Utah Department of Environmental Quality
Division of Water Quality
TMDL Section

Matt Warner Reservoir TMDL

EPA Approval Date: July 9, 2007

Waterbody IDs	14040106-033 Matt Warner Reservoir
Location	Uintah County, Utah
Pollutants of Concern	Total Phosphorus Water Temperature
Impaired Beneficial Uses	3A – Cold Water Fishery Protected for cold water species of game fish and other cold water aquatic life, including the necessary aquatic organisms in their food chain.
Current Load: **Loading Capacity (TMDL):** **TMDL Load Reduction:** **Wasteoad**	223 kg/yr 201 kg/yr 22 kg/yr
Wasteload Allocation **Load Allocation** **Margin of Safety**	0 kg/yr (no point sources in watershed) 201 kg/yr 22 kg/yr
Defined Targets/Endpoints	1) 50 percent of the water column above 4 mg/L DO 2) 201 kg/yr Total Phosphorus Load Maximum: 3) Average Carlson TSI between 40 and 50 (Mesotrophy) 4) Decrease in dominance of blue green algae 4) No fish kills
Implementation Strategy	1) Maintain and improve existing watershed management and grazing practices 2) Maintain fishery management practices

Utah Department of Environmental Quality
Division of Water Quality
TMDL Section

Calder Reservoir TMDL

EPA Approval Date: July 9, 2007

Waterbody IDs	14040106-034 Calder Reservoir
Location	Uintah County, Utah
Pollutants of Concern	Total Phosphorus
Impaired Beneficial Uses	3A – Cold Water Fishery Protected for cold water species of game fish and other cold water aquatic life, including the necessary aquatic organisms in their food chain.
Current Load: **Loading Capacity:** **TMDL Load Reduction:** **Wasteoad**	263 kg/yr 145 kg/yr 118 kg/yr
Wasteload Allocation **Load Allocation** **Margin of Safety** **Margin of Safety**	0 kg/yr (no point sources in watershed) 119 kg/yr 26 kg/yr
Defined Targets/Endpoints	1) 50 percent of the water column above 4 mg/L DO 2) 145 kg/yr Total Phosphorus Load Maximum: 3) Average Carlson TSI between 40 and 50 (Mesotrophy) 4) Decrease in dominance of blue green algae 4) No fish kills
Implementation Strategy	1) Maintain and improve existing watershed management and grazing practices 2) Maintain fishery management practices

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Chapter 1: Executive Summary

Matt Warner and Calder Reservoir Water Quality Study and TMDL

1.1 Introduction

Matt Warner and Calder Reservoirs are small stabilized lakes on Pot Creek located in Uintah County. Matt Warner Reservoir, the largest lake, is located several miles upstream of Calder Reservoir. Matt Warner Reservoir has a surface area of 297 acres, and average depth of 9.4 feet and an elevation of 7,540 feet above sea level. Calder Reservoir has a surface area of approximately 99 acres, an average depth of 17 feet and an elevation of 7,291 feet above sea level. The watershed and reservoir locations are illustrated in Figure 1-1. The reservoirs are primarily used for fishing, but in drought years Calder Reservoir is utilized for agricultural uses.

Matt Warner and Calder Reservoirs are identified as having the following beneficial uses: 2B (secondary contact recreation), 3A (cold-water fishery), and 4 (agriculture). Both reservoirs are listed as partially supporting their cold-water fishery beneficial use on the 2004 303(d) list for waters requiring the development of TMDLs as shown in Table 1-1.

Table 1-1: Beneficial Use Impairments

	Constituents of Concern	Beneficial Use Impaired	Priority	Targeted for TMDL
Matt Warner Reservoir	Temperature	Cold water fishery (3A)	Low	No
Calder Reservoir	Dissolved Oxygen, Total Phosphorus	Cold water fishery (3A)	High	Yes

Although Matt Warner Reservoir was identified as a low priority for TMDL development its proximity and hydrologic linkage to Calder Reservoir facilitated its development without affecting the timely development and submission of the State's other high priority TMDLs. The purpose of this study is to determine if and to what extent the reservoirs' beneficial use is impaired. Various types and sources of data will be considered to make this assessment.

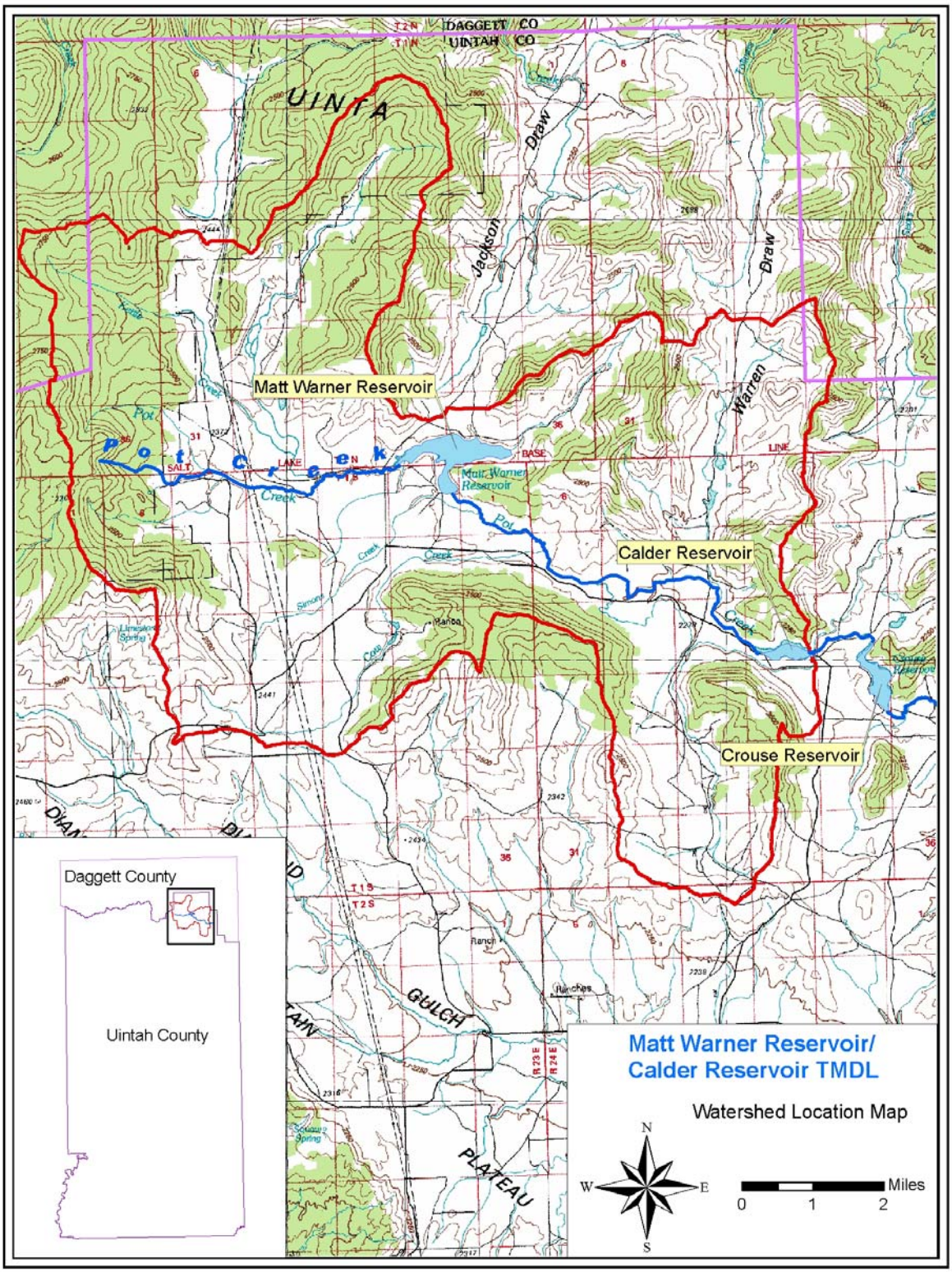
1.2 Sources of Data

Table 1-2 lists the sources of data utilized for this study. Chapter 2 contains a detailed explanation of the sources of data, data gaps, and statistical methods used in this study.

Table 1-2: Data Sources

Source	Type of Data
Utah DWQ	Water Quality, Flow
Utah Water Rights	Flow
USGS	Flow

Figure 1-1: Reservoirs and Watershed Location



1.3 Reservoir Impairment Assessment

Table 1-3 shows the reservoir impairment analysis methods and conclusions described in Section 3.6. Both reservoirs appear to be impaired when comparing individual samples to a 6.5 mg/L dissolved oxygen standard. However, when analyzing the percent of the water column with dissolved oxygen concentrations below 4 mg/L, the reservoirs do not appear to be impaired. Therefore, although dissolved oxygen near the bottom of the reservoir is depleted at times, overall it does not impair the entire water column. Total water column phosphorus exceeds the indicator value, yet this does not appear to impair the dissolved oxygen concentrations or fish habitat.

Table 1-3: Impairment Conclusions

Method	Calder Reservoir	Matt Warner Reservoir
Exceedances		
TP	**Yes**	**Yes**
DO (Grab Sample)	**Yes**	**Yes**
Temp	No	No
TSI	**Yes**	**Yes**
Vollenweider Loading	**Yes**	No
Water Column Temp	No	No
Water Column TP	**Yes**	**Yes**
Water Column DO (Profiles)	No	No
Water Column Fish Habitat	No	No

Additionally, it was concluded that conditions within the reservoirs have always been at least partially supporting and are fully supporting about 80 percent of the time. Although Calder Reservoir has experienced fish kills in the past, it is thought that they were due to drought, not water quality conditions. Both reservoirs have healthy, robust fisheries with the exception of a few weeks each summer. During these weeks, algae blooms cause the water in reservoirs to resemble “pea soup” and the fish to have a poor taste.

The results of the analyses indicate that total phosphorus concentrations have decreased slightly and dissolved oxygen concentrations have increased slightly in both reservoirs since the early 1990s. However, both reservoirs have been classified as eutrophic for a large portion of the last 12 years. Based on these trends, opinions of local fisherman, and their general fully supporting status, it was determined that the Matt Warner Reservoir fishery is not impaired and Calder Reservoir is somewhat impaired.

1.4 TMDL

The TMDL load allocation assigns loads to all sources including point, non-point and background sources. In addition, a margin of safety (MOS) is included to account for the uncertainty inherent in the analysis such that beneficial uses are protected into the foreseeable future. The MOS is a required part of the TMDL development process. There are two basic methods for incorporating the MOS (USEPA, 1991). Implicit methods incorporate the MOS using conservative model assumptions to develop allocations. Explicit methods specify a portion of the total TMDL as the MOS, allocating the remainder to sources.

Because there wasn’t a consistent conclusion from the methods considered in the impairment assessment section, and because of the limited amount of data, a 10 percent MOS, included explicitly, is recommended. This allocates 10 percent of the

loading capacity, or 22 kg/yr (50 lbs/yr) for Matt Warner Reservoir and 26 kg/yr (58 lbs/yr) for Calder Reservoir to the MOS.

Table 1-4 and Table 1-5 outline current loads, proposed reductions, and future loading allocations for each major source of phosphorus. The loads into Matt Warner and Calder Reservoirs are 223 kg/yr and 263 kg/yr, respectively. Details on the methods used to determine these loads can be found in the Pollutant Loadings section.

Table 1-4: Total Phosphorus TMDL Load Allocations (kg/yr) – Matt Warner Reservoir

Source	Current	Reduction	Allocation
Stream Inflows	223	0	223
Future sources	-	0	0
Margin of Safety	-	22	0
Total	223	22	201

Table 1-5: Total Phosphorus TMDL Load Allocations (kg/yr) - Calder Reservoir

Source	Current	Reduction	Allocation
Stream Inflows	263	92	171
Future sources	-	0	0
Margin of Safety	-	26	0
Total	263	118	145

1.5 Recommendations

It has been determined that Matt Warner Reservoir is supporting its cold water fishery beneficial use. It is also recommended that Matt Warner Reservoir be de-listed for temperature. Calder Reservoir has been determined to be slightly impaired and load reductions have been recommended accordingly. As best management practices are implemented under an adaptive management approach, continued monitoring will be used to assess improvement.

2.1 Introduction

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

The TMDL approach targets watersheds, addressing water quality in a site-specific way tailored to local conditions and objectives. It specifies the maximum pollution loadings where water quality goals are not being met and provides a framework for remedial action.

High temperatures in Matt Warner Reservoir have exceeded the State's water quality standards for the beneficial use designation of cold water aquatic life (Class 3A). High total phosphorus and low dissolved oxygen concentrations in Calder and Matt Warner Reservoirs have also exceeded the State's water quality indicator for the beneficial use designation of aquatic wildlife (Class 3A). These exceedances have resulted in the reservoirs' placement on Utah's 303(d) list of impaired waters.

The purpose of this study is to determine, through a scientifically based approach, if Matt Warner and Calder Reservoirs are impaired and, if so, to what extent. Various types and sources of data will be considered to make this assessment.

2.2 Location and Description

General Watershed Description

Matt Warner and Calder Reservoirs are small stabilized lakes in the Diamond Mountain area northeast of Vernal. They are part of a chain of three stabilized lakes on Pot Creek with Matt Warner and Crouse Reservoirs to the west and east of Calder Reservoir, respectively (see Figure 1-1). The reservoirs are located in an area of rolling hills and flat valley bottoms. Slopes in Pot Creek drainage are not steep (30% maximum) and little erosion is occurring (State of Utah, Division of Water Quality). There are some mid-elevation mountains at the headwaters of Pot Creek, but these are small compared to the higher mountains several miles west.

Pot Creek between Matt Warner and Calder

The watershed covers an area of 42,395 acres. The watershed high point, the east peak of Mount Lena, is 9,147 ft above sea level, thereby developing a complex slope of 4.3% to Calder Reservoir and 5.5% to Matt Warner Reservoir. The average stream gradient of Pot Creek is 0.8%. Pot Creek is both the inflow and outflow of Matt Warner and Calder Reservoirs.

The frost-free season around the reservoirs is 60-80 days per year.

Recreation

Fishing is the primary function of both reservoirs, and they are stocked annually with trout. The reservoirs also have boat ramps and restroom facilities.

Vegetation

The vegetation communities consist of ponderosa pine, sagebrush, oak, and wheatgrass as shown in Figure 2-1.

Soils

The dominant soils in the watershed are loam, very channery silt loam, extremely bouldery loam, and extremely stoney sandy loam as shown in Figure 2-2.

Figure 2-1: Dominant Vegetation Communities

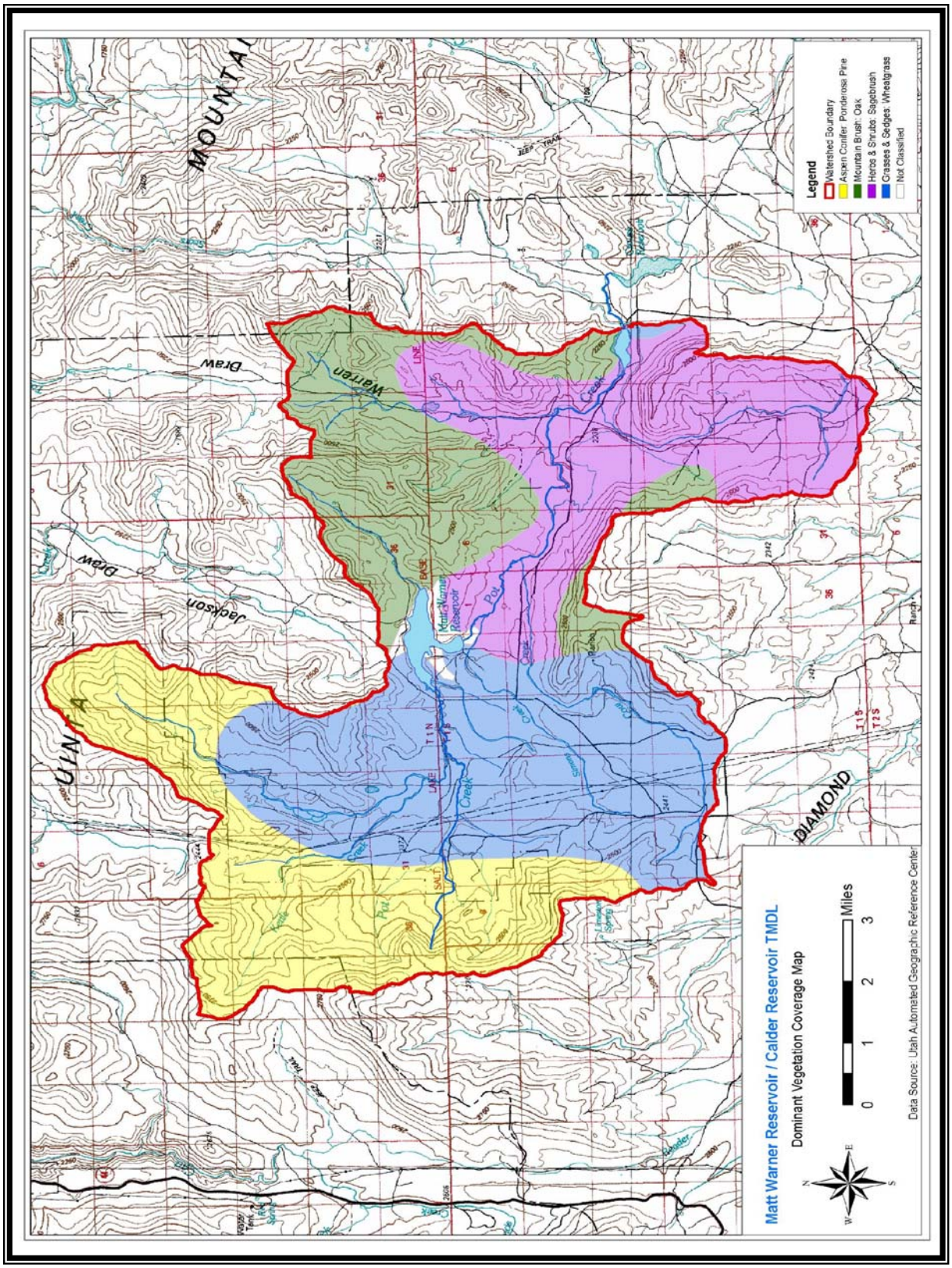
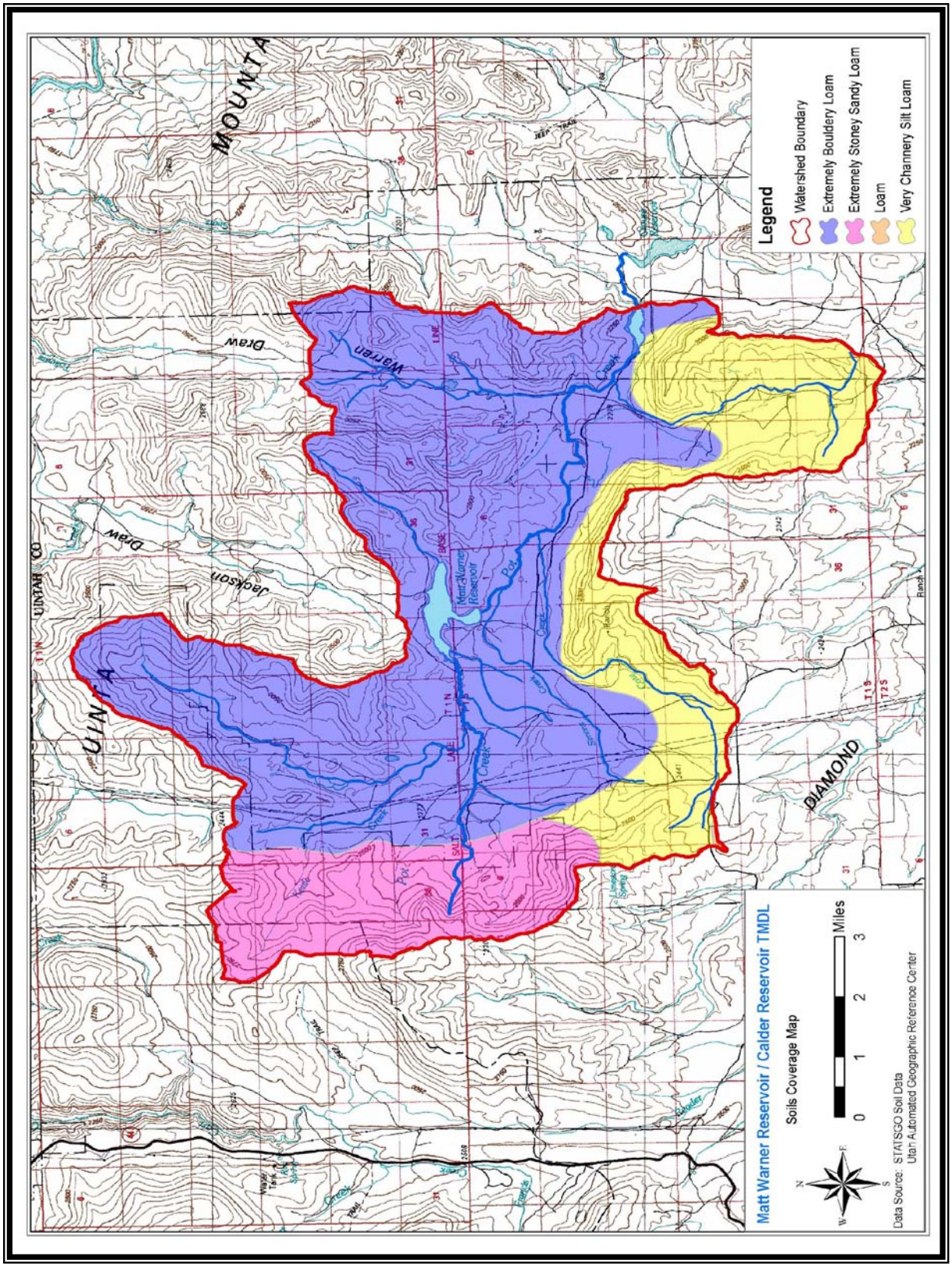


Figure 2-2: Soil Coverage Map



Matt Warner Reservoir

Background

Matt Warner Reservoir is located several miles upstream from Calder Reservoir. It was built for agricultural purposes, but was purchased by the Division of Wildlife Resources (DWLR) in 1978 to provide a fishery for the public. The reservoir was created in 1938 and enlarged in 1986 by the construction of an earth-fill dam. It no longer functions as a reservoir, but as a lake held at full pool, thus enhancing the fishery. The reservoir shoreline is privately owned, but public access is unrestricted.

Statistics

- Lake elevation: 7,540 feet
- Surface area: 297 acres
- Volume capacity: 2,796 acre-feet
- Maximum depth: 23 feet
- Mean depth: 9.4 feet
- Length: 8,458 feet
- Width: 530 feet
- Shoreline: 5.07 miles

(Source: www.waterquality.utah.gov)

Matt Warner Reservoir

Calder Reservoir

Background

Calder Reservoir was created in the 1970s by the construction of an earth-fill dam, and purchased by the DWLR in 1978. The reservoir shoreline is mostly privately owned, but the west end and northeast corner are owned by the Bureau of Land Management (BLM). Public access to the reservoir is unrestricted. Reservoir water is owned by the DWLR for non-consumptive use as a cold-water aquatic habitat and a recreation facility, but in drought years the reservoir is utilized for agricultural uses.

Statistics

- Lake elevation: 7,291 feet
- Surface area: 99 acres
- Volume capacity: 1,630 acre-feet
- Maximum depth: 38 feet
- Mean depth: 17 feet
- Length: 4,510 feet
- Width: 1,310 feet
- Shoreline: 2.23 miles

(Source: www.waterquality.utah.gov)

Calder Reservoir

2.3 Reservoir Operations

The DWLR owns and operates the reservoirs' fisheries. While water rights influence the operations of Matt Warner and Calder Reservoirs, there is some flexibility in how these reservoirs are operated. Because DWLR owns and operates all three reservoirs, Division of Water Rights allows them to "shift" water rights between the reservoirs according to a prescribed agreement. DWLR chooses to operate Matt Warner with the highest priority, then Calder Reservoir. The Utah Division of Water Rights (Water Rights) determines the quantity of water that should be released to satisfy irrigation and other water rights, and notifies the Water Commissioner. The Water Commissioner then operates the head gates themselves.

2.4 Recent Water Quality Events

According to the Utah Division of Wildlife Resources, in September 2004 three adult cows and 15 calves died from liver failure after drinking water from Matt Warner Reservoir containing blue-green algae. The cattle were located near the southeast arm of the reservoir, which had recently experienced blue-green algae blooms.

After six years of drought in Northeastern Utah, Calder Reservoir experienced a nearly total fish kill in 2004. Biologists from the Utah Division of Wildlife Resources believe the winterkill must have happened within a few weeks of ice-off. Crouse Reservoir winterkilled in 2002. Biologists were concerned that Matt Warner Reservoir would be the third lake on Diamond Mountain to fall victim to the drought, however, drought conditions appear to be improving.

Low Water at Calder Reservoir

In spite of these events, it is the opinion of the Division of Wildlife Resources in Vernal that the fishery is doing well (2005). They are pleased with the number of larger, catchable trout that result from the annual restocking of small trout. Due to the numbers in and robustness of the fishery, they feel Matt Warner and Calder Reservoirs are two of the more productive, better fisheries in the state and are unaware of any impairment issues. They did, however, note that for a few weeks of every summer the water in the reservoirs resembles "pea soup" as a result of algae blooms. This causes the fish to have a poor taste during this time period (2005).

2.5 Previous Studies

Previous studies conducted in the Matt Warner and Calder Reservoir watersheds include a vegetation study and fishery studies. Their findings are summarized below.

Warren Draw Soil and Vegetation Trend Study

In September of 2000 the State of Utah's Department of Wildlife Resources performed a soil and vegetation study for the Warren Draw area. Warren Draw runs north and south through the eastern side of the watershed. The area just north of Calder Reservoir was studied for trends in soil, browse (shoots, twigs and leaves used by animals for food), and herbaceous understory. Their findings are summarized below and in Table 2-1.

- Soil conditions were good with abundant protective ground cover from vegetation and litter and low amounts of bare soil

- Soil texture was a sandy clay loam with a neutral pH
- Moderate soil depth
- Slight erosion

Table 2-1: Vegetation Trends

	Dominant Species	Cover	Trend
Browse	Big sagebrush	19%	Decline in population and vigor due to drought
Herbaceous Understory	Perennial grasses: thickspike wheatgrass, mutton bluegrass, pinewoods	15%	Decline in population due to drought
	Perennial Forbes: rose pussytoes, desert phlox, clover	24%	Decline in number of species and populations
	Annual forbs: Douglas knotweed	Little	Decline in population due to drought

2.6 Population Projections

The population of Uintah County has steadily increased over the past decade. Although less than the state average increase rate of 2.3%, Uintah County experienced 0.8% growth between 2003 and 2004. According to the demographic and economic analysis distributed by Utah's Association of Government and Governor's Office of Planning and Budget (June 2000), the population in Uintah County is projected to increase at an annual average rate of 0.6% through the year 2030 as shown in Table 2-2. Currently, Uintah County and adjacent Duchesne County are experiencing significant growth due to recent boom in oil and gas development, particularly around the communities of Vernal and Roosevelt. How this recent growth affects the long term population of Uintah County remains to be seen. Table 2-3 shows projections for the percentage of the population that resides in particular cities in Uintah County.

Table 2-2: Population Projections for Uintah County

Area	2004	2005	2010	2020	2030	AARC
Uintah County	25,688	25,712	26,801	29,058	29,889	0.6%
Ballard	890	903	975	1,017	1,047	0.7%
Naples	1,519	1,520	1,584	1,718	1,767	0.6%
Vernal	7,374	7,381	7,694	8,341	8,580	0.6%
Balance of Uintah	15,905	15,908	16,548	17,982	18,495	0.6%

1) AARC = Annual Average Rate of Change, 2000-2030

Table 2-3: Population Shares

Area	2004	2005	2010	2020	2030
Uintah County	100%	100%	100%	100%	100%
Ballard	3.5%	3.5%	3.6%	3.5%	3.5%
Naples	5.9%	5.9%	5.9%	5.9%	5.9%
Vernal	28.7%	28.7%	28.7%	28.7%	28.7%
Balance of Uintah	61.9%	61.9%	61.7%	61.9%	61.9%

2.7 Future Land Use

The watershed encompassing Matt Warner and Calder Reservoirs currently consists of grazing, agricultural, residential, and recreational land. According to the Uintah County Department of Building, Planning and Zoning, future land use is projected to remain unchanged. The watershed is located in a remote area that is difficult to access, particularly during the winter months. Due to this limitation, and the lack of sewer and water infrastructure in the area, significant development is unlikely.

3.1 Introduction

Water quality and flow data were obtained from various sources that are identified further in this chapter. These data were screened and evaluated to determine their validity and applicability to this study.

In addition to gathering water quality data, flow data for Pot Creek above Matt Warner and Calder Reservoirs were obtained. Flow data for other inflows were not available. Flow data are necessary for determining pollutant loads as well as for establishing the water budget for the reservoirs.

The water quality data used in this analysis were obtained from the State of Utah, Division of Water Quality (DWQ). Flow data were obtained from DWQ, Division of Water Rights (Water Rights), and USGS.

3.2 Data Sources

Water Quality Data

The Utah Division of Water Quality (DWQ) provides access to, by way of the EPA STORET system, a database of water quality data. Data for Pot Creek and data at various depths in both reservoirs were downloaded from this system. Data from 1977 to 2004 were obtained, which is the full period of record for this watershed. Specifically, data were obtained for the sampling locations listed in Table 3-1.

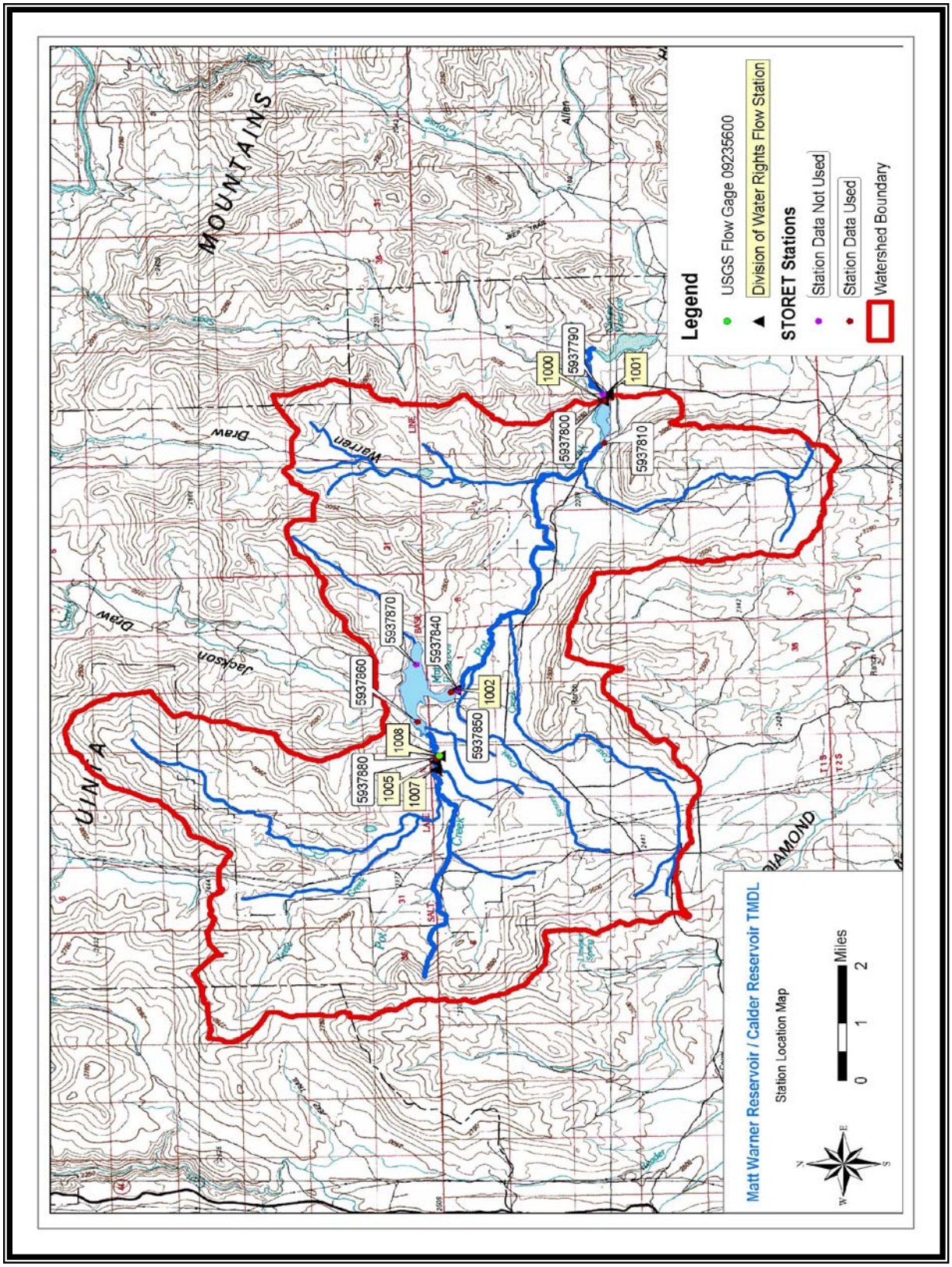
Table 3-1: Water Quality Sampling Stations

STORET	Description	Type
5937790	Pot Creek Below Calder Reservoir and Above Crouse Reservoir	Outflow
5937800	Calder Reservoir Above Dam	Reservoir
5937810	Pot Creek Above Calder Reservoir	Inflow
5937840	Pot Creek Below Matt Warner Reservoir	Outflow
5937850	Matt Warner Reservoir Above Dam	Reservoir
5937860	Matt Warner Reservoir West Midlake	Reservoir
5937870	Matt Warner Reservoir East Midlake	Reservoir
5937880	Pot Creek Above Matt Warner Reservoir	Inflow

Figure 3-1 shows the locations of these sites. In addition to the water quality data obtained from the STORET database, DWQ provided reservoir vertical profile data for the years 1996 - 2004. This profile data included temperature, dissolved oxygen and pH. The locations where these profiles were taken coincide with reservoir STORET sites. While a wide variety of water quality data are available, the following constituents were analyzed at this time:

- Total Phosphorus (TP)
- Dissolved Total Phosphorus (DTP)
- Dissolved Oxygen (DO)
- Water Temperature
- Total Suspended Solids (TSS)

Figure 3-1: Station Location Map



Water Quality Data Gap Analysis

Coverage

Table 3-2 shows the time periods when water quality data are available for each station. Water quality data for Pot Creek above Matt Warner Reservoir and within both reservoirs are available from the 1990s to 2004. Sampling was typically performed every two years, between May and September. However, Pot Creek above Calder Reservoir (Water Rights Station 5937810) has not been sampled since 2000.

Table 3-2: Water Quality Data Availability by Station

Station	Description	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
5937800	Calder Res Abv Dam	■	■		■		■		■		■		■	■	■
5937810	Pot Crk Abv Calder Res		■						■		■				
5937850	Matt Warner Res Abv Dam	■	■		■	■	■		■		■		■	■	■
5937860	Matt Warner Res Midlake		■		■	■	■		■		■		■	■	■
5937880	Pot Crk Abv Matt Warner		■		■				■		■		■	■	■

Stations Excluded From Analysis

Data from 1991 to 2004 was used for this study. This time period was chosen because it contains the most continuous, recent data and is believed to represent current conditions. Several of the stations presented above were not sampled a sufficient number of times to be useful in this study. A decision was made to exclude stations which were only sampled once, or which were only sampled prior to 1991. Table 3-3 shows the stations which were excluded from further analysis.

Table 3-3: Water Quality Sampling Station with Insufficient Data

STORET	Description	Type	Reason for Excluding
5937790	Pot Crk Blw Calder Res and Abv Crouse Res	Outflow	Only sampled once (1992)
5937840	Pot Creek Below Matt Warner Reservoir	Outflow	Sampled in 1981 only
5937870	Matt Warner Reservoir East Midlake	Reservoir	Sampled in 1981only

Flow Data

Figure 3-1 shows the locations of the STORET, Water Rights, and USGS sites.

Utah DWQ

Stream flows were estimated during each water quality sampling trip. These flow estimates are also recorded in the STORET database. The methods used to estimate flow have varying degrees of accuracy and are considered to be approximations of actual stream flow. Nevertheless, these estimates are valuable because they are recorded every time a water quality sample is taken.

Utah Water Rights

Data obtained from the Utah Division of Water Rights included mean daily discharge from the areas surrounding Matt Warner and Calder Reservoirs. Data from 1930 to 2003 were obtained. Specifically, data were obtained for the sampling locations listed in Table 3-4. Station IDs were assigned to these stations to facilitate analysis and discussion.

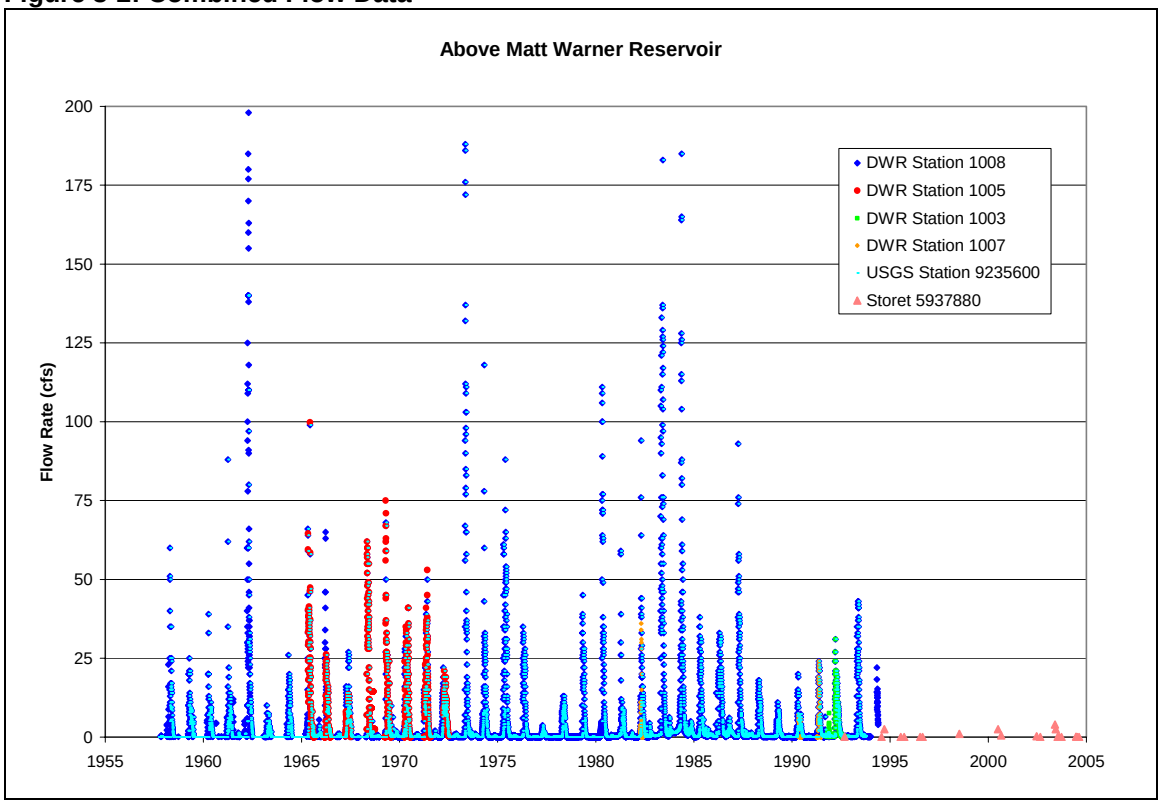
Table 3-4: Water Rights Stations

Station Name	Assigned Station ID	Record Period	Notes
Calder's Reservoir	1000	1964-1995	No data between 1972 and 1995
Calder Reservoir (Game)	1001	1995-2003	Data in May 1995 and June 2003 only
Matt Warner Reservoir	1002	1930-2003	No data between 1930 and 1995
Pot Crk Abv Diversions Nr Vernal	1003	1991-1992	Consistant data between 1991 and 1992
Pot Crk at State Line	1004	1991-1993	Data in May 1991 and May/June 1993
Pot Crk Flow Abv Matt Warner Res	1005	1965-1972	Consistant data between 1965 and 1972
Pot Crk Near CO Line Abv CO Users	1006	1968	Data for 1968 only
Runoff in Pot Crk	1007	1982-1991	No data between 1982 and 1990
Pot Crk Abv Diversions Nr Vernal	1008	1957-1994	Consistant data between 1957 and 1994
Pot Crk Near Vernal	1009	1957-1982	Consistant data between 1957 and 1982

USGS

USGS flow gage 09235600, located above Matt Warner Reservoir, provided mean daily discharge data between 1957 and 1993. Several Water Rights stations appear to utilize this stream gage, as can be seen by the overlap of data in Figure 3-2. USGS also provides groundwater information. However, there is no groundwater data available in the Matt Warner and Calder Reservoir watershed.

Figure 3-2: Combined Flow Data



3.3 Methods

Data Validation Methods

Treatment of Non-Detect Values

The water quality data obtained for this project contained several samples which were reported below the minimum detection limit. Table 3-5 shows the number of samples for each constituent and the number reported as being below the minimum detection limit.

Table 3-5: Non-Detect Samples

Constituent	Total Samples	Non-Detect Samples	% Non-Detect	Detection Limit
Total Phosphorus	165	12	7%	0.02 mg/L
Dissolved Total Phosphorus	165	31	19%	0.02 mg/L
Dissolved Oxygen	178	0	0%	N/A
Temperature	180	0	0%	N/A
Total Suspended Solids	79	21	27%	4.0 mg/L

For the purpose of analyzing these data, an assumption must be made to assign a numerical value to samples which have been recorded as "non-detect". After consulting with DWQ, the assumption was made to represent all non-detect samples as half of the detection limit.

Identification of Outliers

A visual and statistical analysis of the data was conducted in order to determine the values that were not representative of the data set. The visual inspection consisted of plotting the concentration of the constituents at each station over time. Obvious data outliers were visually identified. For stream data, the average value and standard deviation for each constituent were calculated for each station. For reservoir data, the average value and standard deviation for each constituent were calculated for each station and depth code (surface, bottom, mid-depth, etc). Values that both visually and statistically did not represent the data were removed from further analysis. There were a total of 4 data points that were removed (less than 1% of the total number of points). These removed data points are presented below in Table 3-6.

Table 3-6: Removed Data Points

Location	Constituent	Station ID	Date	Value	z-Score
Calder Reservoir Above Dam - Surface	DO	5937800-21	3/14/1991	0.3	-3.23
Calder Reservoir Above Dam - Surface	TP	5937800-21	3/14/1991	0.48	3.93
Matt Warner Reservoir Above Dam - Surface	DO	5937850-21	3/14/1991	2.4	-3.19
Matt Warner Reservoir Above Dam - Surface	DTP	5937850-21	7/27/1994	0.23	3.57

3.4 Water Quality Standards & Criteria

The Utah Department of Environmental Quality (DEQ) establishes water quality standards for Utah streams and reservoirs. Designated beneficial uses determine the applicable water quality criteria. The classifications of Matt Warner and Calder Reservoirs per Utah Administrative Code R317-2 Standards of Quality for Waters of the State are included as Table 3-7.

Table 3-7: Matt Warner and Calder Reservoirs Beneficial use Designations

Beneficial Use Designation	Description
2B	Protected for secondary contact recreation such as boating, wading, or similar uses
3A	Protected for cold water species of game fish and other cold water aquatic life, including the necessary aquatic organisms in their food chain
4	Protected for agricultural uses including irrigation of crops and stock watering

Based on these classifications, Matt Warner and Calder Reservoirs are subject to the water quality standards and pollution indicators listed in Table 3-8 and the dissolved oxygen impairment parameters for cold water fisheries (beneficial use 3A) in Table 3-9.

Table 3-8: Water Quality Standards and Indicator Values

Constituent	2B	3A	4
Total Phosphorus (mg/L)**	0.05 for Streams* 0.025 for Lakes*	0.05 for Streams* 0.025 for Lakes*	-
Dissolved Total Phosphorus (mg/L)**	0.05 for Streams* 0.025 for Lakes*	0.05 for Streams* 0.025 for Lakes*	-
Total Suspended Solids (mg/L)	-	-	-
Water Temperature (°C)**	-	20	-

*Pollution Indicator Value **Key Impairment Parameters

The State of Utah water quality standards specific to the support of the cold water game fishery requires dissolved oxygen concentrations of no less than 6.5 mg/L as a 30-day average; no less than 9.5 mg/L for early life stages and no less than 5.0 mg/L for all life stages as a 7-day average; and no less than 8.0 mg/L for early life stages and no less than 4.0 mg/L for all life stages as a 1-day average (RS317-2-14, Table 3-9). For this study, a dissolved oxygen standard of 6.5 mg/L was used.

Table 3-9: DO Impairment Parameters for Cold Water Fisheries

	30 Day Average (mg/L)	7 Day Average (mg/L)	1 Day Average (mg/L)
All Life Stages	6.5	5.0	4.0
Early Life Stages	-	9.5	8.0

3.5 Water Quality Data Analysis

Analysis of the water quality data included statistical methods and seasonal assessments which are discussed below.

Reservoir Water Quality Data

A statistical analysis of water quality data for reservoir stations is presented in Appendix A. This analysis includes minimum, maximum, mean and standard deviation for the constituents of interest. The number of standard deviations that each point is away from its respective mean value, or "z score", has also been calculated. Individual sample values are also shown. Table 3-10 shows the summary of the statistical analysis for each reservoir station, grouping all depths together for each station.

Table 3-10: Summary of Reservoir Water Quality Data

Reservoir Water Quality Constituent Summary					
	5937800 - Calder Reservoir Above Dam				
	TP mg/L	**DTP mg/L**	**DO mg/L**	**Temp °C**	**TSS mg/L**
Minimum	0.010	0.010	0.1	1.2	0.0
Maximum	0.308	0.221	13.6	23.1	16.0
Mean	0.079	0.049	6.7	16.6	3.3
% Exceeding	54%	34%	37%	9%	N/A
Number of Points	48	50	54	55	22
	5937850 - Matt Warner Reservoir Above Dam				
	TP mg/L	**DTP mg/L**	**DO mg/L**	**Temp °C**	**TSS mg/L**
Minimum	0.010	0.010	0.2	1.2	0.0
Maximum	0.320	0.270	10.5	22.3	11.0
Mean	0.075	0.053	6.2	16.3	3.6
% Exceeding	64%	33%	46%	3%	N/A
Number of Points	66	66	68	69	24
	5937860 - Matt Warner Reservoir West Midlake				
	TP mg/L	**DTP mg/L**	**DO mg/L**	**Temp °C**	**TSS mg/L**
Minimum	0.010	0.010	0.4	11.5	0.0
Maximum	0.125	0.096	9.4	22.8	6.4
Mean	0.060	0.039	6.3	17.2	2.5
% Exceeding	59%	27%	36%	13%	N/A
Number of Points	34	34	39	39	16

Stream Water Quality Data

A statistical analysis of water quality data for stream stations is also included in Appendix A. This analysis includes minimum, maximum, mean, standard deviation for the constituents of interest, and "z score". Individual sample values are also shown. Table 3-11 shows the summary of the statistical analysis for each stream station.

Table 3-11: Summary of Stream Water Quality Data

Stream Water Quality Constituent Summary					
	5937880 - Pot Creek Above Matt Warner Reservoir				
	TP mg/L	**DTP mg/L**	**DO mg/L**	**Temp °C**	**TSS mg/L**
Minimum	0.028	0.010	6.4	8.2	2.0
Maximum	0.098	0.041	11.8	25.4	61.2
Mean	0.058	0.023	8.2	17.1	22.4
% Exceeding	46%	0%	8%	33%	N/A
Number of Points	11	10	12	12	12
	5937810 - Pot Creek Above Calder Reservoir				
	TP mg/L	**DTP mg/L**	**DO mg/L**	**Temp °C**	**TSS mg/L**
Minimum	0.010	0.010	5.7	13.8	0.0
Maximum	0.203	0.120	8.2	23.5	27.0
Mean	0.093	0.068	6.8	19.1	7.2
% Exceeding	67%	60%	60%	40%	N/A
Number of Points	6	5	5	5	5

Seasonality Assessment

Methodology

For the purpose of identifying seasonal patterns of water quality data, monthly scatter plots for the constituents of interest were generated and are provided in Appendix A. These plots show how long-term data is scattered and how seasonal (monthly) values fluctuate for each of these constituents. The monthly average values obtained in this analysis are presented in this section. A minimum of four data points were required to calculate an average. Therefore, months that had fewer than four sampling events are not shown on the monthly average charts below. This limitation was used to improve the accuracy of the calculated averages.

Concentrations

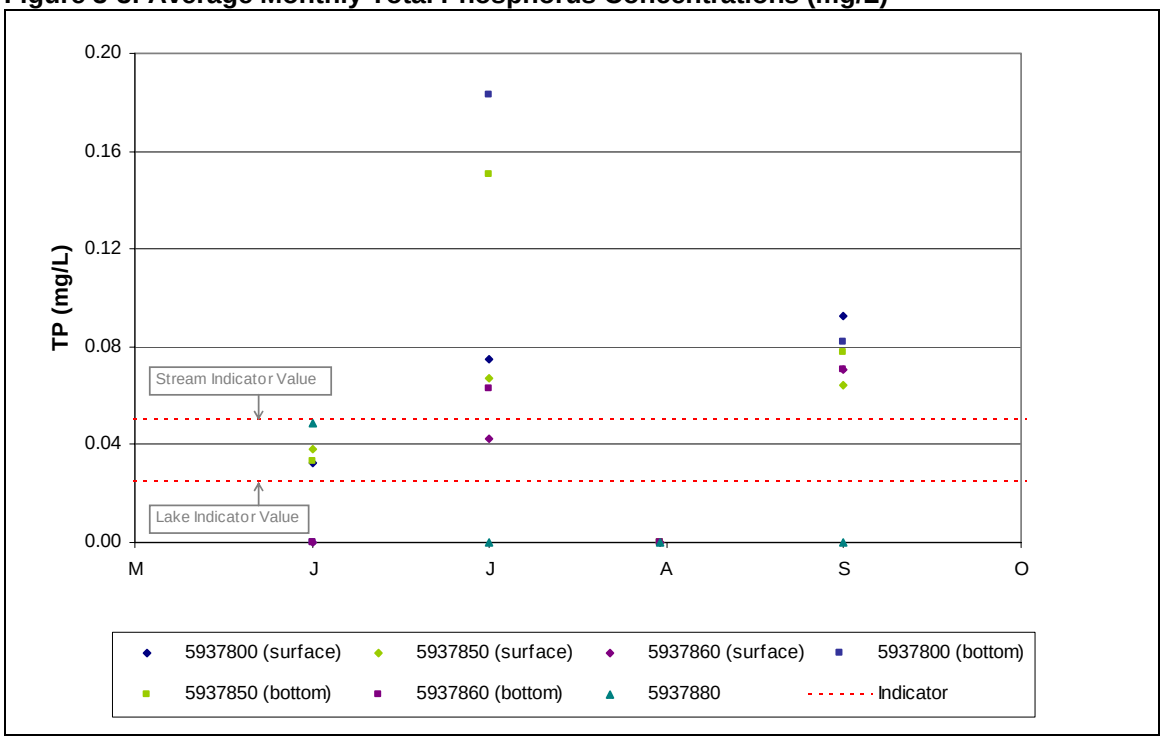
Total Phosphorus

Table 3-12 and Figure 3-3 show the average monthly concentrations of total phosphorus. With the exception of Pot Creek above Matt Warner Reservoir, all average concentrations exceeded the total phosphorus indicator value for every month where sufficient data were available. Average concentrations exceeding the indicator value are shown in red below.

Table 3-12: Average Monthly Total Phosphorus Concentrations (mg/L)

Name	Storet	June	July	August	September
CR Above Dam - Surface	5937800-21	0.032	0.075	-	0.093
CR Above Dam - Bottom	5937800-29	-	0.183	-	0.082
MWR Above Dam - Surface	5937850-21	0.038	0.067	-	0.065
MWR Above Dam - Bottom	5937850-29	0.034	0.150	-	0.078
MWR West Midlake - Surface	5937860-21	-	0.043	-	0.071
MWR West Midlake - Bottom	5937860-29	-	0.063	-	0.071
Pot Creek Above MWR	5937880	0.049	-	-	-

Figure 3-3: Average Monthly Total Phosphorus Concentrations (mg/L)



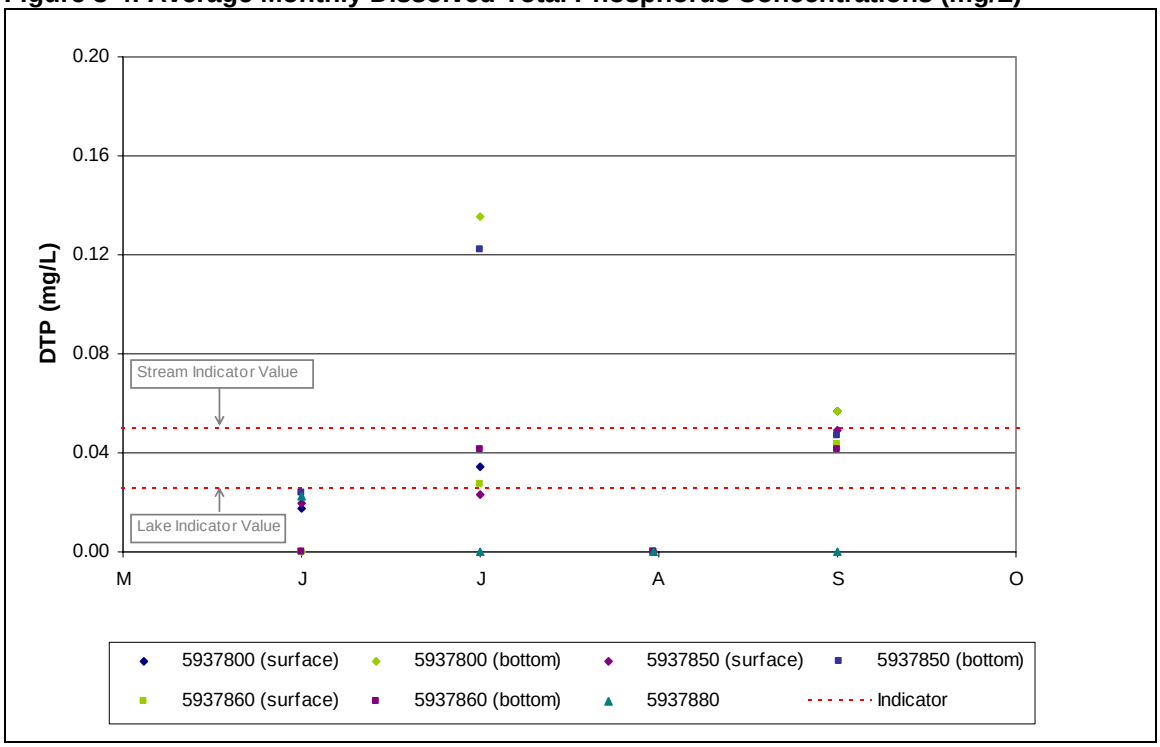
Dissolved Total Phosphorus

Table 3-13 and Figure 3-4 show the average monthly concentrations of dissolved total phosphorus. All reservoir average concentrations exceeded the total phosphorus indicator value for the month of September. With the exception of the surface concentration for Matt Warner Reservoir above Dam, reservoir average concentrations also exceeded the indicator value in July.

Table 3-13: Average Monthly Dissolved Total Phosphorus Concentrations (mg/L)

Name	Storet	June	July	August	September
CR Above Dam - Surface	5937800-21	0.018	0.034	-	0.057
CR Above Dam - Bottom	5937800-29	-	0.135	-	0.057
MWR Above Dam - Surface	5937850-21	0.020	0.023	-	0.049
MWR Above Dam - Bottom	5937850-29	0.024	0.122	-	0.047
MWR West Midlake - Surface	5937860-21	-	0.027	-	0.043
MWR West Midlake - Bottom	5937860-29	-	0.042	-	0.042
Pot Creek Above MWR	5937880	0.023	-	-	-

Figure 3-4: Average Monthly Dissolved Total Phosphorus Concentrations (mg/L)



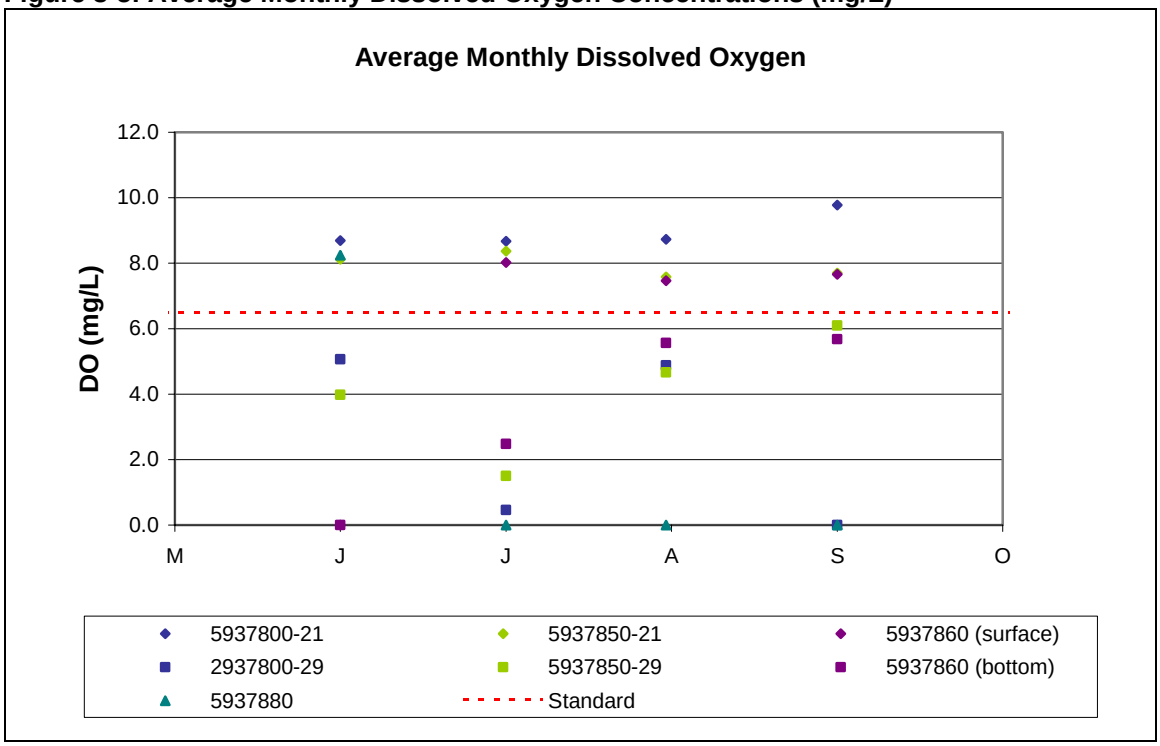
Dissolved Oxygen

Table 3-14 and Figure 3-5 show the average monthly concentrations of dissolved oxygen. Average concentrations exceeding the dissolved oxygen standard are shown in red below. All bottom average concentrations in the reservoirs exceeded the dissolved oxygen standard for all months. No clear monthly trend was determined.

Table 3-14: Average Monthly Dissolved Oxygen Concentrations (mg/L)

Name	Storet	June	July	August	September
CR Above Dam - Surface	5937800-21	8.7	8.7	8.7	9.8
CR Above Dam - Bottom	5937800-29	5.1	0.5	4.9	-
MWR Above Dam - Surface	5937850-21	8.1	8.4	7.6	7.7
MWR Above Dam - Bottom	5937850-29	4.0	1.5	4.7	6.1
MWR West Midlake - Surface	5937860-21	-	8.0	7.5	7.7
MWR West Midlake - Bottom	5937860-29	-	2.5	5.6	5.7
Pot Creek Above MWR	5937880	8.2	-	-	-

Figure 3-5: Average Monthly Dissolved Oxygen Concentrations (mg/L)



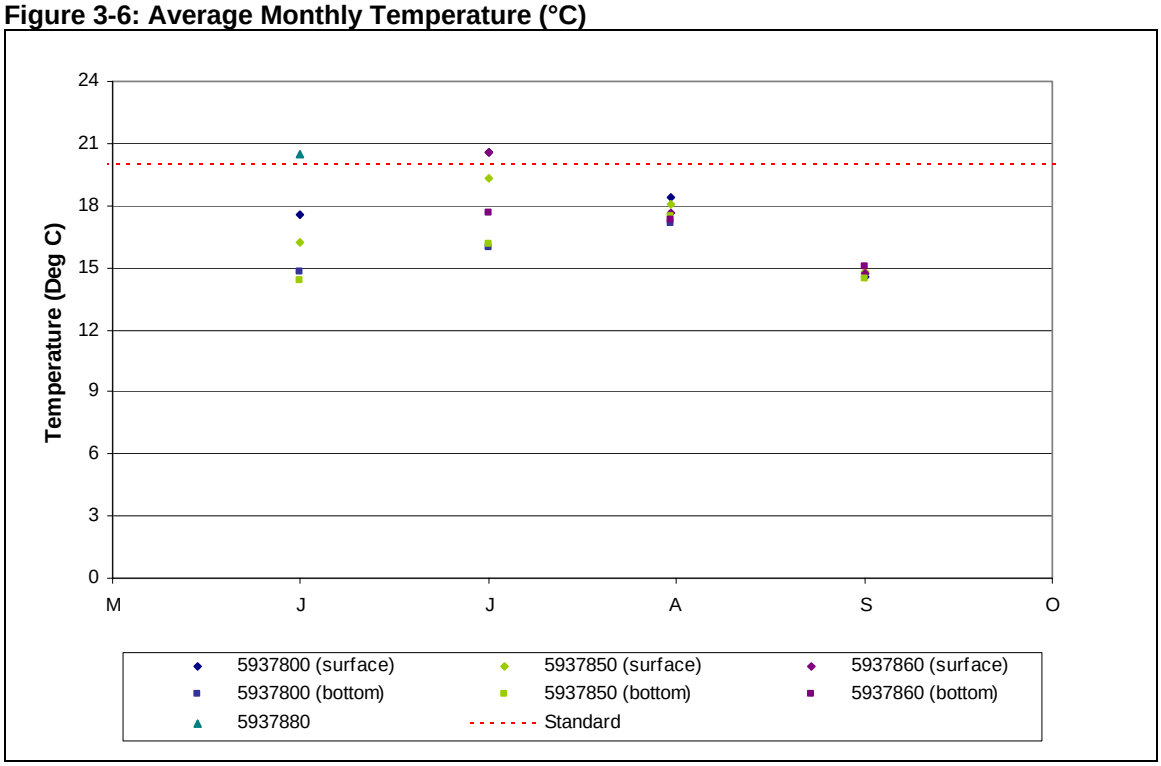
Temperature

Table 3-15 and Figure 3-6 show the average monthly water column temperatures. The highest temperatures were reported in the month of July. The temperature standard was exceeded once in June at Pot Creek above Matt Warner Reservoir. It was also exceeded in July at the surfaces of Matt Warner Reservoir West Midlake and Calder Reservoir Above Dam. Values exceeding the standard are shown in red below.

Table 3-15: Average Monthly Temperature (°C)

Name	Storet	June	July	August	September
CR Above Dam - Surface	5937800-21	17.6	20.6	18.4	14.5
CR Above Dam - Bottom	5937800-29	14.8	16.0	17.1	-
MWR Above Dam - Surface	5937850-21	16.2	19.3	18.1	14.8
MWR Above Dam - Bottom	5937850-29	14.4	16.2	17.5	14.4
MWR West Midlake - Surface	5937860-21	-	20.6	17.6	14.8
MWR West Midlake - Bottom	5937860-29	-	17.6	17.3	15.1
Pot Creek Above MWR	5937880	20.5	-	-	-

Figure 3-6: Average Monthly Temperature (°C)



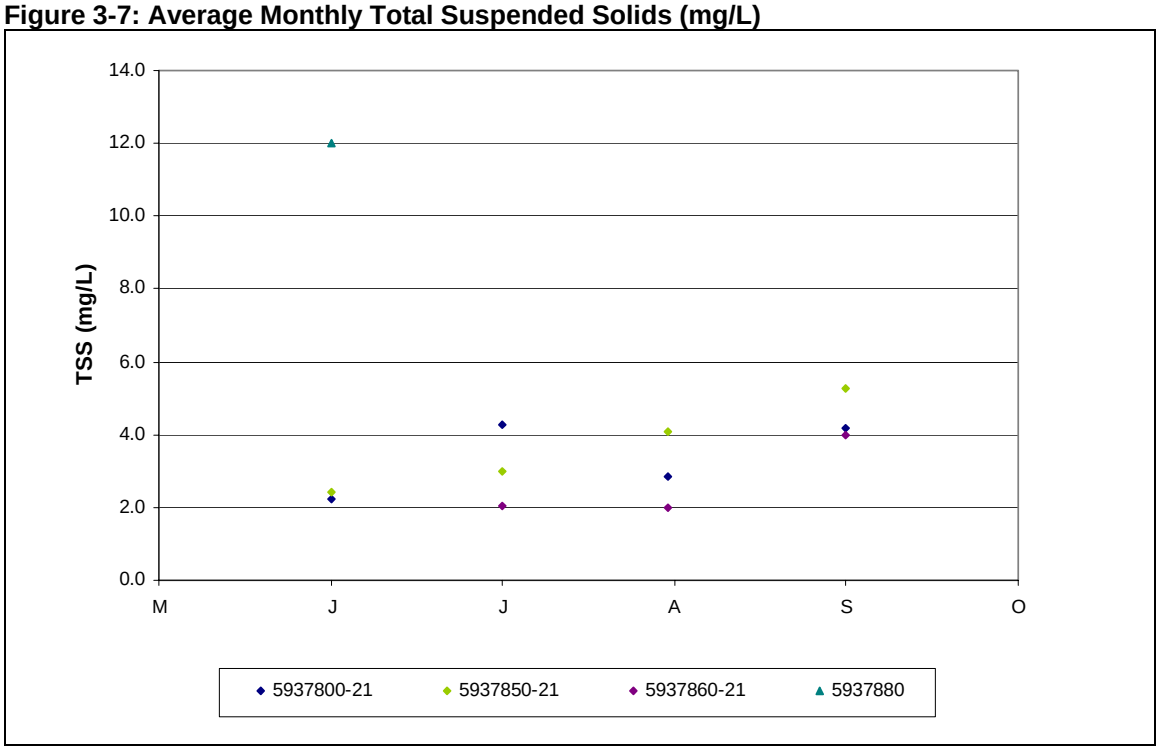
Total Suspended Solids

Table 3-16 and Figure 3-7 show the average monthly total suspended solid concentrations. The highest average concentration was reported in June at Pot Creek above Matt Warner Reservoir. However, all other stations reported the highest concentrations in September.

Table 3-16: Average Monthly Total Suspended Solids (mg/L)

Name	Storet	June	July	August	September
CR Above Dam - Surface	5937800-21	2.2	4.3	2.8	4.2
MWR Above Dam - Surface	5937850-21	2.4	3.0	4.1	5.3
MWR West Midlake - Surface	5937860-21	-	2.1	2.0	4.0
Pot Creek Above MWR	5937880	12.0	-	-	-

Figure 3-7: Average Monthly Total Suspended Solids (mg/L)



Summary of Significant Seasonal Trends

Temperature and concentrations of total phosphorus, dissolved total phosphorus, and dissolved oxygen reached their worst values during the month of July. Additionally, all reservoir stations exceeded the total phosphorus indicator value for every month. Dissolved total phosphorus also exceeded the indicator value at all but one station during July and September.

3.6 Reservoir Impairment Assessment

The State of Utah has determined that Matt Warner and Calder Reservoirs are not supporting their beneficial use 3A (Cold-water fishery). The State of Utah conducts a cursory analysis to determine whether or not a body of water supports it beneficial uses. If their analysis shows that the water body does not support its beneficial uses, it is added to the 303(d) list. The State of Utah relies on the TMDL process to conduct a detailed analysis to determine if the water body is actually impaired.

The 303(d) listed impairment of the cold water fisheries is based solely on the reservoirs data compared to state standards. To determine if the reservoirs are supporting their beneficial uses various analyses were performed. These are briefly described in the following sections

Water Quality Exceedances

Table 3-17 shows the percentage of water quality samples that exceeded the standard/indicator values. Total phosphorus frequently exceeded 0.025 mg/L and dissolved oxygen was frequently less than 6.5 mg/L. However, temperature rarely exceeded 20 °C.

Table 3-17: Water Quality Exceedances

	Calder Above Dam	Matt Warner Above Dam	Matt Warner W. Midlake
Total Phosphorus	54%	64%	59%
Dissolved Oxygen	37%	46%	36%
Temperature	9%	3%	13%

Carlson Trophic State Index (TSI)

Concentrations of dissolved oxygen are influenced by the trophic state of the reservoir. The trophic states of Matt Warner and Calder Reservoirs have been evaluated using the Trophic State Index (TSI) equations proposed by Carlson (1977). The following equations were used:

$$TSI = 60 - 14.41 \ln [\text{ Secchi disk (meters) }] \qquad \textbf{Equation 1}$$

$$TSI = 9.81 \ln [\text{ Chlorophyll } a \text{ (µg/L) }] + 30.6 \qquad \textbf{Equation 2}$$

$$TSI = 14.42 \ln [\text{ Total phosphorus (µg/L) }] + 4.15 \qquad \textbf{Equation 3}$$

The Trophic State Index was calculated for each available reservoir station using secchi depth, total phosphorus, and chlorophyll *a* data for the summer months (June through September) as shown in Table 3-18 and Figure 3-8 through Figure 3-10. For both reservoirs, the TSI has alternated between mesotrophic and eutrophic since 1992. However, the TSI for Matt Warner Reservoir has decreased slightly, while it has increased slightly in Calder Reservoir. However, according to the chlorophyll *a* index, the best predictor of TSI, both reservoirs are currently eutrophic.

Table 3-18: TSI Values

Location	TSI	1992	1994	1995	1996	1998	2000	2002	2003	2004
Calder Reservoir above Dam	chl *a*	47	61	-	65	57	70	48	53	67
	SD	56	43	-	52	53	54	48	48	53
	TP	61	75	-	63	67	49	62	62	66
Matt Warner Reservoir above Dam	chl *a*	41	67	67	51	57	49	46	44	52
	SD	52	55	47	47	49	47	50	53	52
	TP	70	73	63	57	63	61	57	66	45
Matt Warner Reservoir West Midlake	chl *a*	34	57	62	57	59	45	47	42	51
	SD	53	57	45	49	52	52	49	54	48
	TP	69	59	63	59	63	-	64	65	43

Figure 3-8: TSI - Matt Warner Reservoir Above Dam – Water Rights Station 5917850

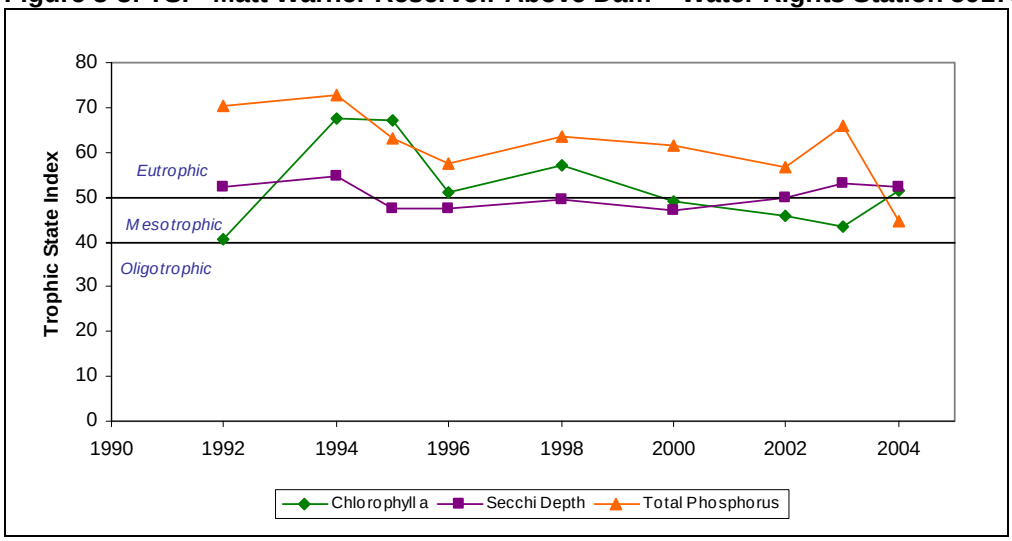


Figure 3-9: TSI - Matt Warner Reservoir West Midlake – Water Rights Station 5917860

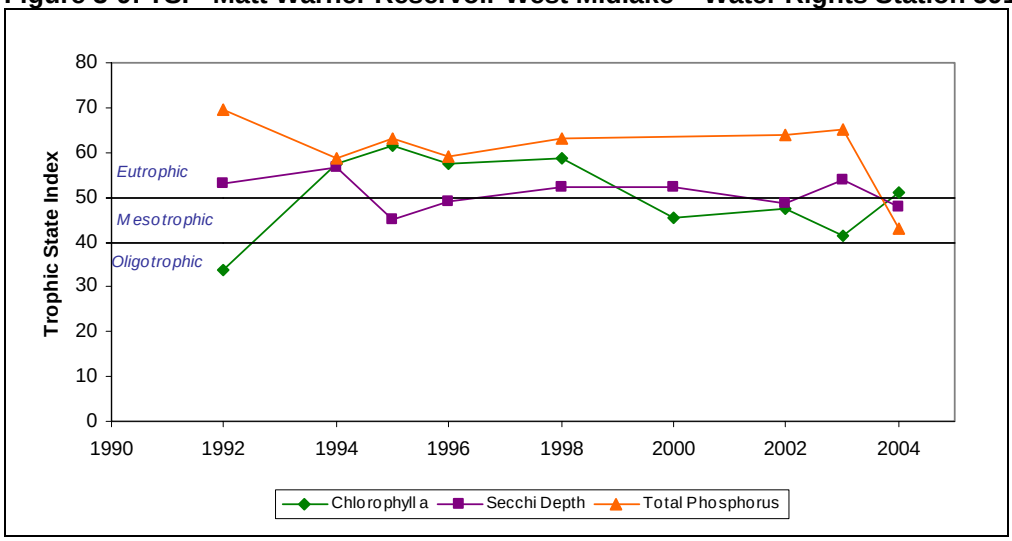
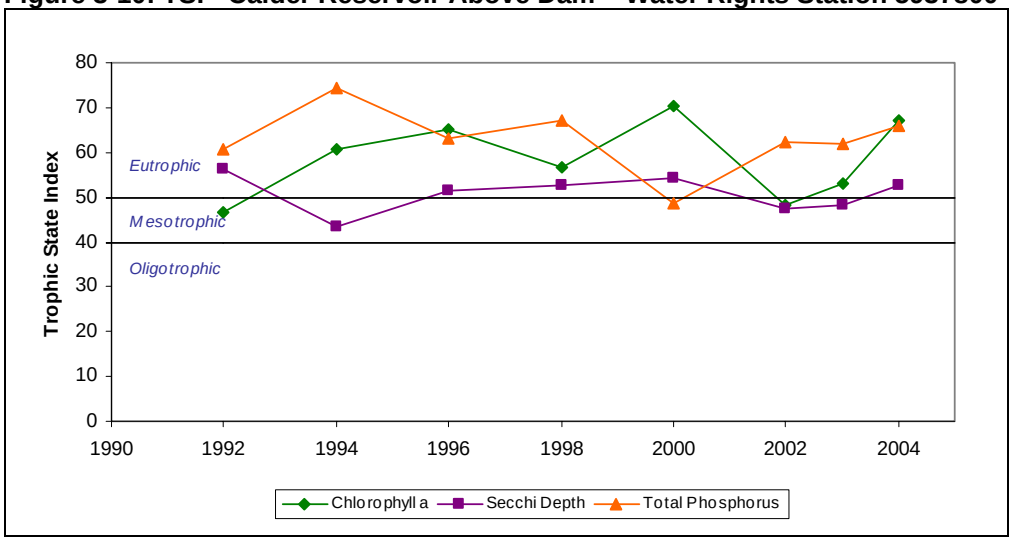


Figure 3-10: TSI - Calder Reservoir Above Dam – Water Rights Station 5937800



Vollenweider Loading

Vollenweider developed a method based on empirical data to determine the health of a reservoir. His method resulted in a plot that delineates zones for oligotrophic, mesotrophic, and eutrophic systems. These plots are based on the total phosphorus load, hydraulic residence time, and mean reservoir depth. To apply the Vollenweider model, the lake must be deep, well-mixed and phosphorus must be the limiting nutrient. Matt Warner and Calder Reservoirs meet all these criteria, therefore Vollenweider equations were applied to the data. This analysis classified Matt Warner Reservoir as mesotrophic and Calder Reservoir as eutrophic as shown below in Figure 3-11 and Figure 3-12.

Figure 3-11: Vollenweider Loading - Matt Warner Reservoir

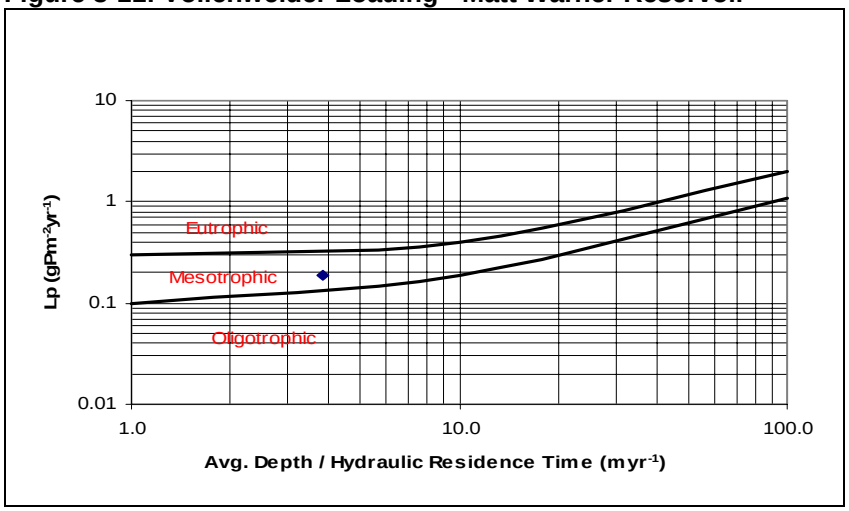
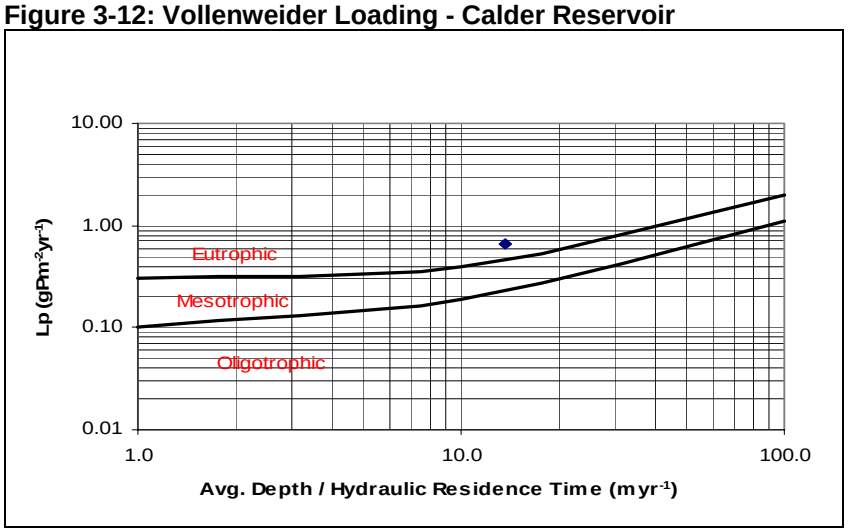


Figure 3-12: Vollenweider Loading - Calder Reservoir



Water Column Temperature

Table 3-19 shows the average monthly water column temperature. These temperatures represent an average temperature for the entire water column. Water temperature begins to increase in June, peaks during July, and declines in August. Average temperatures do not exceed the standard of 20 °C in either reservoir for any month.

Table 3-19: Monthly Average Water Column Temperature

Name	Storet	May	June	July	August	September
Calder Res Above Dam	5937800	-	16	19	17	14
MW Res Above Dam	5937850	14	15	18	18	15
MW Res West Midlake	5937860	-	16	19	17	15
Average		14	16	19	17	15

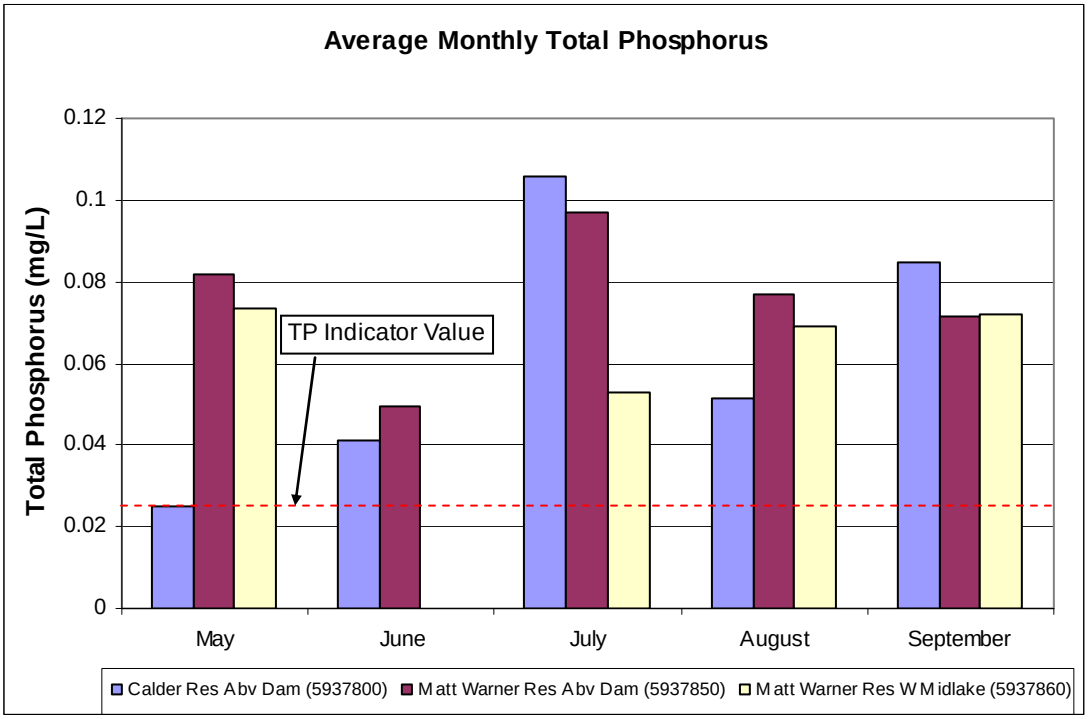
Water Column Total Phosphorus

Table 3-20 and Figure 3-13 show the average monthly total phosphorus concentrations in the water column. An average was calculated only for days that both the surface and bottom depths were sampled. This excluded 9 of the 57 sampling events. Inconsistencies between data from the various stations made it difficult to establish a seasonal pattern between month and total phosphorus concentration. In order to better understand this relationship, monthly phosphorus profiles for the entire water column were generated and are included as Appendix C. The phosphorus indicator value was exceeded every month, at all depths in the water column as shown below in red. The exceedance was most apparent during the month of July.

Table 3-20: Average Monthly Water Column Total Phosphorus

Name	Storet	May	June	July	August	September
Calder Res Above Dam	5937800		0.041	0.106	0.051	0.085
MW Res Above Dam	5937850	0.082	0.049	0.097	0.077	0.071
MW Res West Midlake	5937860	0.074		0.053	0.069	0.072
Average		0.078	0.045	0.085	0.066	0.076

Figure 3-13: Average Monthly TP Concentration in the Water Column



Water Column Dissolved Oxygen Profiles

Concentrations of dissolved oxygen in the reservoir are directly related to the stratification cycle. As the reservoir becomes stratified and mixing between layers ceases, dissolved oxygen concentrations are depleted due to biological and chemical processes. Eventually, in the deeper portions of the reservoir, oxygen levels may become completely depleted, or anoxic. At this point only anaerobic chemical and biological processes continue. Changes in water chemistry and redox potential, resulting from anoxic conditions, may release phosphorus from lake sediments.

Profile plots that show how water temperature and dissolved oxygen concentration vary with depth have been included as Appendix B.

Table 3-21 shows the monthly average percentage of the water column measured to be below 4 mg/L. These averages are based on the profile data obtained from DWQ. Data are only available for the summer months, which cover the critical period. Dissolved oxygen conditions are best in September and worst during the month of July.

Table 3-21: Monthly Percent of Water Column DO below 4mg/L

Name	Storet	June	July	August	September	Avg (June-Sept)
Calder Res Above Dam	5937800	3%	27%	0%	0%	8%
MW Res Above Dam	5937850	8%	22%	10%	0%	10%
MW Res West Midlake	5937860	0%	7%	5%	0%	3%

Water Column Fish Habitat

Water temperatures and dissolved oxygen are considered to determine how much of the water column (from the surface to the bottom of the reservoir) is supporting the beneficial use designation. The annual number of samples which support, and those which do not support, the beneficial uses are also considered to determine the support status of a water body. Table 3-22 shows the frequency that the reservoirs were fully supporting, partially supporting and not supporting their cold water fisheries. As the table shows, there were no days that either reservoir had non-supporting status, indicating that dissolved oxygen concentrations are not significantly affecting the fishery.

Table 3-22: Reservoir Support Status

Reservoir	% of Water Column with DO < 4mg/L	Support Status	Frequency of Occurrence
Matt Warner Reservoir	50% or greater	Non-Supporting	0%
	25% to 50%	Partially Supporting	17%
	25% or less	Fully Supporting	83%
Calder Reservoir	50% or greater	Non-Supporting	0%
	25% to 50%	Partially Supporting	18%
	25% or less	Fully Supporting	82%

Figure 3-14 through Figure 3-16 show the historical water column conditions at each of the reservoir sites. The water column is divided into the following three zones:

- Anoxic Zone
- High Temperature Zone
- Ideal Fish Habitat Zone

Figure 3-14: Calder Reservoir Above Dam - Station 5937800

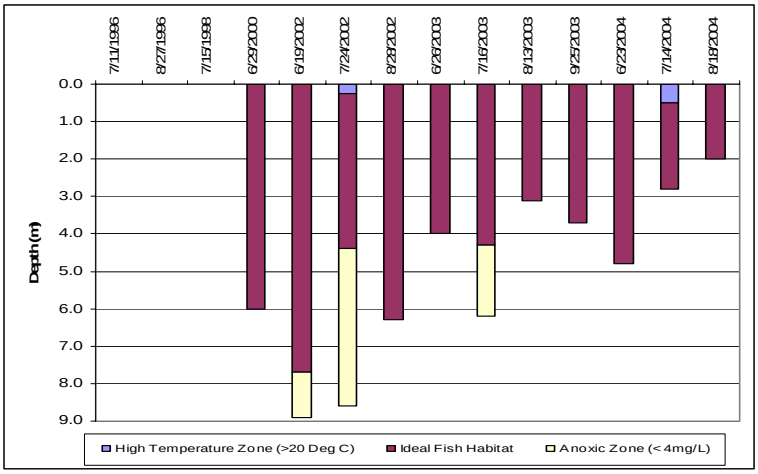


Figure 3-15: Matt Warner Reservoir Above Dam - Station 5937850

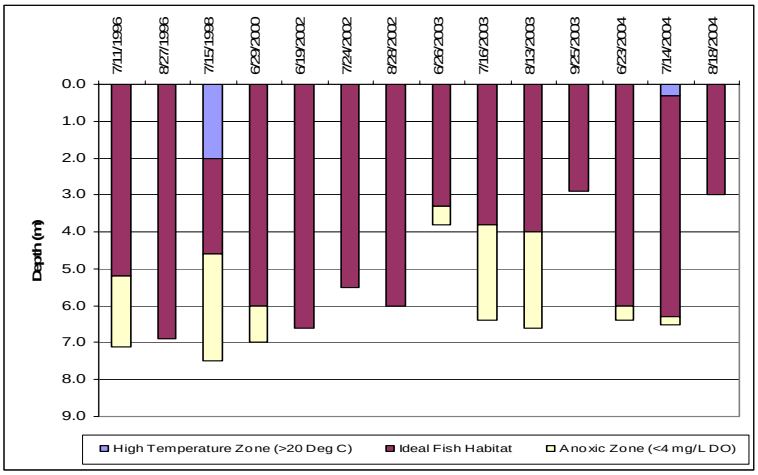
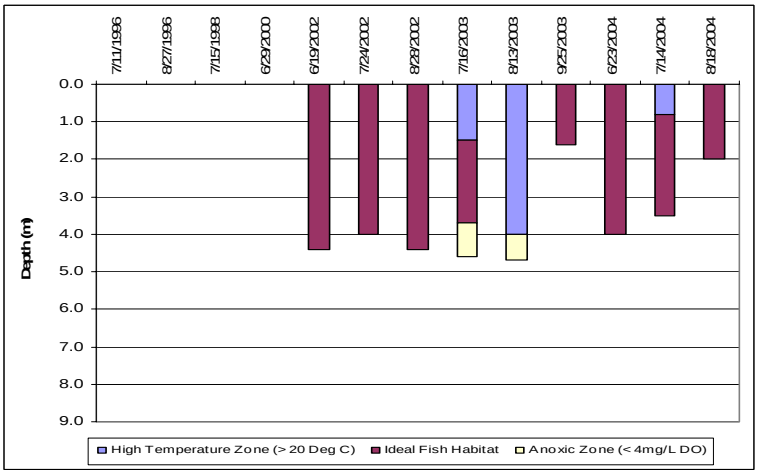


Figure 3-16: Matt Warner Reservoir West Midlake - Station 5937860



Anoxic conditions were observed at all reservoir sites to different extents. During these months, concentrations of DO ranged from 48 % anoxic (July, Calder Reservoir above Dam) to 0 % anoxic. The water column was particularly poor for fish on August 13, 2003 at the west midlake in Matt Warner Reservoir. The upper portion of the water column is a high temperature zone, and the lower portion is an anoxic zone. This eliminates all ideal fish habitat in the water column for the day. On this day, however, suitable habitat was available at the Above Dam Site.

Impairment Conclusions

Table 3-23 shows the results of the reservoir impairment analysis methods described above. Recognizing that some data indicate impairment and other data do not, it appears that the reservoirs are not critically impaired. However, load reductions are necessary to reduce the concentration of constituents that are contributing to the impairment of the reservoirs.

Table 3-23: Impairment Conclusions

Method	Calder Reservoir	Matt Warner Reservoir
Exceedances		
TP	**Yes**	**Yes**
DO (Grab Sample)	**Yes**	**Yes**
Temp	No	No
TSI	**Yes**	**Yes**
Vollenweider Loading	**Yes**	No
Water Column Temp	No	No
Water Column TP	**Yes**	**Yes**
Water Column DO (Profiles)	No	No
Water Column Fish Habitat	No	No

3.7 Hydrologic Analysis

Available Flow Data

Flow data for this study were obtained from Utah DWQ, Utah Water Rights, and USGS. Generally, very few flow data are available. Average monthly stream flows were calculated and are shown in Table 3-24. To calculate average monthly flows, a minimum of five data were required for a given month. Therefore, months with fewer than five sampling events will appear blank in Table 3-24. Average flows were greatest in the spring and summer.

Table 3-24: Average Monthly Flow (cfs)

Location	Station ID	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Calder's Res	1000			1.4	8.6	11.6	8.5	2.4					
Calder Res (Game)	1001					23.0	2.5						
Matt Warner Res	1002				5.8	0.4	0.7	0.7	0.7		0.7		
Pt Ck Ab Div near Vernal	1003	0.3	0.3	10.7	14.5	5.8	0.9	0.3	0.1	0.0	0.5	1.5	0.4
Pt Ck at State Line	1004					5.6	1.9						
Pt Ck Flow Ab MW Res	1005			1.6	11.3	19.5	10.8	2.4	7.4	2.5			
Pt Ck near CO Line	1006		1.4	5.1	69.6	603.2	447.7		125.0	146.6			
Runoff in Pt Ck	1007				4.1	6.7	1.5						
Pt Ck Ab Div near Vernal,UT	1008	0.3	0.4	2.2	15.5	21.0	7.9	0.9	0.6	0.4	0.6	0.6	0.4
Pt Ck near Vernal	1009	0.1	2.6	3.3	8.3	10.3	5.1	3.4	3.5	1.8	2.5	0.1	0.7
Pt Ck Ab Calder Res	5937810							0.2	0.2				
Pt Ck Ab Matt Marner Res	5937880							0.2	0.1				

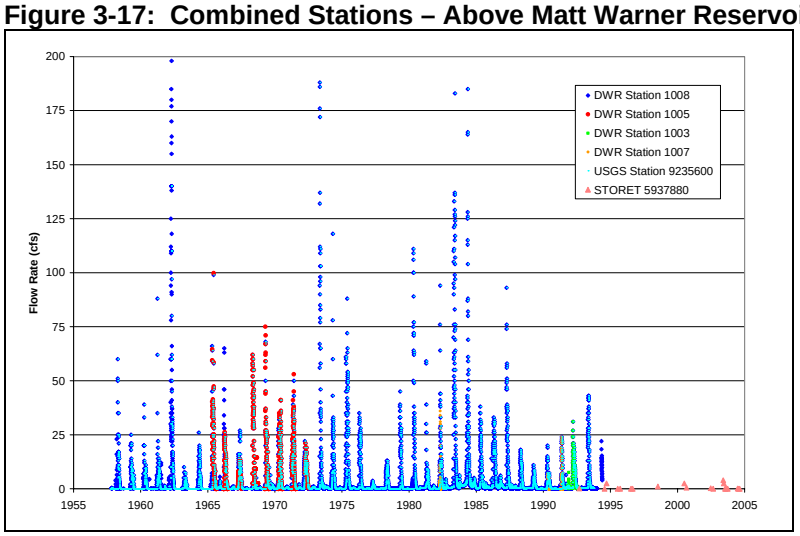
Combining Stations by Location

STORET, Water Rights and USGS flow stations are located in similar areas above and below each reservoir. Most stations have gaps in the flow data, some spanning decades. In order to better understand the inflow and outflow of each reservoir, stations in similar locations were combined in one figure to fill in the data gaps.

Above Matt Warner Reservoir

Above Matt Warner Reservoir, data from STORET, Water Rights and USGS flow gage 09235600 are combined as shown in Figure 3-17. Prior to 1995, Water Rights Station 1008 encompasses data from all other stations in the area. After 1995, STORET Station 5937880 is the only station that provides flow data.

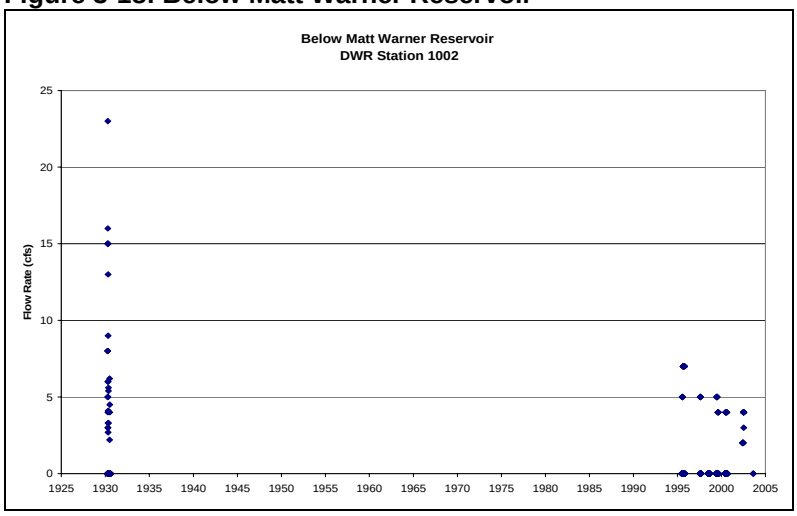
Figure 3-17: Combined Stations – Above Matt Warner Reservoir



Below Matt Warner Reservoir

Minimal flow data are available for the area below Matt Warner Reservoir. Only Water Rights Station 1002 provides flow data in the area, and is very limited as shown in Figure 3-18.

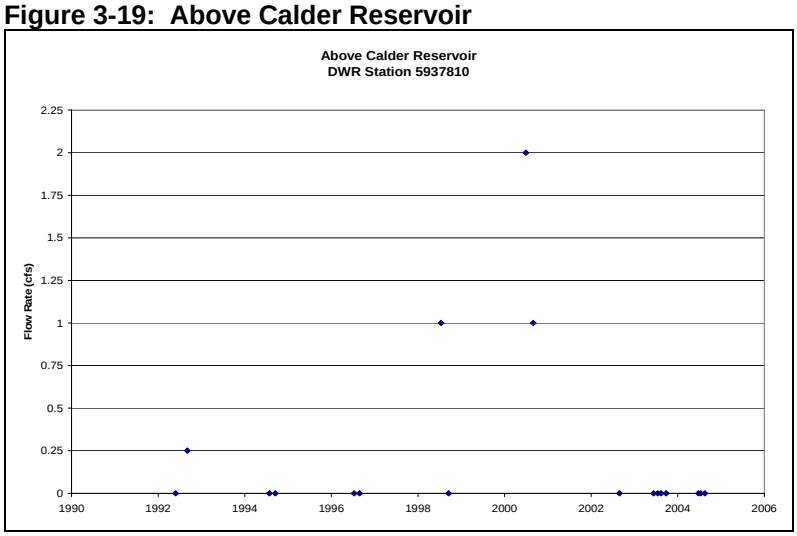
Figure 3-18: Below Matt Warner Reservoir



Above Calder Reservoir

Flow data for the area above Calder Reservoir are only available from Water Rights Station 5937810 and is shown below in Figure 3-19. Very few flow data are available at this location.

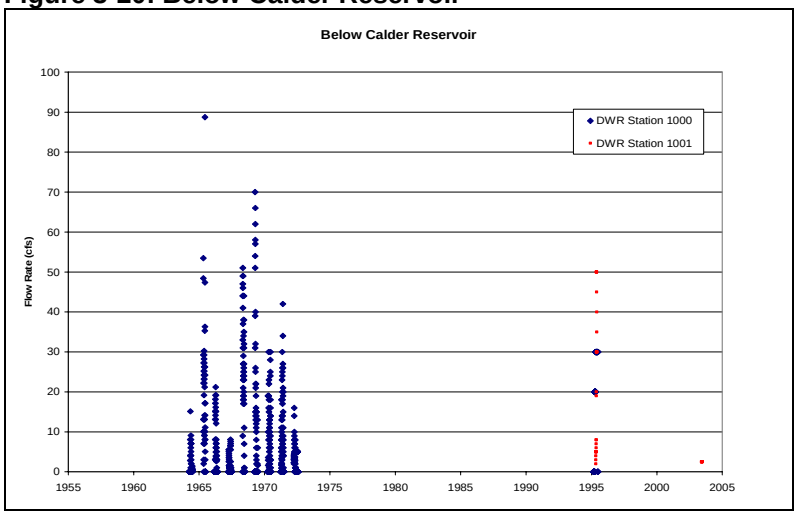
Figure 3-19: Above Calder Reservoir



Below Calder Reservoir

Recent flow data for the area below Calder Reservoir is limited. Flow data from Water Rights Stations 1000 and 1001 are available and are combined in Figure 3-20. There is little overlap in the data; therefore data from these stations will be combined to understand the outflow from Calder Reservoir.

Figure 3-20: Below Calder Reservoir



Estimating Annual Flow

Available flow data are limited to Pot Creek inflow to Matt Warner and Calder Reservoirs. In order to calculate an average annual inflow from Pot Creek into Matt Warner Reservoir, a correlation was made between precipitation data and available flow data from Pot Creek above Matt Warner Reservoir (Water Rights Station 1008).

Precipitation Data

Allen's Ranch, Flaming Gorge and King's Cabin weather stations were considered as potential sources for precipitation data because of their close proximity to the reservoirs

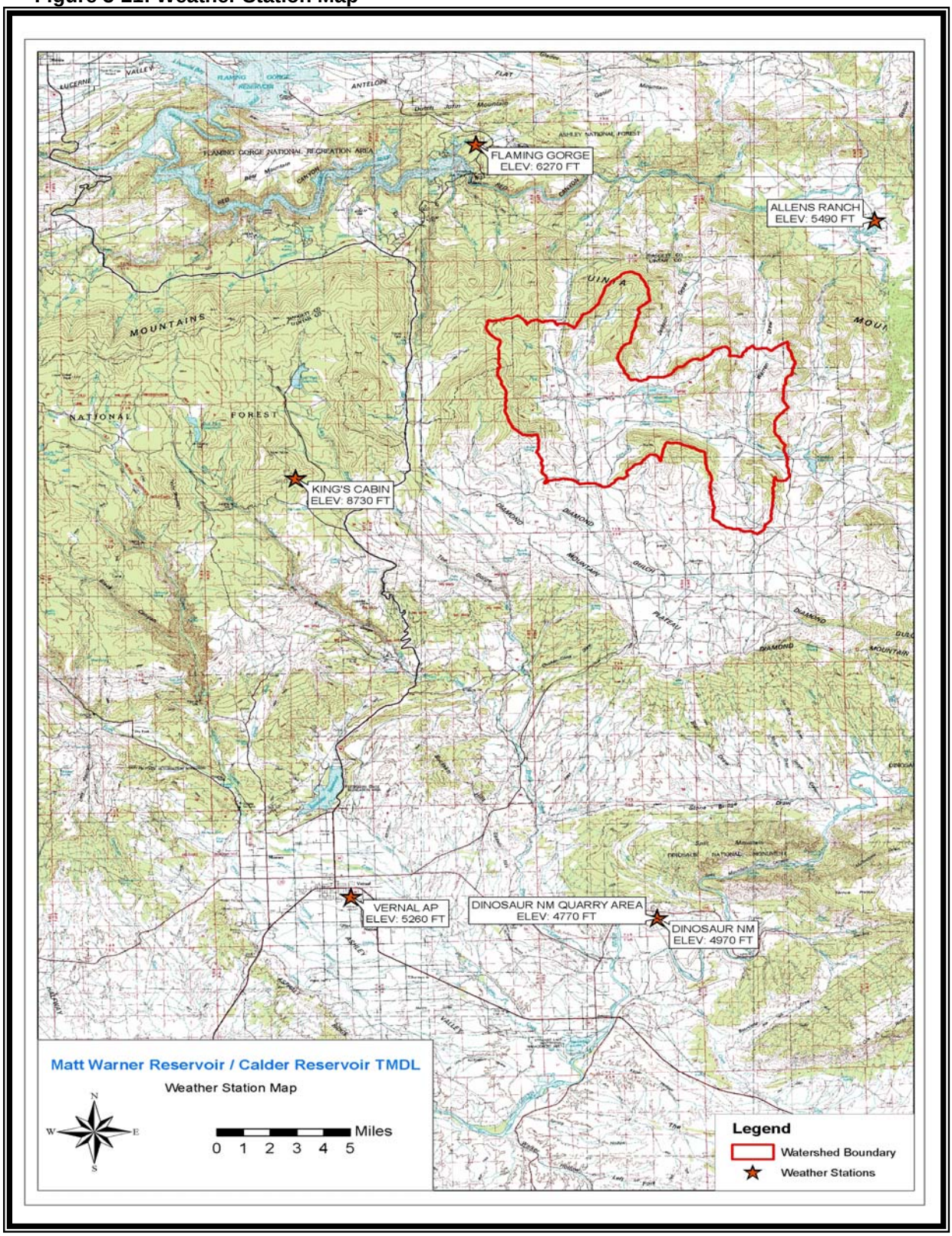
as shown in Figure 3-21. Distances to Water Rights Station 1008 and elevations of the weather stations are shown below in Table 3-25.

Table 3-25: Weather Stations

Weather Station	Annual Precipitation (in/ yr)	Distance to Matt Warner Reservoir (mi)	Elevation (ft)
Allen's Ranch	8.9	12.3	5,490
Flaming Gorge	12.8	12.6	6,270
King's Cabin	26.0	12.8	8,730

The average elevation of the watershed area draining into Matt Warner Reservoir is approximately 8,122 feet. King's Cabin weather station, located at an elevation of 8,730 feet, was chosen as the most representative of precipitation in the watershed due to its similar elevation to that of the reservoirs. Daily precipitation at King's Cabin is available from 1980 to 1994 and was obtained for these years. A 30 year normal was not available at King's Cabin weather station. However, 30 year normals that are available at surrounding weather stations are approximately equal to their 15 year average for 1980 to 1994. Therefore the 15 year normal, calculated to be 26 in/yr for this period, was determined to be a realistic estimate.

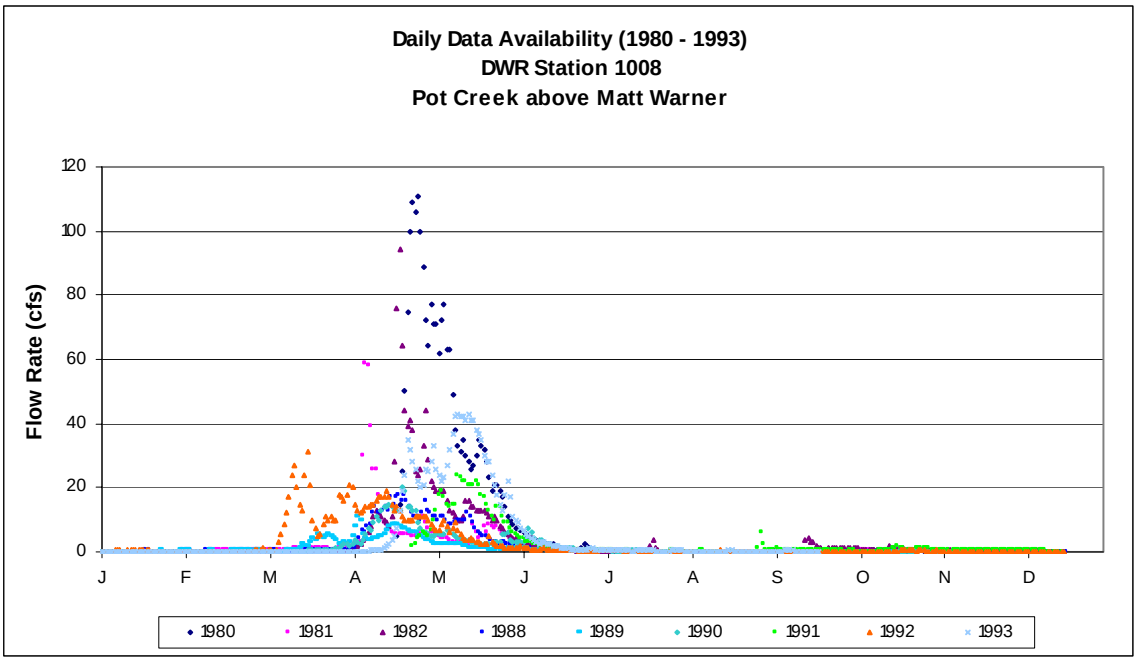
Figure 3-21: Weather Station Map



Flow Data

Only Water Rights Station 1008, located at Pot Creek above Matt Warner Reservoir, had somewhat consistent daily flow data. Data are available at this station from 1957 to 1993. In order to correlate with available years of precipitation data, only flows from 1980 to 1993 were considered. With the exception of 1983 to 1987, each year had missing flow data as shown below in Figure 3-22. However, there were few missing data and they were frequently during the low flowing months of January through April. These months, and other missing daily flows, were interpolated to be consistent with the seasonal trend of the data.

Figure 3-22: Pot Creek Above Matt Warner Seasonal Flows



Correlation

The correlation between average annual flow (water years) from Pot Creek above Matt Warner Reservoir and annual precipitation totals at King's Cabin (Figure 3-23) is shown below as Figure 3-24. Applying the 15 year precipitation normal at King's Cabin (26 in/yr) to the correlation, an average annual flow of 3,056 ac-ft/yr was estimated to flow into Matt Warner Reservoir from Pot Creek.

Figure 3-23: Precipitation and Annual Flow

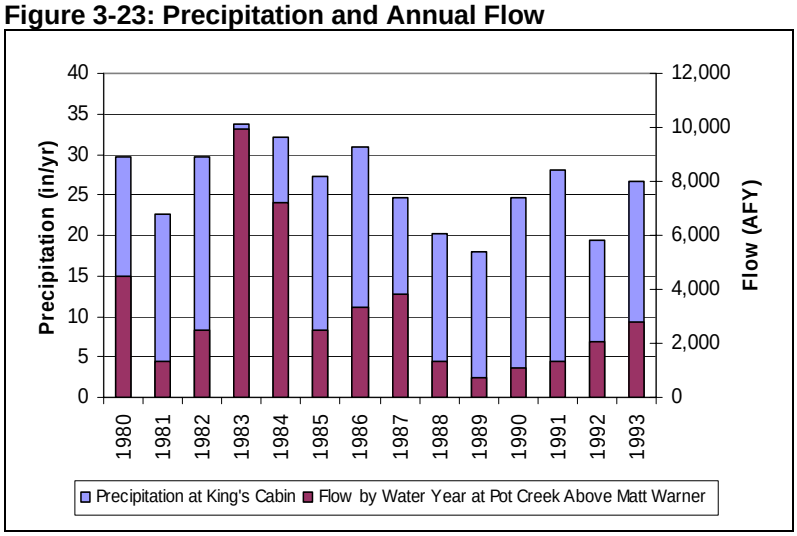
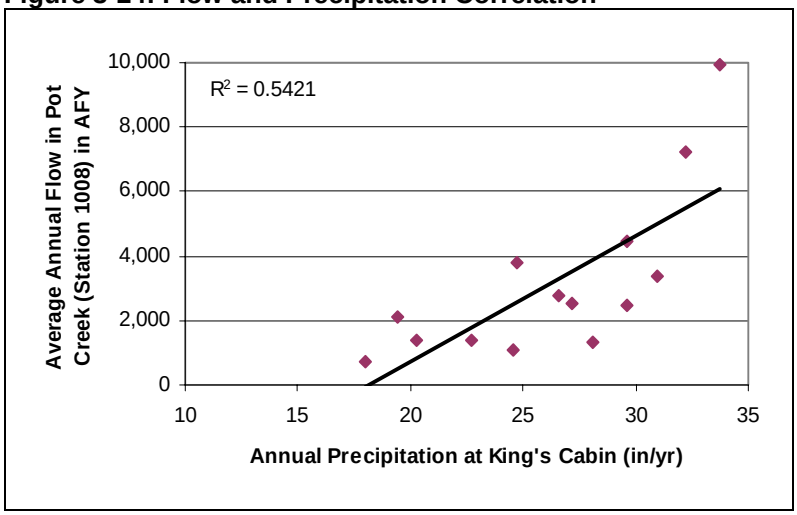
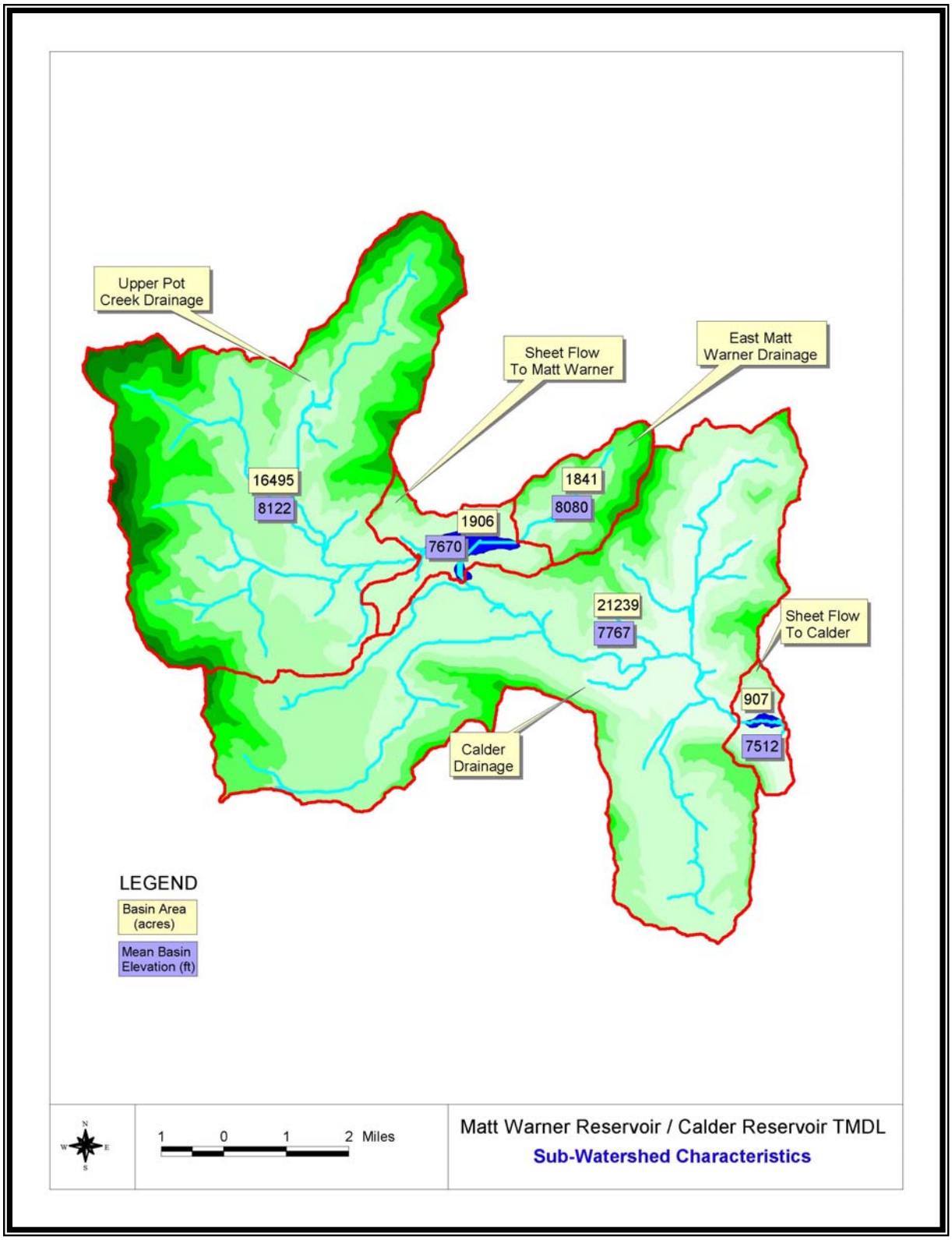


Figure 3-24: Flow and Precipitation Correlation



Quarterly flows were determined by dividing the watershed into five sections, shown in Figure 3-25. The sections draining into Matt Warner Reservoir include Upper Pot Creek Drainage, Sheet Flow to Matt Warner, and East Matt Warner Inflow. The sections draining to Calder Reservoir include Calder Drainage and Sheet Flow to Calder.

Figure 3-25: Sub-watershed Characteristics



Sub-watershed Flow

Matt Warner Reservoir

No flow data were available for the remaining drainages to Matt Warner Reservoir. Therefore, an assumption was made that the remaining areas draining to Matt Warner Reservoir had similar runoff and infiltration characteristics to the Upper Pot Creek Drainage. A volume coefficient of 0.19 AFY/ac was calculated by dividing the flow volume contributed from the Upper Pot Creek Drainage to Matt Warner Reservoir (3,056 AFY) by the sub-watershed drainage area (16,495 ac). Previous studies have shown that geographically close drainages have similar annual runoff volumes per acre. This factor was applied to drainages where contributing areas were known, but flow rates were unavailable. Multiplying the sub-watershed drainage area by the volume coefficient provided flow volume estimates as shown in Table 3-26.

Table 3-26: Sub-Watershed Flow

	Area (ac)	Flow Volume (ac-ft/y)
Upper Pot Creek Drainiage	16,495	**3,056**
Sheet Flow to Matt Warner	1,906	**362**
East Matt Warner Inflow	1,841	**350**

Volume Coefficient = 0.19

Flow Volume = Area x Volume Coefficient

Flow Volume was calculated from a flow / precipitation correlation at King's Cabin weather station

Monthly flow contributions were calculated based on flow data in Pot Creek above Matt Warner Reservoir and are shown in Figure 3-26 . The largest percentage of total flow is noticed in April and May, after spring runoff. These values were used to determine quarterly flow rates for each drainage, shown in Table 3-27.

Figure 3-26: Monthly Percentage of Flow

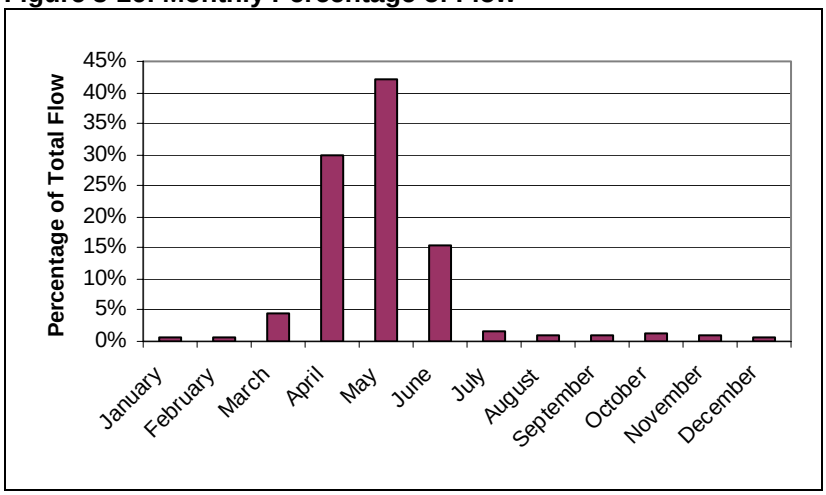


Table 3-27: Quarterly Flow (ac-ft/quarter)

	Jan/Feb/Mar	Apr/May/Jun	Jul/Aug/Sept	Oct/Nov/Dec	*Annual Total*
Upper Pot Creek Drainage	179	2,672	113	93	*3,056*
Sheet Flow to Matt Warner	21	317	13	11	*362*
East Matt Warner Inflow	20	306	13	11	*350*
Total	***220***	***3,294***	***139***	***115***	***3,768***

Calder Reservoir

Flow volumes were calculated for each sub-watershed area draining to Calder Reservoir as shown in Table 3-28. Flow data were unavailable for the Calder Reservoir Drainage. However, as shown in the watershed analysis provided by the Division of Water Rights (Appendix D), infiltration rates for the Calder Reservoir Drainage (0.14 to 0.28 in/hr) are similar to those for the Matt Warner Reservoir drainage (0.16 to 0.30 in/hr). This indicates that for a particular storm, similar percentages of precipitation will be lost to the soil and similar percentages will occur as runoff to the reservoirs. Therefore, the same volume coefficient (0.19 AFY/ac) was applied to the Calder Reservoir Drainage as was calculated for the Matt Warner Reservoir drainage. Again, flow volumes were calculated by multiplying the sub-watershed area by the volume coefficient (0.19 AFY/ac).

Table 3-28: Calder Reservoir – Sub-watershed Flow Volume

Calder Drainage	Area (ac)	Flow Volume (ac-ft/y)
Calder Drainage	21,240	**4,036**
Sheet Flow to Calder	907	**172**
Release from Matt Warner	-	**115**

Volume Coefficient = 0.19

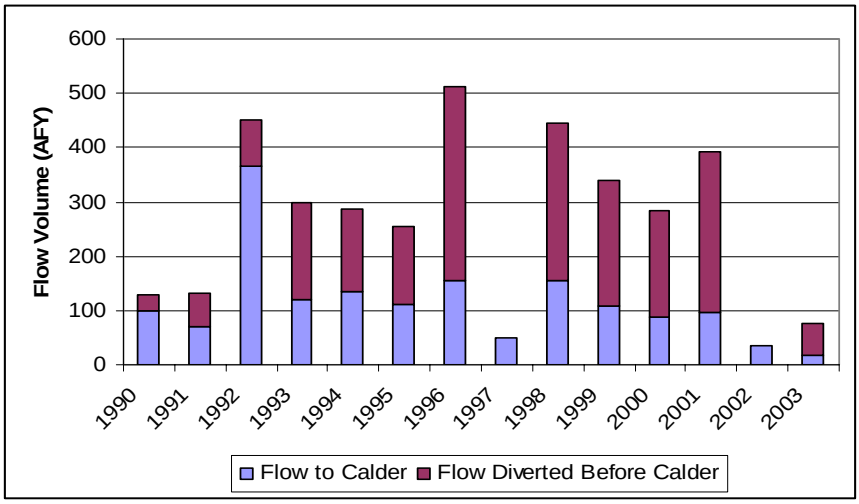
Flow Volume = Area x Volume Coefficient

Flow Volume was calculated from a flow / precipitation correlation at King's Cabin weather station

Flow Volume provided by Water Rights

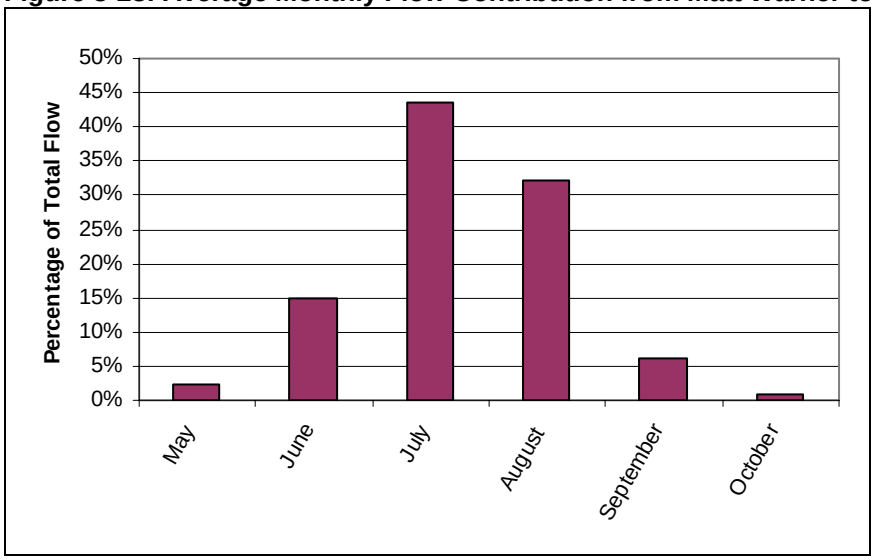
No flow data were available for the stretch of Pot Creek that connects Matt Warner and Calder Reservoirs. However, the outflow from Matt Warner Reservoir is manually controlled by the State Water Commissioner and recorded in reports each year. These reports were obtained for the years between 1990 and 2003. Recorded in these reports are individual water rights that are fulfilled for the year. By establishing where the points of diversion were for each water right, it was determined if the allocated water was diverted before, or if it flowed through Calder Reservoir. The volume of water flowing from Matt Warner Reservoir to Calder Reservoir via Pot Creek was calculated for each year by subtracting the volume of water diverted for water rights before reaching Calder Reservoir from the total volume of water released. On average, 263 AF is released from Matt Warner Reservoir each year. 148 AF is diverted before it reaches Calder. Therefore, 115 AF (263-148 AF) actually makes it to Calder. The historical data provided by these reports are shown in Figure 3-27.

Figure 3-27: Discharge from Matt Warner Reservoir



The monthly distribution of the Matt Warner Reservoir release to Calder Reservoir was obtained by averaging values from the commissioner's reports. Typical monthly distributions of outflows from Matt Warner Reservoir are shown in Figure 3-28.

Figure 3-28: Average Monthly Flow Contribution from Matt Warner to Calder Reservoir



Considering the typical monthly contributions to the total flow from the watershed and the Matt Warner Reservoir outflow, quarterly flow volumes were calculated as presented in Table 3-29.

Table 3-29: Calder Reservoir- Quarterly Flow Volumes (AFY)

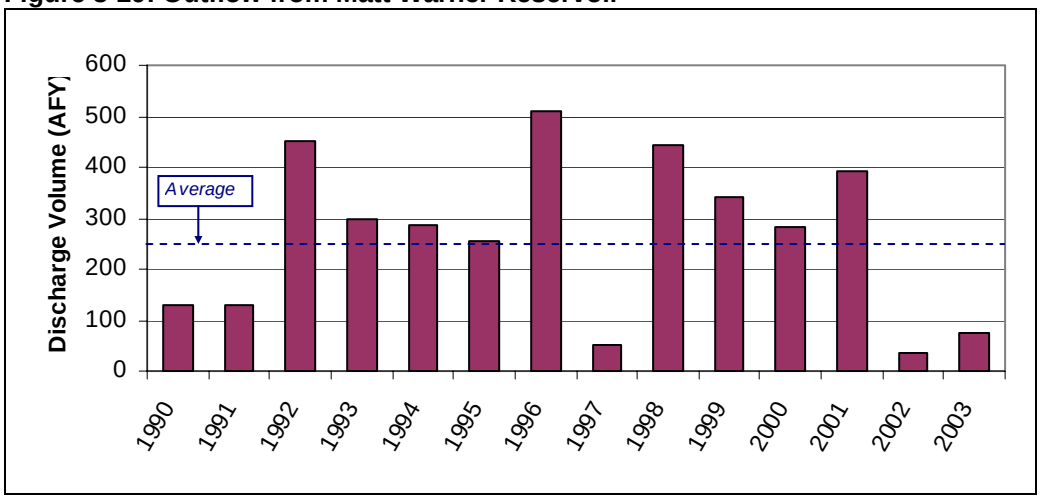
	Jan/Feb/Mar	Ap/May/Jun	Jul/Aug/Sep	Oct/Nov/Dec	*Annual Total*
Calder Drainage	236	3,528	149	123	*4,036*
Sheet Flow to Calder	10	151	6	5	*172*
Release From Matt Warner	0	20	94	1	*115*
Total	***246***	***3,699***	***249***	***129***	***4,323***

Water Budget

Matt Warner Reservoir

After the inflow of 3,768 AFY was estimated, the water budget for Matt Warner Reservoir was determined. The water budget was determined by subtracting outflows from inflows to equal the change in storage of the reservoir. Outflows from Matt Warner Reservoir include Pot Creek outflow and evaporation. Inflows include those from surrounding drainages and precipitation. Groundwater can be either an inflow or an outflow and is used to balance the final water budget. Pot Creek outflow from Matt Warner Reservoir was estimated to be 263 AFY by averaging outflows obtained from the Commissioner's Reports between1990 and 2003, as shown in Figure 3-29.

Figure 3-29: Outflow from Matt Warner Reservoir



A normal evaporation of 35 inches per year was obtained from data at Vernal Airport, the closest weather station with available evaporation data. A total evaporation value of 866 AFY was estimated by multiplying normal evaporation (35 in/y) by the surface area of Matt Warner Reservoir (297 ac).

As mentioned previously, precipitation at King's Cabin was determined to be the most indicative of precipitation in the Matt Warner and Calder Reservoirs watershed. Therefore, a normal precipitation of 26 inches per year was multiplied by the surface area of Matt Warner Reservoir to calculate a total precipitation of 644 AFY.

The change in storage was assumed to be zero. The lake level has fluctuated as a function of drought, and therefore deliverable water rights. However, the long term change in storage can be estimated as zero. Groundwater was calculated as the sum of inflows and outflows. A summary of the water budget is shown below in Figure 3-9.

Table 3-30: Water Budget Summary – Matt Warner Reservoir

	Flow (AFY)
Inflow	
Tributaries	3,768
Precipitation	644
Outflow	
Pot Creek*	-264
Evaporation	-866
Balance	
Groundwater/Ungaged Flow**	-3,282

*As recorded by Water Commissioner

**Calculated to balance

Calder Reservoir

After the inflow of 4,323 AFY flowing into Calder Reservoir was estimated, the water budget was determined. The water budget was determined by subtracting outflows from inflows to equal the change in storage of the reservoir. Outflows from Calder Reservoir include Pot Creek outflow and evaporation. Inflows include Pot Creek, those from surrounding drainages and precipitation. Groundwater can be either an inflow or an outflow and is used to balance the final water budget. Pot Creek outflow from Calder Reservoir was estimated to be 440 AFY by averaging outflows obtained from the Commissioner's Reports between1990 and 2003 and adding in the water rights for Matt Warner that flow through Calder. The same processes used in determining the remaining inflows and outflows in the Matt Warner Reservoir water budget were used for determining those in the Calder Reservoir water budget. The results are summarized below in Table 3-31.

Table 3-31: Water Budget Summary – Calder Reservoir

	Flow (AFY)
Inflow	
Tributaries	4,323
Precipitation	215
Outflow	
Pot Creek*	-440
Evaporation	-289
Balance	
Groundwater/Ungaged Flow**	-3,809

*As recorded by Water Commissioner

**Calculated to balance

4.1 Introduction

This chapter will identify and describe non-point pollution sources into Matt Warner and Calder Reservoirs. No point sources exist within the watershed. This section provides a basis for subsequent action to quantify the problem, identify responsible parties, develop and assess options to reduce pollution, and implement appropriate management plans. In the case of Matt Warner and Calder Reservoirs, four types of information were compiled and analyzed to complete this task:

- Identifying existing local conditions
- Calculating loadings for the watershed and in-lake sources
- Identifying and locating non-point sources of pollution
- Identifying possible future sources

4.2 Existing Local Conditions

The local conditions of the watershed affect the amount of phosphorus that is put into the system. This section briefly describes land use patterns and ownership.

Land Use Patterns and Ownership

Uintah County

State owned public lands within Uintah County are managed by State School and Institutional Trust Lands Administration, the State Office of Sovereign Lands and Forestry, the Utah Division of Wildlife Resources, and the Utah Division of State Parks. Nearly 70% of Uintah County is publicly owned. Additionally, 16% of the County is Indian lands.

Matt Warner and Calder Reservoir Watershed

Land ownership within the watershed is divided as shown in Table 4-1 and Figure 4-1. The watershed area within Uintah County is currently zoned for Recreation, Forestry, and Mining as shown in Figure 4-2. The results of 2003 Water Resources land use surveys in the watershed are shown in Figure 4-3. Areas not classified in the figure are either not developed or were not surveyed. Very little of the watershed is developed. Some areas are used for farmsteads, irrigated crops, and irrigated pasture for grazing.

Table 4-1: Watershed Land Ownership

Land Owner	Acres	% of Total Acres
BLM	9,077	21%
National Forest Service	6,679	16%
Private	22,181	52%
State Trust	430	1%
State Wildlife Reserves	4,028	10%
Total	**42,395**	

Figure 4-1: Land Ownership Map

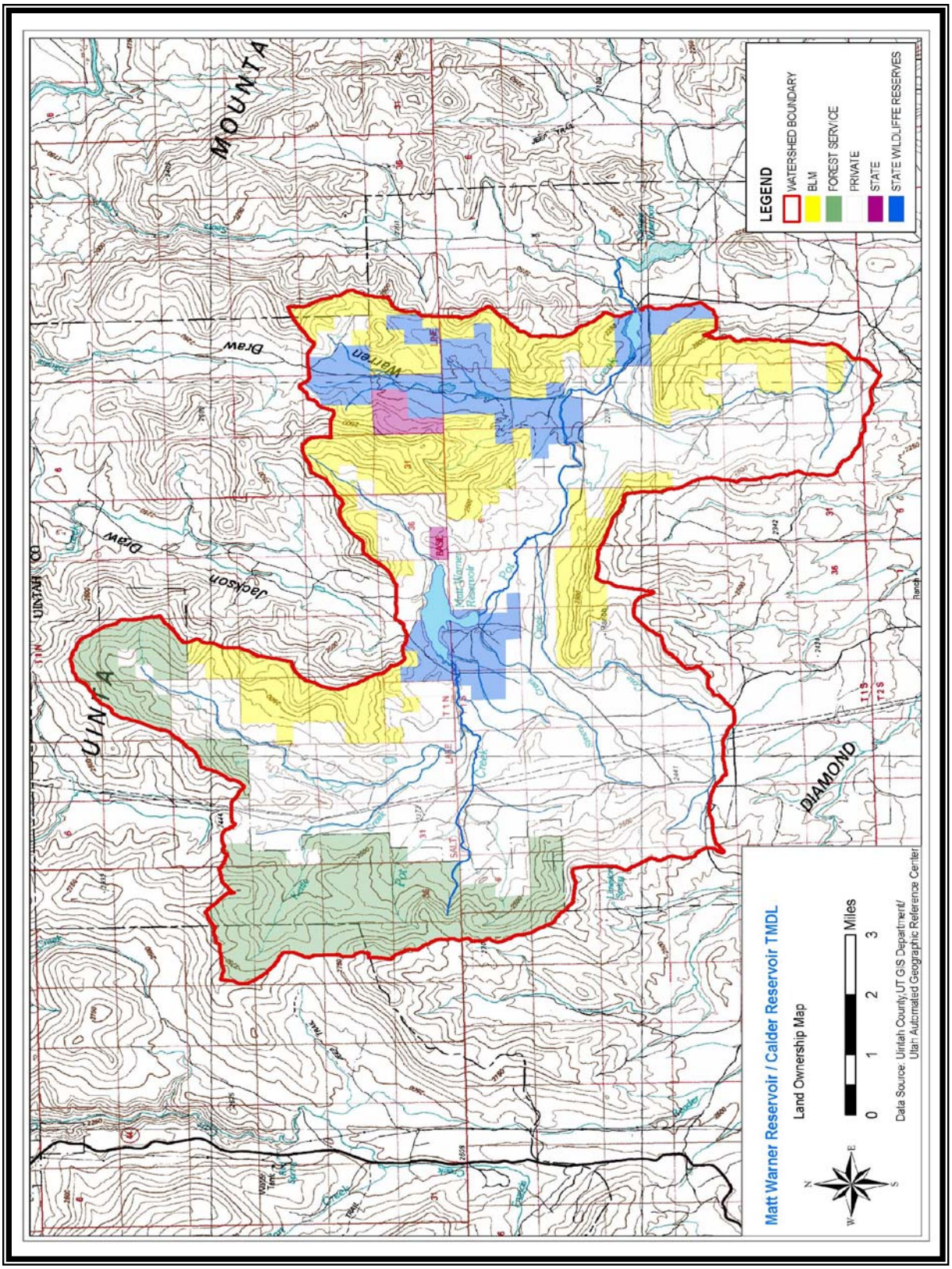


Figure 4-2: Uintah County Zoning Map

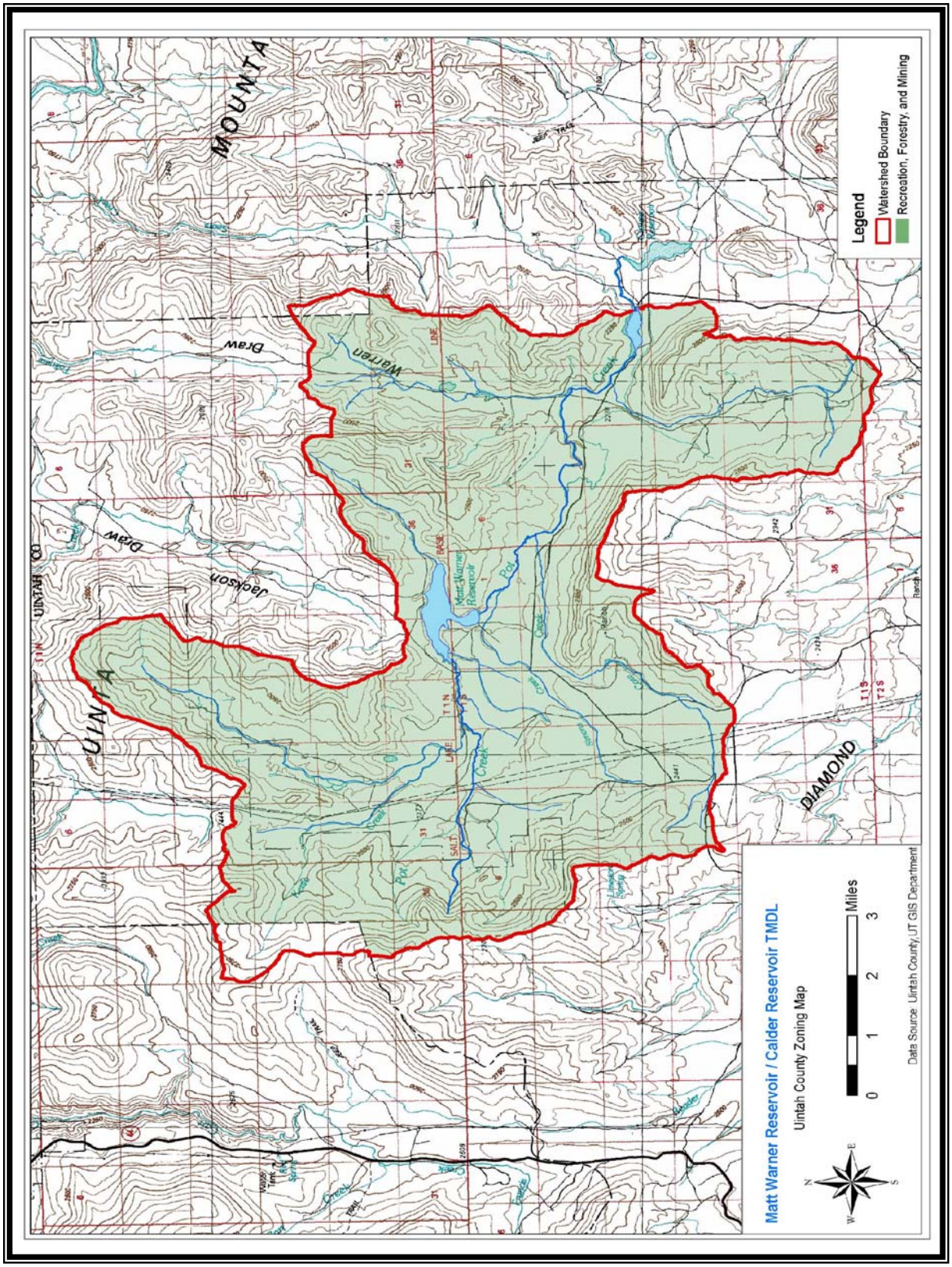
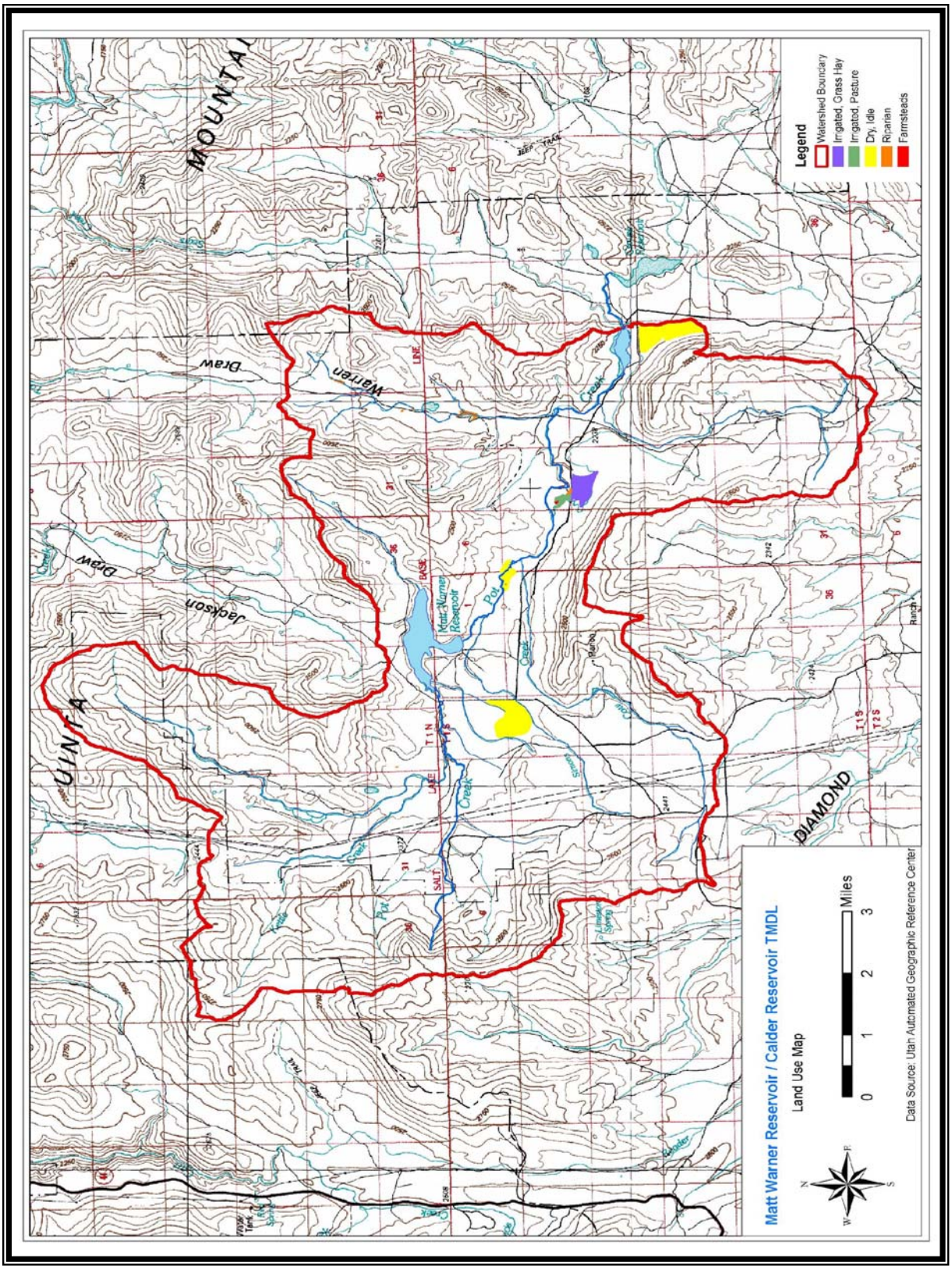


Figure 4-3: Land Use Map



4.3 Pollutant Loadings

There are no point sources of pollution within the watershed, all existing pollution results from non-point sources. Current non-point sources of phosphorus in the watershed include: in-lake sources, animal waste from livestock and wildlife, upland soil erosion, stream bank erosion, and natural geologic sources. An adaptive management approach was chosen as the most appropriate means to address these sources due to the uncertainty associated with their diffuse and highly variable nature, the level of stakeholder cooperation, and the assurance of future data collection to measure progress towards the identified load reduction goals.

Source Identification

There are several potential mechanisms by which phosphorus can enter the water column from sources within and external to Matt Warner and Calder Reservoirs. These include in order of significance:

- Upland soil erosion
- Internal loading
- Animal waste
- Streambank erosion
- Human recreational sources
- Shoreline erosion
- Natural geologic sources

The following sections describe these sources and mechanisms in more detail and provide, where appropriate, an approximation of the relative magnitude of the loading from each source to the reservoirs.

Upland soil erosion

Soils contain nutrients from many different sources including weathered bedrock, plant litter, animal waste and the atmosphere. When soils are washed off and enter surface waters the nutrients contained within the soil are then transported to the receiving water. Many different factors influence the susceptibility for upland soils to erode including slope, plant cover and soil texture. Based on observations during a storm event in October, 2004 the majority of soil erosion within the Pot Creek watershed appears to originate from the flatter mid to lower elevation slopes that are characterized by fine clays and silty soils with sparse plant cover made up of primarily sagebrush. Due to the high volume of runoff observed entering Pot Creek and its sediment load, upland soil erosion is estimated to be a moderate source of phosphorus loading into Matt Warner and Calder Reservoirs.

Internal Loading

Bottom sediments have long been acknowledged as a potential source of phosphorus to the overlying waters of lakes and reservoirs (Chapra, 1997). This is particularly true in lakes and reservoirs in which anaerobic conditions occur in the hypolimnion (the deepest portion of the water column). Under anaerobic hypolimnetic conditions, phosphorus in

the sediments can be converted into soluble forms that are more available for algae. The soluble phosphorus can then be re-entrained in the overlying water column. When mixing occurs during spring and fall turnover, the soluble phosphorus can be carried into the photic zone where it is available for algal uptake and growth.

The process by which the sediments interact with the overlying water column is controlled by several factors, including:

- The length and severity of the anoxic conditions in the hypolimnion
- The chemical characteristics and phosphorus content of the sediments
- The surface area of sediment exposed to anoxic conditions and the overlying water column

Matt Warner and Calder Reservoirs do exhibit short periods of anoxia in the hypolimnion during the summer months as shown by profile data collected by the Division of Water Quality. However, these events are not frequent enough to likely cause a significant release of phosphorus from the bottom sediments. Therefore the internal loading in these reservoirs is assumed to be a moderate source of phosphorus loading in Matt Warner and Calder reservoirs.

Animal Waste

Animal waste refers to the excreta of wildlife and livestock that typically contains high concentrations of available nutrients, particularly phosphorus. If the animal waste is deposited or washes into a waterbody, it contributes to the eutrophication of those receiving waters. Based on site visits to the Pot Creek watershed there appears to be opportunity for animal waste to enter receiving waters. Pot Creek is accessible along the majority of its length to wildlife and livestock. There appears to be considerable use of the creek bottom area due to the scarcity of woody riparian vegetation and presence of animal waste on the ground. Estimating the magnitude of phosphorus loading from animal waste is difficult however due to the migratory nature of wildlife, specifically elk and deer, and the variation from year to year in the number of livestock within the watershed during the short summer grazing season. Accordingly, animal waste is estimated to be a minor source of phosphorus loading based primarily on site visits and discussion with local resource professionals.

Streambank Erosion

Streambank erosion is a natural process in many streams throughout the West that experience wide variations in flow. However, the magnitude and rate of erosion can be significantly affected by human activities. Channelization and removal of woody riparian vegetation increases streambank erosion, degrading riparian habitat and downstream water quality. Although there does not appear to be much evidence of channelization where stream channels are straightened or otherwise confined from their flood plain there is an apparent lack of woody riparian vegetation such as willows over much of Pot Creek's length. Based on observations of Pot Creek at several locations, streambank erosion is estimated to currently be a minor source of phosphorus loading into Matt Warner and Calder Reservoirs. However, if stream flows were to significantly increase under a wetter climatic cycle Pot Creek has to potential to degrade and become a moderate source.

Human Recreational Sources

Human recreational sources include direct deposition of human waste or other litter into the reservoir. The primary recreational uses on Matt Warner and Calder Reservoir are fishing and boating. Swimming is rare in these waterbodies due to cold water temperatures. Restroom facilities and trash receptacles are available at both reservoirs. Given the above information, it is concluded that human recreational sources are a negligible source of phosphorus in Matt Warner or Calder Reservoirs.

Shoreline Erosion

Shoreline erosion occurs as wind and boats create waves that detach sediment from the shore of the reservoir and entrain it in the water column. Livestock and wildlife may also contribute to bank erosion as they walk over the shore to water. The eroded sediments contain phosphorus which is subsequently released into the water. When bank erosion occurs, the detached sediment is typically entrained in the water column within 3 to 6 feet of the shore, after which it generally settles out and becomes part of the lake bottom sediments. The water surface elevation of both reservoirs is relatively stable and soils surrounding the reservoir are high in sands, gravel and rock thereby reducing the potential for fine sediments to erode and wash into the reservoirs. Therefore bank erosion is considered a negligible source of phosphorus loading in Matt Warner and Calder Reservoirs.

Natural Geologic Sources

The primary source of phosphorus within the natural environment originates from geologic formations. Phosphate is a naturally occurring mineral that is primarily found in sedimentary and igneous rock formations. The Pot Creek watershed is located on the eastern shoulder of the Uinta Mountains which are made up of primarily pre-Cambrian metamorphic rock that does not contain high concentrations of phosphate. Therefore natural geologic sources are considered a negligible source of phosphorus loading into Matt Warner and Calder Reservoir.

Phosphorus Loading from Stream Inflows

One of the principal objectives of the TMDL process is to quantify the amount, or loading, of pollutants that enter the water body. The stream load represents the total mass of the pollutant that passes a given point in the stream during the time period considered. The loading into a reservoir represents the total of the loads from all of the inflows into the reservoir. For Matt Warner and Calder Reservoirs, total phosphorus (TP) loads into the reservoir were estimated. This section describes the methodology used to determine these loads.

The load in a stream may be calculated by multiplying flow with the concentration of the constituent and a conversion factor. Due to extremely limited data in the watershed, quarterly averages for both flow and phosphorus concentration were used. To improve the statistical reliability of the analysis, a minimum of four data points were required to calculate an average.

Matt Warner Reservoir

Quarterly loads for Matt Warner Reservoir were calculated by multiplying the quarterly flow volumes with the TP concentrations and a conversion factor. Annual loads were also determined and are presented with quarterly loads below in Table 4-2. The Upper Pot Creek Drainage sub-watershed drains to STORET Station 5937880. This station

provided TP concentrations for the second and third quarters only. Based on these values, TP concentrations for the remaining two quarters were linearly interpolated. Because higher resolution data were not available, an assumption was made that the rest of the water draining to Matt Warner Reservoir had similar TP concentrations to those of the Upper Pot Creek Drainage, and the sub-watersheds were therefore assumed to have the same quarterly concentration values.

Table 4-2: Matt Warner Reservoir - Total Phosphorus Loading

		Upper Pot Creek Drainage (5937880)	Sheet Flow to Matt Warner	East Matt Warner Inflow	Total Load
Jan/Feb/Mar	Flow (AF)	179	21	20	
	TP (mg/L)	0.060	0.060	0.060	
	Load (kg)	**13**	**2**	**2**	***17***
Apr/May/Jun	Flow (AF)	2,672	317	306	
	TP (mg/L)	**0.045**	0.045	0.045	
	Load (kg)	**148**	**18**	**17**	***183***
Jul/Aug/Sep	Flow (AF)	113	13	13	
	TP (mg/L)	**0.081**	0.081	0.081	
	Load (kg)	**11**	**1**	**1**	***13***
Oct/Nov/Dec	Flow (AF)	93	11	11	
	TP (mg/L)	0.070	0.070	0.070	
	Load (kg)	**8**	**1**	**1**	***10***
				Total Load:	***223***

TP concentration is averaged from 7 data

TP concentration is averaged from 4 data

All other TP concentrations were interpolated

Load = TP concentration (mg/L) x Flow (AF/quarter) x 1.233 kg/ac-ft

Calder Reservoir

Calculated quarterly and annual loads for Calder Reservoir are presented below in

Table 4-3. The Calder Drainage sub-watershed drains to STORET Station 5937810. This station provided a TP concentration for the third quarter which was approximately equal to that provided by STORET 5937880. Because higher resolution data were not available, the sub-watersheds in Calder Drainage were assumed to have the same quarterly TP concentrations found in the Matt Warner Drainage. Also, an assumption was made in order to determine the quarterly concentrations leaving the reservoir. Since the water in Matt Warner Reservoir is released near the bottom of the dam, it was assumed that the water quality at the bottom near the dam is indicative of the water quality in Pot Creek, below the dam. The bottom depth in-lake TP concentrations from STORET Station 5937850 (Matt Warner Reservoir above Dam) were therefore used as the concentrations being released from Matt Warner Reservoir. This station provided second and third quarter concentration values; the remaining quarters were linearly interpolated.

Table 4-3: Calder Reservoir – Total Phosphorus Loading

		Calder Drainage	Sheet Flow to Calder (5937810)	Release from Matt Warner (5937850-29)	Total Load
Jan/Feb/Mar	Flow (AF)	236	10	0	
	TP (mg/L)	0.060	0.060	0.070	
	Load (kg)	**17**	**1**	**0**	***18***
Apr/May/Jun	Flow (AF)	3,528	151	20	
	TP (mg/L)	0.045	0.045	**0.050**	
	Load (kg)	**196**	**8**	**1**	***205***
Jul/Aug/Sep	Flow (AF)	149	6	94	
	TP (mg/L)	0.081	**0.080**	**0.110**	
	Load (kg)	**15**	**1**	**13**	***29***
Oct/Nov/Dec	Flow (AF)	123	5	1	
	TP (mg/L)	0.070	0.070	0.090	
	Load (kg)	**11**	**0**	**0**	***11***
				Total Load:	***263***

TP concentration averaged from 16 data

TP concentration is averaged from 5 data

TP concentration is averaged from 4 data

All other TP concentrations were interpolated

Load = TP concentration (mg/L) x Flow (AF/quarter) x 1.233 kg/ac-ft

The majority of total phosphorus loading (82% in Matt Warner and 78% in Calder Reservoirs) is estimated to occur during the second quarter of the year, Apr/May/Jun, due to high flows (see Figure 3-26). The high flows are primarily fed by snowmelt that appears to dilute phosphorus concentrations but the corresponding loads are still much higher.

4.4 Future Sources of Pollution

Because the watershed is located in a remote area with little or no infrastructure (water, sewer, etc.), the area is essentially undeveloped with little growth anticipated in the future. The Pot Creek watershed has been identified by the BLM as having very low to no potential for oil and gas development.

5.1 Introduction

The Total Maximum Daily Load (TMDL) process is an analytical method included within the Clean Water Act to determine the maximum amount of contaminants that a water body can contain and still support all of its beneficial uses. This chapter discusses in detail the TMDL that is being established for Matt Warner and Calder Reservoirs to address the water quality problems that have been explained in the Technical Analysis section. This chapter reviews how water quality endpoints would be achieved and maintained through actual load reductions from the sources.

5.2 Endpoints

Endpoints have been determined from the analysis described in the Technical Analysis section, and are shown in Table 5-1. Current data indicate that, for the most part, these endpoints have been achieved. The endpoints identified are meant to maintain and control the overall health of the reservoir and the fishery.

Table 5-1: Summary of Recommended Endpoints

Parameter	Proposed Target	Notes
Dissolved Oxygen	>50% of the water column above 4 mg/L	Both reservoirs have maintained dissolved oxygen concentrations greater than 4 mg/L in more than 50% of the water column
Total Phosphorus Load to Reservoir	Matt Warner: 223 kg/y TP Calder Reservoir: 263 kg/y TP	Maintain current total loadings
Average TSI	40 - 50	Using chlorophyll a values from May through September to calculate TSI
Fish Habitat Indicator	No fish kills	
Blue-Green Algae	Decrease the dominance of blue-green algae	

5.3 Dissolved Oxygen – Phosphorus Linkage

One of the essential components of developing a TMDL is to establish a link between predicted nutrient loads and the numeric indicators that have been chosen to measure the attainment of uses. Once this link has been established, it is possible to determine the total capacity of the water body to assimilate nutrient loadings while still supporting its designated uses. Allowable loads can then be allocated among the various pollutant sources.

The link can be established by using one or more analytical tools. Ideally, the link is based on a long-term set of monitoring data that allows an association to be developed between certain water body responses to flow and loading conditions. More often, however, the link must be established by using a combination of monitoring data,

statistical and analytical tools (including simulation models), and best professional judgment.

TSI and Vollenweider Analysis

Since the early 1990s, individual TSI scores have alternated between mesotrophic and eutrophic for both reservoirs as shown previously in Figure 3-8 and Figure 3-9. However, the TSI calculated from chlorophyll a data, the most accurate predictor of trophic status, shows a decreasing trend in Matt Warner Reservoir and, recently, an increasing trend in Calder Reservoir. This may indicate that Calder Reservoir has been affected more by the recent long term drought and the resulting lower inflow and lake levels.

The TSI results are corroborated by the Vollenweider equations that classify the trophic status of lakes and reservoirs based on the total phosphorus load, hydraulic residence time, and mean reservoir depth. This analysis classified Matt Warner Reservoir as mesotrophic and Calder Reservoir as eutrophic as shown previously in Figure 3-11 and Figure 3-12.

Phosphorus Trends

Annual average total phosphorus loading was estimated to be 223 kg (492 lb) into Matt Warner Reservoir and 263 kg (580 lb) into Calder Reservoir.

Figure 5-1 and Figure 5-2 show the annual total phosphorus trends in Matt Warner and Calder Reservoirs using the months that typically exhibit the highest total phosphorus concentrations (June, July and August). The overall total phosphorus trend in both reservoirs shows a slight decline, with a more evident rate of decline in the bottom concentrations. However, due to extremely limited data, the confidence in these trends is weak.

Figure 5-1: Matt Warner Reservoir (Stations 5937850 and 5937860)- In-Lake TP Trends

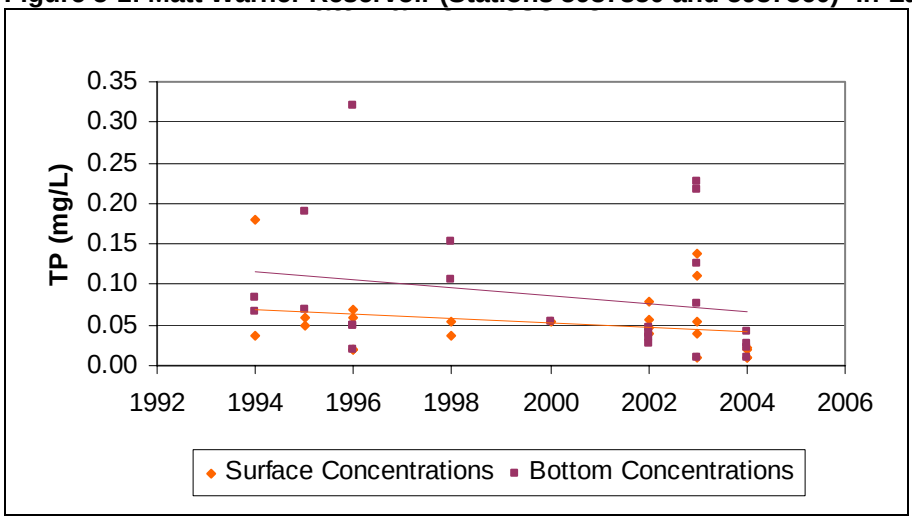
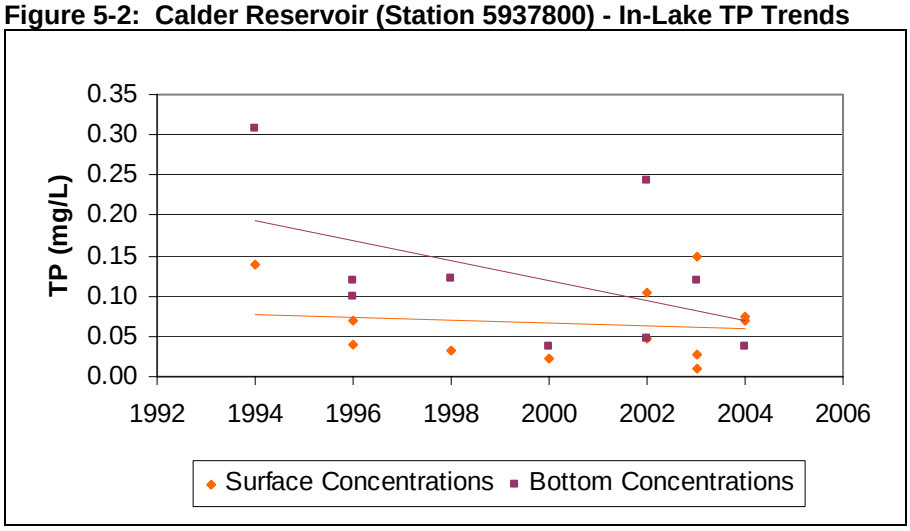


Figure 5-2: Calder Reservoir (Station 5937800) - In-Lake TP Trends



Dissolved Oxygen Trends

Figure 5-3 and Figure 5-4 show the annual dissolved oxygen trends in Matt Warner and Calder Reservoirs. Bottom concentrations from the months typically displaying the lowest concentrations of dissolved oxygen (June, July and August) were used to calculate annual averages. There is a slight increase in dissolved oxygen concentrations at the bottom depths of both reservoirs.

Figure 5-3: Matt Warner Reservoir - In-Lake DO Trends

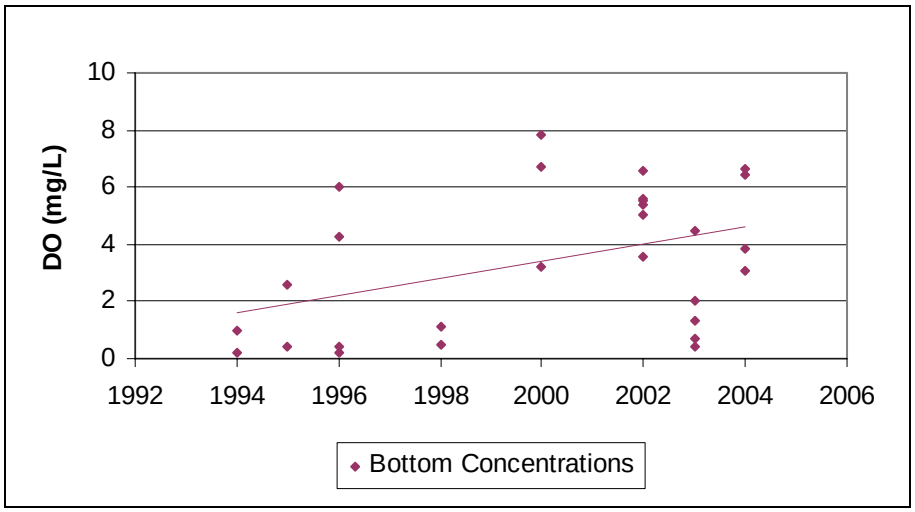
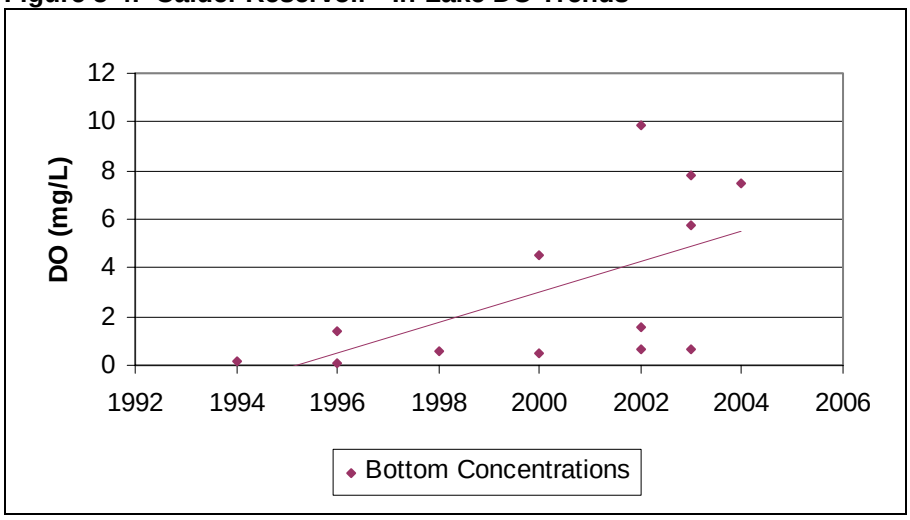


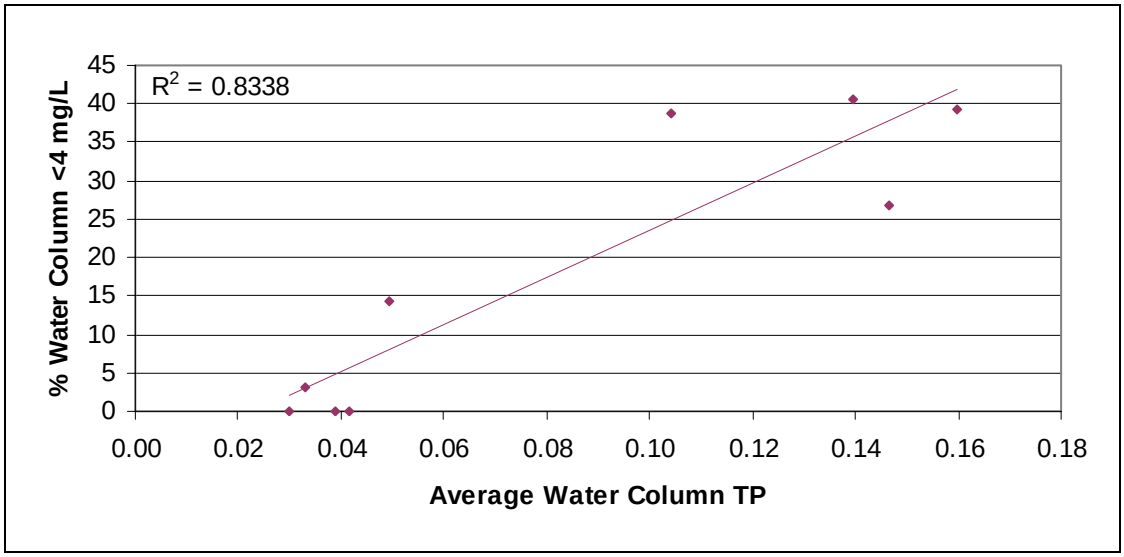
Figure 5-4: Calder Reservoir - In-Lake DO Trends



Linkage

Due to limited data, there is not strong confidence in these trends. The slight increases in dissolved oxygen and slight decrease in total phosphorus indicate a potential linkage between a reduction in phosphorus and an increase in dissolved oxygen. Figure 5-5 further demonstrates this linkage. As the average concentration of total phosphorus in the water column increases, the percentage of the water column with dissolved oxygen concentrations below 4 mg/L also increases, providing less suitable habitat for fish.

Figure 5-5: TP and DO relationship - Matt Warner Reservoir above Dam



5.4 Load Allocations

The TMDL load allocation assigns loads to all sources including point, non-point and background sources. In addition, a margin of safety (MOS) is included to account for the uncertainty inherent in the analysis and ensure that beneficial uses are protected into the foreseeable future. The MOS is a required part of the TMDL development process. There are two basic methods for incorporating the MOS (USEPA, 1991). Implicit methods incorporate the MOS using conservative model assumptions to develop allocations. Explicit methods specify a portion of the total TMDL as the MOS, allocating the remainder to sources.

Matt Warner's cold water fisheries beneficial use was assessed as not impaired in this study based upon the TSI and Vollenweider analyses whereas Calder Reservoir's was assessed as partially supporting. Although the water column in both reservoirs has always been partially supporting with respect to dissolved oxygen, Calder Reservoir is classified as eutrophic by both the Vollenweider and TSI analyses. Because there wasn't a consistent conclusion from the methods considered in the impairment assessment, and the limited data set, a 10 percent MOS, included explicitly, is recommended. This allocates 10 percent of the loading capacity, or 22 kg/yr for Matt Warner Reservoir and 26 kg/yr for Calder Reservoir to the MOS.

Because the Vollenweider analysis is the only method that accounts for phosphorus loading into the reservoir, this was used as the basis for determining load reductions. According to the Vollenweider analysis, Matt Warner Reservoir is classified as mesotrophic and therefore additional load reductions other than for the margin of safety are not required. However, Calder Reservoir is classified as eutrophic. In order for Calder Reservoir to attain mesotrophy a 35% reduction (92 kg/y) in phosphorus loads is needed. A small amount (5%) of the contributing phosphorus load into Calder Reservoir comes from water released from Matt Warner Reservoir. However, most of the phosphorus load into Calder (95%) is from the Calder drainage. Therefore, the full 35% load reduction is allocated to sources within the Calder drainage.

Table 5-2 and Table 5-3 outline the current loads, proposed reductions, and future loading allocations. Details on the methods and calculations that were used to arrive at

these loadings can be found in Section 4.3, "Pollutant Loadings". For the purpose of prioritizing implementation activities, load allocations were quantified by each nonpoint source based upon the following assumptions; moderate sources of loading represent 35% of the total load and minor sources represent 15%. These assumptions are based on best professional judgment of the site specific factors within the Pot Creek watershed. As best management practices are implemented through an adaptive management approach, continued monitoring will be used to assess improvement.

Table 5-2: Matt Warner Reservoir - TP TMDL Load Allocations (kg/yr)

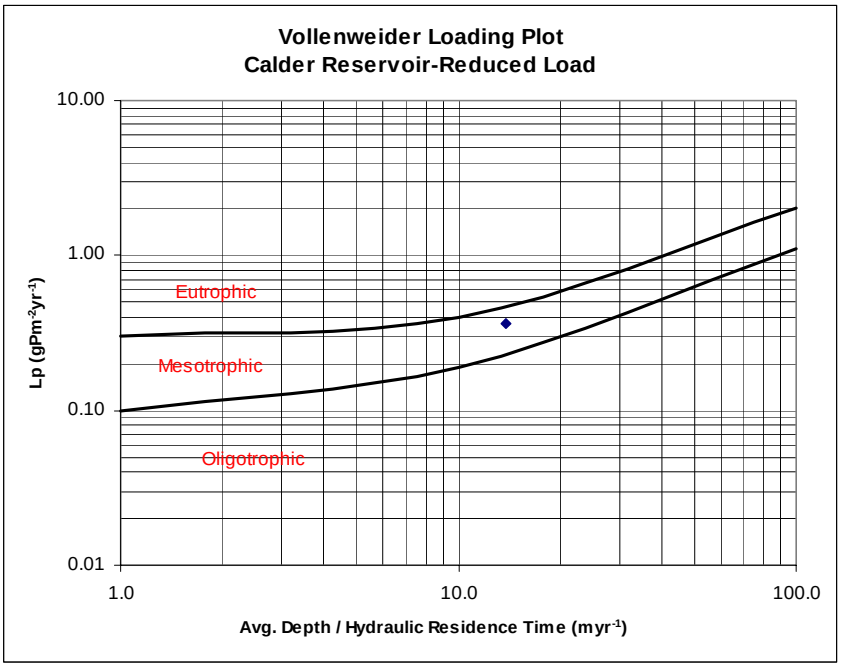
Source	Current Load	Annual Allocation	Load Reduction
Upland Soil Erosion	78	62	16
Internal Loading	78	62	16
Animal Waste	33	27	6
Streambank Erosion	33	27	6
All other sources	1	1	0
Margin of Safety	-	22	(22)
Total	223	201	22

Table 5-3: Calder Reservoir - TP TMDL Load Allocations (kg/yr)

Source	Current Load	Annual Allocation	Load Reduction
Upland Soil Erosion	92	41	51
Internal Loading	92	41	51
Animal Waste	39	18	21
Streambank Erosion	39	18	21
All other sources	1	1	0
Margin of Safety	-	26	(26)
Total	263	145	118

Figure 5-6 shows the effect that the phosphorus load reductions will have on Calder Reservoir according to the Vollenweider loading model. These reductions are expected to bring the reservoir into the Mesotrophic zone thereby restoring its cold water fisheries beneficial use.

Figure 5-6: Vollenweider Loading Plot, Calder Reservoir, After Reduction

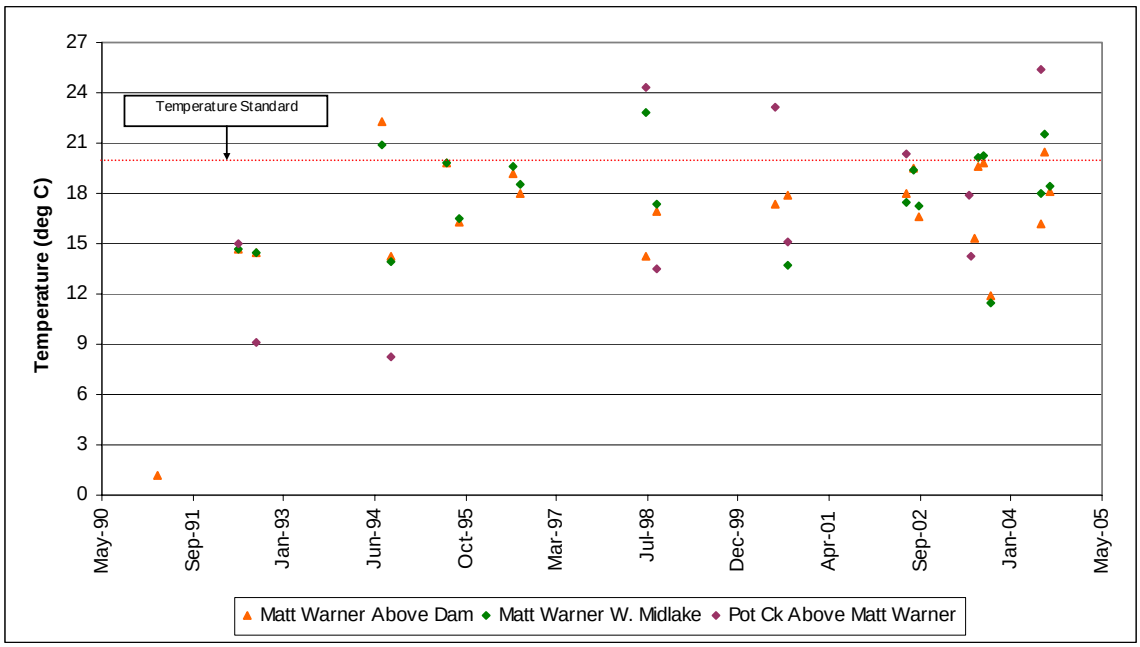


5.5 Temperature Delisting

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

The primary reason for delisting Matt Warner Reservoir is that our analysis has determined that the source of temperature impairment is not the result of human activities. Beginning in 1998, the temperature in Pot Creek flowing into Matt Warner Reservoir often exceeded the temperature standard as shown in Figure 5-7. These temperature exceedances correspond with the years having less than average precipitation. Therefore, the likely cause of temperature exceedances is due to natural drought conditions.

Figure 5-7: Temperature - Matt Warner Reservoir



5.6 Public Participation

A public hearing on the TMDLs was held on October 26 with notification of the hearing published in the Salt Lake Tribune, Deseret News and Vernal Express on November 21. The comment period was opened on November 21 and closed on December 16. No formal comments were received.

6.1 Introduction

To achieve the TMDL goals and endpoints, it is necessary to implement various watershed controls. BMPs that reduce soil erosion play a major role in reducing the potential for phosphorus movement from the watershed to the reservoirs. BMPs that minimize grazing impacts also reduce phosphorus entering the reservoirs. Watershed erosion controls and grazing management practices can potentially reduce the amount of soluble and total phosphorus entering the reservoirs. Calder Reservoir has been identified as needing phosphorus load reductions. Therefore, the watershed controls described below are most applicable to the Calder Reservoir drainage, but may also be applied to the Matt Warner watershed if necessary.

Watershed Erosion Controls

Sediments act as a transport mechanism for nutrients into the reservoirs. The rate at which sediments, and therefore nutrients, enter the reservoirs is related to the rate of erosion. When the soil structure is weakened due to natural or anthropogenic causes, embankments are easily scoured, and sediments carrying nutrients are washed into the reservoirs. Increasing watershed vegetation and improving riparian areas will increase the strength of the soil and minimize erosion.

Improved Watershed Vegetation

Vegetation protects soil from erosion by rainfall, runoff, wave action and wind. It is possible to decrease the velocity of runoff, which in turn results in less erosion, by the strategic planting of vegetation around the reservoirs and in the watershed. Plant root systems will improve infiltration and the water-retaining capacity of the soil as well as the rate of snowmelt. This will result in increased soil strength, stability, and porosity. The above ground portion of the vegetation will shade habitat areas while offering protection from the wind. By improving vegetation in the watershed, erosion will decrease and sediment and nutrient loads into the reservoirs will be reduced.

Improved Riparian Habitat

Riparian areas are vegetated regions on each side of the stream. These vegetated areas naturally prevent soil erosion around streambanks while providing food, habitat and thermal protection for fish and wildlife. Vegetation stabilizes the streambank while acting as a nutrient and sediment filter for water entering the stream. Improving the riparian areas on Pot Creek above Matt Warner Reservoir and the stretch of the creek between the two reservoirs, sediments and nutrients into the reservoirs could be reduced.

Grazing Controls

Livestock feed on vegetation, reducing the plant cover and thereby damaging the soil structure and increasing nutrients into the reservoirs. Livestock trampling also directly causes erosion and compaction to occur in the watershed. This can lead to an increase in sediment and phosphorus entering the reservoirs. By promoting proper grazing management, healthy and sufficient vegetation can be maintained, thereby decreasing erosion.

Improved Grazing Management

Overgrazing of a particular area reduces plant cover and increases erosion and sediment transport into the reservoirs. By monitoring the intensity and duration of grazing, and rotating grazing areas accordingly, healthy and adequate vegetative cover can be preserved. Additionally, season of use should be a consideration. During spring, plants grow faster and are more resilient to grazing. In fall or winter, livestock may need to be relocated to another part of the watershed and their feed supplemented to prevent overgrazing and damage to the watershed. Maintaining healthy vegetation and protecting the integrity of the soil structure will thereby reduce nutrients into the reservoir.

Shoreline and Streambank Fencing

High concentrations of nutrients enter the reservoirs via direct deposit of animal waste. Additionally, livestock trampling damages vegetation and causes erosion and compaction to occur in the watershed. These adverse affects can be minimized by fencing shoreline areas and the streambanks of Pot Creek to exclude livestock.

Off Site Water Development

As described above, livestock can have adverse affects on the watershed areas. By developing off site water sources, livestock will be drawn away from the reservoirs and Pot Creek to an alternate drinking water source. This will result in less animal waste being deposited into the reservoir and fewer livestock trampling the areas directly around the reservoirs. Providing water sources that are accessible to livestock but away from the reservoirs and Pot Creek will reduce nutrients into the reservoirs.

Table 6-1: BMPs Summary

BMP	Description	Desired Result	Implementation Location
Improved Watershed Vegetation	Increase vegetation cover in watershed. Vegetation protects soil from erosion by rainfall, runoff, wave action and wind. Plant root systems increase soil strength, stability and porosity.	Improve infiltration and water-retaining capacity of soil. This will decrease erosion thereby decreasing sediment and nutrient loads into the reservoir.	Watershed areas surrounding the reservoirs.
Improved Grazing Management	Monitor the intensity and duration of grazing. Rotate grazing areas to allow vegetation to grow. Consider season of use; in spring plants grow faster and respond better to grazing. In other seasons livestock may need to be relocated or their feed supplemented.	Maintain healthy and sufficient vegetation to decrease erosion. This will result in a reduction of nutrients into the reservoirs.	Watershed areas surrounding the reservoirs.
Fencing	Exclude livestock from the reservoirs and Pot Creek, encouraging revegetation. High concentrations of nutrients enter the reservoirs via direct deposition of animal waste. Livestock trampling damages vegetation and causes erosion	Reduce the animal waste entering the reservoirs and maintain the integrity of the soil thereby reducing nutrients into the reservoirs.	Shoreline areas and streambanks of Pot Creek.
Off Site Water Development	Off site water development will provide livestock with an alternate source of drinking water.	Draw livestock away from the reservoirs and Pot Creek. This will result in less animal waste being deposited into the reservoirs and fewer livestock trampling areas directly around the reservoir. This will decrease erosion and reduce	Area accessible to livesock but away from reservoirs and Pot Creek.
Improved Riparian Habitat	Riparian areas naturally prevent soil erosion, improve streambank stability and filter nutrients before they reach the reservoirs.	Decrease nutrients into the reservoir while providing food, habitat and thermal protection for fish and wildlife.	Pot Creek above Matt Warner Reservoir and Pot Creek between

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