controlling pollution from these farms.

It is estimated that the cost of clean-up will average approximately $30,000 per farm with a total cost of $150,000. The UACD is responsible to ensure that CNMPs are prepared and implemented. If discharges continue from these facilities, the Utah Division of Water Quality would be required to issue a UPDES permit to the feedlots.

Integrated Watershed Information System

Deer Creek Reservoir is a key drinking water source for five separate utilities in Utah and Salt Lake Counties. An

Integrated Watershed Information System is needed for all interested parties to access and share common watershed information. Utilities, State and Federal agencies, and other parties interested in water quality information associated with the Deer Creek Reservoir watershed will be able to collaborate and share data and information. Key benefits from an Integrated Watershed Information System include:

1. Timely information which enables:

    a. Early detection of water quality problems

    b. Proactive and collaborative solutions to these problems

    c. The reduction of costs associated with data management

2. Expanded knowledge and data sharing resulting from:

    a. Coordinated information sharing with State, local and federal parties

3. A resource that supports existing JTAC coordination efforts

It is recommended that a web-based database system be developed as a user-friendly and accessible tool to facilitate communication between agencies and other interested parties. The site would be central to the activities of the Jordanelle Technical Advisory Committee. Part of the information system should include an early warning detection system, which will help detect major water quality incidents that may impair Deer Creek Reservoir as a drinking water source.

The objectives of the new watershed information system are to provide the following:

1. A tool to allow for optimal water quality data uses and the ease of sharing the data within a utility and among neighboring utilities and agencies.

2. A Common water quality data system with consistent sampling, analysis, storage, and retrieval practices.

3. Common reporting practices among Federal and State agencies and water utilities.

4. Tools to assist participants in using data effectively to manage water systems within the watershed and use the data for proactive decision making.

It is estimated that the costs of such a system would be approximately $250,000 and include development of customized application software, associated hardware, facilitation, training and outreach efforts with the watershed group.

Main Creek Stream Bank Restoration

Main Creek has high concentrations of nutrients and sediments in its flow to Deer Creek Reservoir. The high sediments indicate that stream bank stabilization is likely a problem. It is recommended that a project be implemented which incorporates buffer areas, stabilizes stream banks and restores riparian vegetation along Main Creek. It is recommended that approximately $500,000 be obtained from federal grants to perform this work and be coordinated through the NRCS.

Heber Valley Pasture BMP Projects

Field investigations revealed that there is a need for increased BMPs in the watershed, especially in pastures with cattle. Many farms allow cattle to water in the channels of streams and canals which increases nutrient loads and bank erosion. It is recommended that the local conservation district work with the agricultural community to improve management practices.

Suggested BMPs include but should not be limited to:

- Fencing off streams and canals.
- Allowing riparian vegetation to grow along streams and canals.
- Watering livestock away from stream channels.
- Preventing overgrazing of pastures.

The cost of these practices are mostly related to a change in management practices and represent little additional operational costs. Fencing and off-stream watering facilities are difficult to estimate without specific information but it is assumed that a significant impact to water quality could be achieved with the investment of approximately $500,000 in the pastures with the largest problems such as the North Fields. The NRCS and local conservation district should collaborate together to help local farms implement these practices.

Midway Fish Hatchery

The Midway Fish Hatchery has continued to make significant improvements to reduce phosphorus loadings since the installation of settling ponds before discharging into Snake Creek. It is recommended that maintenance of settling ponds be reviewed and if possible that the efficiency of these ponds be improved. A reduction of 200 kilograms per year is anticipated from improved management practices. The Utah Division of Wildlife Resources is responsible for this action. The costs of this action should be fairly negligible except for some potential additional maintenance costs estimated at $5,000 per year.

Cautious Responsible Growth in Heber Valley and Jordanelle Basin

As Wasatch County continues to experience high rates of growth, County officials need to continue to be wary of the potential impact of developments on water quality. Wasatch County has thus far been a proactive and cooperative participant in the protection of the Provo River watershed. JTAC should continue to work together with Wasatch County in the as the Heber Valley and the Jordanelle Basin continue to develop. Developers should meet County water quality guidelines and install water quality protection control measures. Larger developments should be required to conduct sampling to determine water quality impacts to the watershed.

Table 6-1. Summary of Recommended Watershed Projects with Costs and TP Load Reductions.

Project	Responsibility	Estimated Construction Costs	Potential TP Reduction kg/yr
Provo River Restoration Project*	Utah Mitigation Reclamation and Conservation Commission	$ 24,000,000	465
Conversion to Sprinkler Irrigation*	CUWCD, NRCS, and Irrigation Companies	10,000,000	500
Heber Valley Water Quality Basins	Wasatch County	2,000,000	800
Cleanup of Potential CAFOs	UACD	150,000	350
Integrated Watershed Management System	JTAC	250,000	n/a
Agricultural BMPs	UACD, NRCS	600,000	350
Midway Fish Hatchery	UDWR	n/a	200
Main Creek Stream Restoration	UDWQ	500,000	300
Cautious Responsible Growth in Heber Valley and Jordanelle Basin	Wasatch County, JTAC	n/a	n/a
Totals		**$ 38,100,000**	**2,965**

* Note: For these projects related to the Central Utah Project Completion Act, the water quality benefits of phosphorus reduction are secondary goals.

REFERENCES:

Carlson, R.E. 1977. A trophic state index for lakes. Limnology and Oceanography 22:361-369

Carpenter, S.R., N.F. Caraco, D.L. Correll, R.W. Howarth, A.N. Sharpley, and V.H. Smith. 1998.

Chapra, S.C. 1997. Surface Water Quality Modeling. The McGraw Hill Companies, Inc., New York, NY.

HA&L. 1994. Wasatch County Hydrogeologic/Water Quality Study. Hansen Allen & Luce, Inc. Salt Lake City, UT.

Lewis, W.M., J.F. Saunders, D.W. Crumpacker, and C. Brendecke. 1984. Eutrophication and Land Use Lake Dillon, Colorado. Springer-Verlag, New York, NY.

Nonpoint Pollution of Surface Waters with Phosphorus and Nitrogen. Ecol. Appl. 8(3):559-568.

NRCS. 2001. Soils in Wasatch County (GIS Data). U.S. Natural Resources Conservation Service.

Nurnberg, G.K. 1995. The Anoxic Factor, a Quantitative Measure of Anoxia and Fish Species Richness in Central Ontario Lakes. Trans. Am. Fish. Soc. 124:677-686.

Nurnberg, G.K. 1995a. Quantifying anoxia in lakes. Limnol. Oceonogr. 40(6):1100-1111.

Nurnberg, G.K. 1996. Trophic State of Clear and Colored, Soft- and Hardwater Lakes with Special Consideration of Nutrients, Anoxia, Phytoplankton and Fish. Lake and Reserv. Manage. 12(4):432-447.

Nurnberg, G.K. 1997. Coping with Water Quality Problems due to Hypolimnetic Anoxia in Central Ontario Lakes. Water Qual. Res. J. Canada. 32(2):391-405.

Psomas. 1999. Upper Provo River Water Quality Management Plan. Salt Lake City, UT.

Psomas. 2000(a). 2000 Water Quality Implementation Report, Deer Creek and Jordanelle Reservoirs Water Management Plan for 1999. Salt Lake City, UT.

Psomas. 2000(b). Heber Valley Storm Water Management Plan. Psomas. Salt Lake City, Utah

Rushforth, S.R. and R.G. Sinclair. 2001. Phytoplankton Floras from Deer Creek Reservoir, Wasatch County, Utah 2000. Utah Valley State College. Orem, UT.

Rushforth, S.R., R.G. Sinclair, R. Fleshman, and D. George. 2001 A Time Series Study of Phytoplankton Floras from Deer Creek Reservoir, Wasatch County, Utah, 1971-1999. Utah Valley State College, Orem, UT.

Thompson, C.W. 1993. Deer Creek Reservoir Fisheries Surveys, 1993. Utah Division of Wildlife Resources, Springville, UT.

Thompson, C.W. 1994. Deer Creek Reservoir Fisheries Surveys, 1994. Utah Division of Wildlife Resources, Springville, UT.

Thompson, C.W. and D.E. Wiley. 1995. Deer Creek Reservoir Fisheries Surveys, 1995. Utah Division of Wildlife Resources, Springville, UT.

URMCC. 1997. Provo River Restoration Project Final Environmental Impact Statement. Utah Reclamation Mitigation and Conservation Commission. Salt Lake City, Utah.

USEPA. 1999. Draft Guidance for Water Quality-based Decisions: The TMDL Process (Second Edition) (EPA 841-D-99-001) United States Environmental Protection Agency, Office of Water, Washington, DC.

USEPA, 2001. Lake Erie: Tracking depletion of dissolved oxygen. http://www.epa.gov/glnpo/lakeerie/dostory.html

Utah AFO/CAFO Committee. 2001. A Utah Strategy to Address Water Pollution From Animal Feeding Operations. Utah Department of Environmental Quality. Salt Lake City , UT.

Utah Agricultural Statistics Service. 1997 Census of Agriculture, Highlights of Agriculture: 1997 and 1992, Wasatch County, Utah. http://www.nass.usda.gov/census/census97/highlights/ut/utc026.txt

Utah Division of Water Quality. 2000. Utah's Year 2000 303(d) List of Waters. Utah Department of Environmental Quality, Salt Lake City, UT.

Vollenweider, R.A. 1975. *Input-Output models with special reference to the phosphorus loading concept in limnology*. Schweiz. Z. Hydrol. 37:53-84.

Vollenweider, R.A. 1976. *Advances in defining critical loading levels for phosphorus in lake eutrophicatio*n. Mem. Inst. Ital. Idrobiol. 33:53-83.

Wasatch County. 2001. Wasatch County General Plan 2001 – 2016, Draft. Wasatch County Planning Commission. Heber City, Utah.

Wiley, D.E. and C.W. Thompson. 1996. 1995 Deer Creek Reservoir Creel Survey. Utah Division of Wildlife Resources, Springville, UT.

Wiley, D.E. and C.W. Thompson. 1997. 1996 Deer Creek Fish Population Survey. Utah Division of Wildlife Resources, Springville, UT.

Wiley, D.E. and C.W. Thompson. 1998. Deer Creek Reservoir Fisheries Surveys: 1997. Utah Division of Wildlife Resources, Springville, UT.

Wiley, D.E. and C.W. Thompson. 2000. Deer Creek Reservoir Fisheries Surveys: 1999-2000. Utah Division of Wildlife Resources, Springville, UT.