PIUTE RESERVOIR

LIMNOLOGICAL ASSESSMENT OF WATER QUALITY

Photo Provide By: Sevier River Water Users Association

Utah Division of Water Quality

February 2008

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EXECUTIVE SUMMARY

The designated beneficial uses for Piute Reservoir are secondary contact recreation (2B), cold water game fish and the associated food chain (3A), and agricultural water supply (4). The cold water game fish designated use (3A) was identified as partially supporting on the 2006 303(d) list because of elevated in-lake total phosphorus concentrations. However, analysis of current water quality data indicates that the reservoir is currently supporting its 3A designated beneficial use. Piute Reservoir is recommended to be placed in Category 5B of the State of Utah's 303(d) List and requested for removal from the current listing of impaired waters based on the following elements:

- Current and historical dissolved oxygen data indicate greater than 50% of the water column has more than 4 mg/L dissolved oxygen in all depth integrated profile samples.
- Total phosphorus concentrations are greater than the in-lake State indicator value of 0.025 mg/L; however, reservoir productivity is less than expected with current phosphorus levels.
- TSI values indicate that the reservoir is mesotrophic the majority of the time with eutrophic conditions in late summer that correspond to the period after de-stratification.
- Exceedances of the in-lake pH standard do not occur.
- Exceedances of temperature criteria were determined to be naturally occurring.
- No fish kills have been reported.
- Some blue-green algal species are present in the late summer and early fall, but the limited dataset show low relative abundance.
- Additionally, TMDLs developed for total phosphorus for the East Fork Sevier River and the Sevier River, which provide 100 percent of the inflow to Piute Reservoir, will reduce total phosphorus loads to the reservoir by approximately 50 percent.

1.0 INTRODUCTION

1.1. Piute Reservoir Impairment

Piute Reservoir was identified as water-quality limited due to excess in-lake phosphorus concentrations. Piute Reservoir's beneficial uses are secondary contact recreation (2B), cold water game fish and the associated food chain (3A), and agricultural water supply (4). The cold water game fish designated use (3A) was identified as partially impaired on the State of Utah 2006 303(d) list. The secondary contact recreation and agricultural water supply designated uses were assessed as fully supported on this same list.

1.2. EPA Delisting Requirements

Analysis of current water quality in Piute Reservoir indicates that the reservoir is meeting all designated beneficial uses. Piute Reservoir is recommended to be placed in Category 5B of the State of Utah's 303d List and requested for removal from the current 303(d) listing of impaired waters.

According to EPA regulations, each State must demonstrate good cause for not including waters on the list (40 C.F.R. Part 130.7(b)(6)(iv)) or removing them from the list. These include:

- A water body listed due to error in assessment or because a water body was listed incorrectly in place of another water body or any other error not based on a water quality assessment.
- The most recent data assessment indicates that the water body is supporting all of its designated beneficial uses.
- A total maximum daily load analysis has been completed and approved by EPA.
- New modeling information indicates no TMDL is required in order to maintain water quality standards.
- Data assessment methodologies have been modified.

Utah may also recommend delisting of a water body when:

- The water body is meeting all applicable water quality standards or is expected to meet these standards in a reasonable time frame (*e.g.*, two years) as a result of implementation of required pollutant controls or
- If, upon re-examination, the original basis for listing is determined to be inaccurate.

2.0 WATER QUALITY ASSESSMENT

2.1. Beneficial Use Classification

The State of Utah has designated the beneficial uses of Piute Reservoir to be: secondary contact recreation (2B), cold water game fish and the associated food chain (3A), and agricultural water supply (4). The cold water game fish designated use (3A) was identified as partially supporting on the State of Utah 2006 303(d) list. Secondary contact recreation and agricultural water supply designated uses were reported as being fully supported on this same list.

Waters designated for cold water game fish and associated food chain use are required to exhibit appropriate levels of dissolved oxygen, temperature, pH, ammonia and turbidity for cold water aquatic life support. Piute Reservoir is not listed as impaired for temperature or pH. The analysis presented in section 2.4.4 of this assessment indicates that exceedances of the water temperature criteria are associated with natural conditions.

2.2. Water Quality Standards

Water quality standards under the Clean Water Act consist of three main components: designated beneficial uses, water quality criteria that are established to protect designated beneficial uses, and anti-degradation policies and procedures.

Water quality criteria can be either numeric limits for individual pollutants and conditions, or narrative descriptions of desired conditions. Table 2.1 summarizes the applicable State of Utah water quality criteria for the 3A beneficial use impairment to Piute Reservoir.

Table 2.1. 3A Water Quality Numeric Standards and Pollution Indicator Values (Utah State Code RS 317-2-14)

Parameter and Designated Beneficial Use	Criterion	Utah State Code	Comments
Dissolved Oxygen (DO)			
2B	N/A		
3A	No less than 6.5 mg/L (30-day average), 9.5 early life stages / 5.0 all life stages (7-day average), 8.0 early life stages / 4.0 all life stages (1-day average)	Table 2.14.2	These limits are not applicable to lower water levels in deep impoundments.
4	N/A		
Total Phosphate as P (pollutant indicator value)			
2B	No greater than 0.05 mg/L	Table 2.14.1	Total phosphorus as P (mg/L) limit for lakes and reservoirs shall be 0.025 mg/L.
3A	No greater than 0.05 mg/L	Table 2.14.2	
4	N/A		
pH			
2B	No less than 6.5 AND no greater than 9.0 pH units	Table 2.14.1	
3A	No less than 6.5 AND no greater than 9.0 pH units	Table 2.14.2	
4	No less than 6.5 AND no greater than 9.0 pH units	Table 2.14.1	
Total Dissolved Gas			
2B	N/A		
3A	Not to exceed 110% of saturation.	Table 2.14.2	
4	N/A		
Temperature			
2B	N/A		The temperature standard shall be at background where it can be shown that natural or un-alterable conditions prevent its attainment. In such cases rulemaking will be undertaken to modify the standard accordingly.
3A	No greater than 20 ^oC, No greater than 2 ^oC change	Table 2.14.2	
4	N/A		

2.3. Water Quality Data Analysis

2.3.1. Analytical Methods

Data collected and assessed for Piute Reservoir water quality analysis consisted of samples evaluated by four primary categories of analytical methodology: APHA, USEPA, Utah DWQ generic and Utah DWQ field methods.

APHA Methods.

Refers to American Public Health Association (APHA), *Standard Methods for the Examination of Water and Wastewater*, 18th edition (1992), American Public Health Association, 1015 Fifteenth Street, NW, Washington, DC 20005 (from http://www.epa.gov/STORET/metadata.html).

APHA approved methods specific to the available data for Piute Reservoir include analytical procedures for measuring alkalinity, chemical oxygen demand, chloride, chlorophyll, dissolved solids, fecal coliform bacteria, fecal streptococcus group bacteria, fixed solids, pH, total coliform bacteria, total organic carbon, total suspended solids, volatile solids, and others not pertinent to this TMDL effort.

USEPA Methods

Refers to US Environmental Protection Agency (US EPA), *Methods for Chemical Analysis of Water and Wastes (1983)*, USEPA, EPA 600/4-79-020 (from http://www.epa.gov/STORET/metadata.html).

USEPA approved methods specific to the available data base for Piute Reservoir TMDL include analytical procedures for measuring ammonia, biochemical oxygen demand, chloride, nitrate + nitrite, phosphorus, specific conductance, total suspended solids, turbidity, volatile solids, and others not pertinent to this TMDL effort.

Utah DWQ Generic Methods (generic method and generic method 2)

Refers to Utah Division of Water Quality (DWQ) entered in the STORET data base where historical methodology may not be available, method is listed as *unknown*, method is listed as *no cite*, method is listed as *Method not cited*, or others.

UTAH DWQ GENERIC METHODS (GENERIC METHOD AND GENERIC METHOD 2) specific to the available data base for Piute Reservoir TMDL include measurements of alkalinity, ammonia, biochemical oxygen demand, chemical oxygen demand, chloride, chlorophyll *a*, nitrate, nitrate + nitrite, nitrite, pH, ortho-phosphate, phosphorus, specific conductance, total Kjeldahl nitrogen, total organic carbon turbidity, and others not pertinent to this TMDL effort.

Due to the fact that the data in this analysis category were collected, reviewed and submitted to the STORET database by DWQ, it was assumed that all sampling protocols and analytical methods employed were carried out in a fashion approved by DWQ and contained and attained a DWQ-approved level of quality assurance and quality control.

Utah DWQ Field Measures

Refers to Utah Division of Water Quality (DWQ), *Quality Assurance/Quality Control Manual (1996)*. Utah DWQ Field Measures approved methods specific to the available data base for

Piute Reservoir TMDL include analytical procedures for measuring chlorine, dissolved oxygen, flow, pH, salinity, Secchi depth, specific conductance, and temperature (air and water).

2.3.2. Quality Assurance/Quality Control

The data were assessed to ensure that all data points included in the process met an appropriate level of quality. Basic statistical analyses were used to characterize data the range and quality. Statistical parameters assessed included the number of data points, determination of mean, median, maximum and minimum values, assessment of variance and an analysis of seasonality. The completeness of the data set was also evaluated in a spatial, temporal and parameter-specific fashion and critical data gaps were identified. Further evaluation is discussed in the following sections.

Treatment of Nondetects

Some the data points collected in this dataset are concentration values identified as below detection limits. Standard methods were used to statistically interpret these values. This was accomplished by assigning a numeric value of one-half of the detection limit (in the case of concentrations identified as below detection limits.

Detection limits are reported in the STORET database for most data points and provided a specific nondetect values for most data. If data point specific detection limits were not provided, detection limits were applied based on specific analytical methods.

Treatment of Errors

An initial assessment of the data was performed to identify transcription and other errors such as inappropriate values inaccurate sample information, and errors in physical information. No such errors were identified in this analysis.

Treatment of Outliers

To identify data representative of water quality conditions in the Piute Reservoir, a threshold of plus or minus three standard deviations from the mean was applied to the available data sets for relevant in-lake water quality data. The exclusion of these outlier had an insignificant effect on mean concentrations for total phosphorus, chorlophyll-*a*, temperature, pH, secchi depth, dissolved oxygen, and dissolved oxygen saturation.

2.4. Beneficial Use Support Assessment

2.4.1. Dissolved Oxygen

Dissolved oxygen (DO) is important to the health and viability of fish and other aquatic life. Aquatic life depends on high concentrations of dissolved oxygen from 6–8 mg/L or greater. Dissolved oxygen concentrations below 5 mg/L can result in stress, reduced resistance to other environmental stressors, and even death at very low levels (less than 2 mg/L).

In addition to direct effects on aquatic life, low dissolved oxygen concentrations can lead to changes in water and sediment chemistry that can influence the concentration and mobility of nutrients and toxins such as phosphorus, ammonia, and mercury. Low dissolved oxygen at the sediment-water interface can result in substantial release of sorbed phosphorus in the overlying water column, which in turn can lead to increased algal growth and decreased dissolved oxygen concentrations. Finally, increased water column concentrations of ammonia can result from the chemical changes caused by anoxic conditions. Elevated ammonia levels threaten the health of aquatic life forms and, at extreme concentrations, can result in death.

Low dissolved oxygen often results from high nutrient, organic, or algal loading to a surface water system. Nutrients promote algae growth, which in turn consumes oxygen from the water column during night time respiration. In addition, dead algae and other organic matter settle to the bottom of the water body where decomposition consumes oxygen.

Dissolved oxygen concentrations are also reduced by pollutants that require oxygen in oxidation processes. Biochemical oxygen demand (BOD) is a measure of the dissolved oxygen required to oxidize material. Some of the delivered organic material is algae and some is detritus, both of which exert a certain amount of BOD. Additionally, organic loads delivered to the reservoir during high volume and high velocity spring flow events can contribute to BOD.

Data collected in Piute Reservoir since 1999 indicate that dissolved oxygen concentrations are generally high with mean concentrations ranging from 4.1 mg/L to 8.6 mg/L. Minimum dissolved oxygen concentrations range from 0.15 to 7.5 mg/L and are limited to the sediment-water interface at the bottom of the reservoir.

The State of Utah has defined the support status of game fish populations relative to the percentage of the total water column experiencing depressed dissolved oxygen concentrations. A water body's dissolved oxygen concentration is defined to be non-supporting for cold water game fish when less than 25 percent of the water column depth exhibits dissolved oxygen concentrations of 4.0 mg/L or greater. If 25 to 50 percent of the water column depth exhibits dissolved oxygen concentrations of 4.0 mg/L or greater, the water body is defined to be partially supporting. Where greater than 50 percent of the water column depth exhibits dissolved oxygen concentrations of 4.0 mg/L or greater, a full-support status has been defined. These criteria were assessed for each depth integrated profile sample.

Table 2.2 shows the percent of each water column profile with DO concentrations below 4.0 mg/L. Examination of the table shows that the reservoir is fully supporting the 3A DO criterion and that no profile has greater than 31.1% of the profile with less than 4.0 mg/L.

Additionally, an examination of historical profiles collected between 1991 and 1997 show that 17 of 22 (77 percent) profiles had dissolved oxygen concentrations greater than 4.0 mg/L throughout the entire water column. One profile observed on 8/8/1995 at the above dam site had 31 percent (the maximum observed) of the water column below 4 mg/L DO. Historic data demonstrates no violations of the 50 percent water column 3A criteria.

Table 2.2. Percent of Water Column Profile Exceeding 4 mg/L Dissolved Oxygen.

Site Name	Month	2001	2003	2005	2007
PIUTE RES AB DAM 01	May				
	June			0%	
	July	2.4%		28.1%	5.7% & 7.0%
	Aug	0%		33.1%	
	Sept			0%	
PIUTE RES MIDWAY UP LAKE 02	May				
	June			0%	
	July	7.0%		31.6%	16.4
	Aug	0%		20.2%	
	Sep			0%	
PIUTE RES UPPER REACHES 03	May				
	June			0%	
	July	0%		0%	0%
	Aug	0%		0%	
	Sep			0%	

2.4.2. Dissolved Oxygen Saturation

The water quality criteria for dissolved gases established by the State of Utah is a maximum saturation of 110% due to the stress supersaturated water can cause for fish. Dissolved oxygen supersaturation (concentrations greater that 110% of saturation) was experienced in 6.8% of recent samples collected in the water column profiles throughout the reservoir. 5.7 percent of water column samples were greater than 110 percent saturations at the dam site, while 7.5 percent and 7.8 percent of samples were greater than the standard at the mid lake and upper reaches site, respectively (Table 2.3). Additionally, available historic profiles do not demonstrate exceedances of the 100% DO saturation criteria.

Table 2.3. Piute Reservoir Percent Dissolved Oxygen Saturation.

Site Name	Start	End	n	Min (%)	Average (%)	Max (%)	n > 110 %
PIUTE RES AB DAM 01	7/5/2001	9/6/2005	88	1.8	76.7	126.7	5
PIUTE RES MIDWAY UP LAKE 02	7/5/2001	9/6/2005	69	2.2	77.3	128.7	5
PIUTE RES UPPER REACHES 03	7/5/2001	9/6/2005	38	60.6	90.0	121.3	3

2.4.3. pH

A key indicator of acidity or alkalinity of a system is pH, as measured by the hydrogen ion activity in the water. A pH value of 7.0 is neutral, with values from 0–7 indicating acidic water and values those from 7–14 indicating alkaline water. Extremely acid or alkaline waters can be toxic to aquatic life. Even at less extreme levels, acidic or alkaline conditions can cause chemical shifts in a system; acidic conditions can release metallic compounds from sediments while alkaline conditions can increase ammonia toxicity and release sorbed phosphorus.

Piute Reservoir pH observations are displayed in Table 2.4. The table shows that the minimum and maximum observed pH values observed for each in-lake site during depth integrated sampling are 7.4 and 8.8, respectively. A review of all available pH data throughout the entire data record reveals no exeedances of the State's minimum and maximum pH standard for the 3A beneficial use. Additionally, an analysis of profile data presented in section 2.4.8 demonstrates that pH values are very stable throughout the depth profile, which indicates that reservoir productivity is not high enough to adversely affect water column pH.

Table 2.4. Piute Reservoir depth integrated pH values.

Site Name	Start	End	Count	Min	Average	Max
4949160	7/5/2001	9/6/2005	88	7.4	8.3	8.8
4949170	7/5/2001	9/6/2005	69	7.5	8.3	8.8
4949180	7/5/2001	9/6/2005	38	8.0	8.4	8.8

2.4.4. Temperature

High water temperatures can be harmful to fish at all life stages, especially when high temperatures combine with other habitat limitations such as low dissolved oxygen or poor food supply. As a stressor to adult fish, elevated temperatures can lower body weight, reduce oxygen exchange, and diminish reproductive capacity. Extremely high temperatures can result in death if they persist for an extended length of time. Juvenile fish are more sensitive to temperature variations and duration than adult fish.

High water temperatures are routinely observed throughout the water column profile samples and historic water samples in Piute Reservoir. Piute Reservoir was listed on the 2004 Utah 303(d) list of impaired waters as partially supporting its 3A beneficial use for temperature. As the reservoir has little natural cover and the watershed is located in an area experiencing warm, dry climate conditions, the State of Utah conducted a heat budget analysis for the reservoir and determined that the primary source of temperature loading was from solar radiation and heat transfer. The heat budget analysis determined elevated water temperature was the result of natural solar radiation.

2.4.5. Total Phosphorus

Excessive nutrient concentrations (nitrogen and phosphorus) can directly affect water quality by causing algal blooms and excessive macrophyte growth, which can create objectionable odors and appearance in water used for recreation. Excessive nutrient concentrations also have indirect effects on water quality. During the daytime photosynthesis from algae produces excess oxygen; however, at night time algae respire and consume sufficient oxygen from the water column that can stress or kill fish and other aquatic organisms. Additionally, when algae die, they sink to the bottom sediments where biochemical processes consume oxygen from the surrounding water. Because most of the decomposition occurs in the lower levels of the water column, dissolved oxygen concentrations near the bottom of lakes and reservoirs can be substantially depleted.

Where depth-integrated total phosphorus data are available for 1996 and 1998, concentrations are observed to increase with depth during summer months. Concentrations in deeper water generally average about three times greater than concentrations at the water's surface Mid-Reservoir, and about six times greater than concentrations at the water's surface at the dam. Increases in total phosphorus with depth are generally correlated with low dissolved oxygen (less than 3 mg/L) in the lower layers of the reservoir and most likely indicate dissolution from sediment-bound phosphorus delivered during spring runoff.

Mean total phosphorus concentrations are presented in Figure 2.1 and summarized in Table 2.5 for all sampled depths at each site. Depth codes 21, 23, 27, and 29 correspond to the surface, 1 meter above the thermocline, 1 meter below the thermocline, and 1 meter above the bottom, respectively. Mean concentrations range from 0.04 mg/L at the Dam Site to 0.09 at the mid-lake site. Concentrations are generally lower in the surface water samples (depth of 21) than at the bottom samples (depth of 29). This is most likely explained by the re-suspension of phosphorus that occurs in anoxic conditions in the bottom of the reservoir.

The total phosphorus indicator concentration is 0.025 mg/L for lakes and reservoirs. The indicator value is not considered a water quality standard but a pollution indicator level that is used along with other water quality parameters to assist in the determination of the reservoir impairment. While the majority of total phosphorus samples are greater than the indicator value, expected levels of in-lake productivity and subsequent beneficial use impairment are not evident. An analysis of the tropic state of the reservoir presented in section 2.4.10 demonstrates that algal productivity is under-predicted by total phosphorus concentrations. One likely explanation is that total phosphorus is bound to suspended particles and is unavailable for algal growth. A more in-depth analysis of the reservoir's trophic state is presented in section 2.4.10.

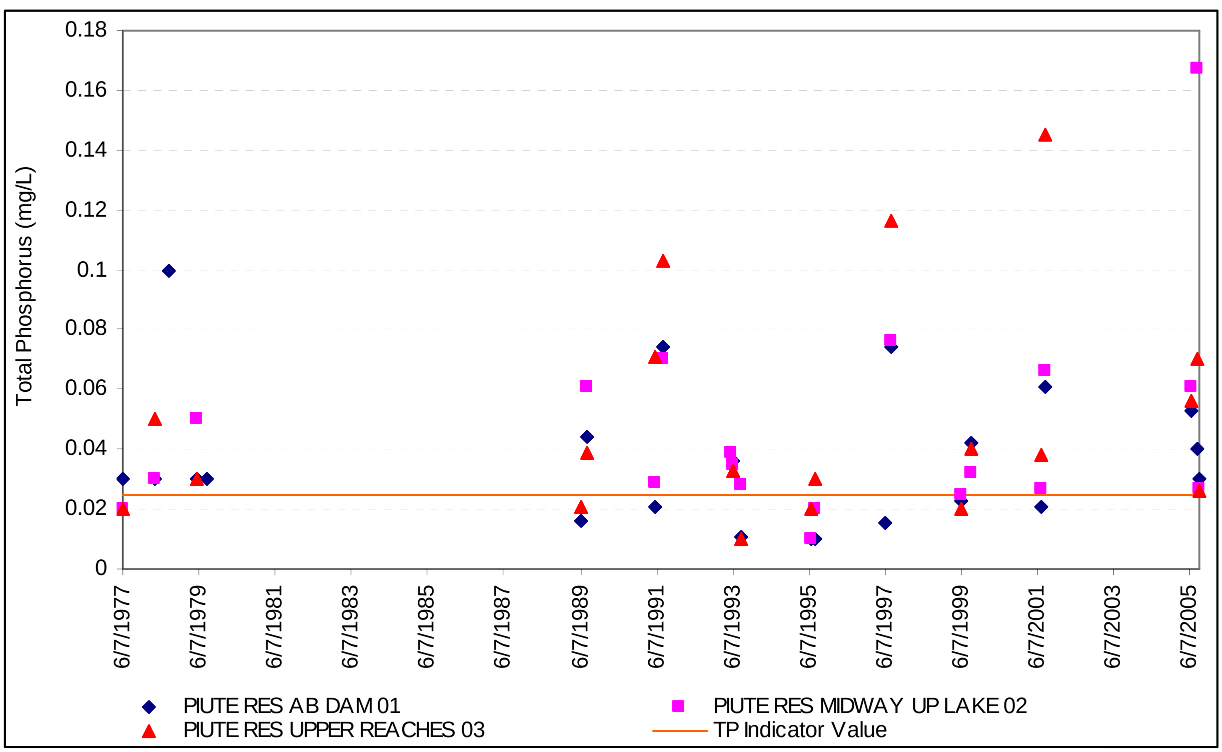

Figure 2.1. Total phosphorus trend data for Piute Reservoir

Table 2.5. Summary of Total Phosphorus Data in Piute Reservoir watershed.

Site Name	Start	End	Depth Code	Count	Min (mg/L)	Average (mg/L)	Max (mg/L)
PIUTE RES AB DAM 01	6/17/1999	9/6/2005	21	7	0.01	0.04	0.06
PIUTE RES AB DAM 01	6/17/1999	9/6/2005	23	7	0.01	0.04	0.06
PIUTE RES AB DAM 01	6/17/1999	9/6/2005	27	7	0.02	0.04	0.07
PIUTE RES AB DAM 01	6/17/1999	9/6/2005	29	7	0.04	0.10	0.17
PIUTE RES MIDWAY UP LAKE 02	6/17/1999	9/6/2005	21	7	0.01	0.04	0.07
PIUTE RES MIDWAY UP LAKE 02	6/17/1999	9/6/2005	29	6	0.03	0.09	0.17
PIUTE RES UPPER REACHES 03	6/17/1999	9/6/2005	21	7	0.01	0.05	0.15
PIUTE RES UPPER REACHES 03	6/17/1999	9/6/2005	29	6	0.04	0.08	0.12

2.4.6. Chlorophyll *a*

Chlorophyll *a* is a pigment found in plants for use in photosynthesis. Chlorophyll *a* contained in a reservoir can be used as a surrogate measure of phytoplankton production and as an indicator of trophic state of the water body. A literature review regarding nuisance thresholds of algae growth and chlorophyll *a* demonstrates that chlorophyll *a* concentrations between 10–15 µg/L protect waters inhabited by salmonids (Pilgrim et al. 2001).

Current mean in-reservoir chlorophyll *a* concentrations range from 6.3 µg/L (Mid-Reservoir) to 8.4 µg/L (Upper Reaches) (Table 2.6). Figure 2.2 displays all chlorophyll *a* measurements in Piute Reservoir since 1999. The figure demonstrates that chlorophyll *a* concentrations are generally less than 10 µg/L.

Table 2.6. Piute Reservoir Chlorophyll *a* Data (µg/L) Summary.

Site Name	Start	End	Count	Min (ug/L)	Average (ug/L)	Max (ug/L)
PIUTE RES AB DAM 01	6/17/1999	9/6/2005	7	0.2	6.8	16.1
PIUTE RES MIDWAY UP LAKE 02	6/17/1999	9/6/2005	7	0.5	6.3	9.9
PIUTE RES UPPER REACHES 03	6/17/1999	9/6/2005	6	0.9	8.4	22.9

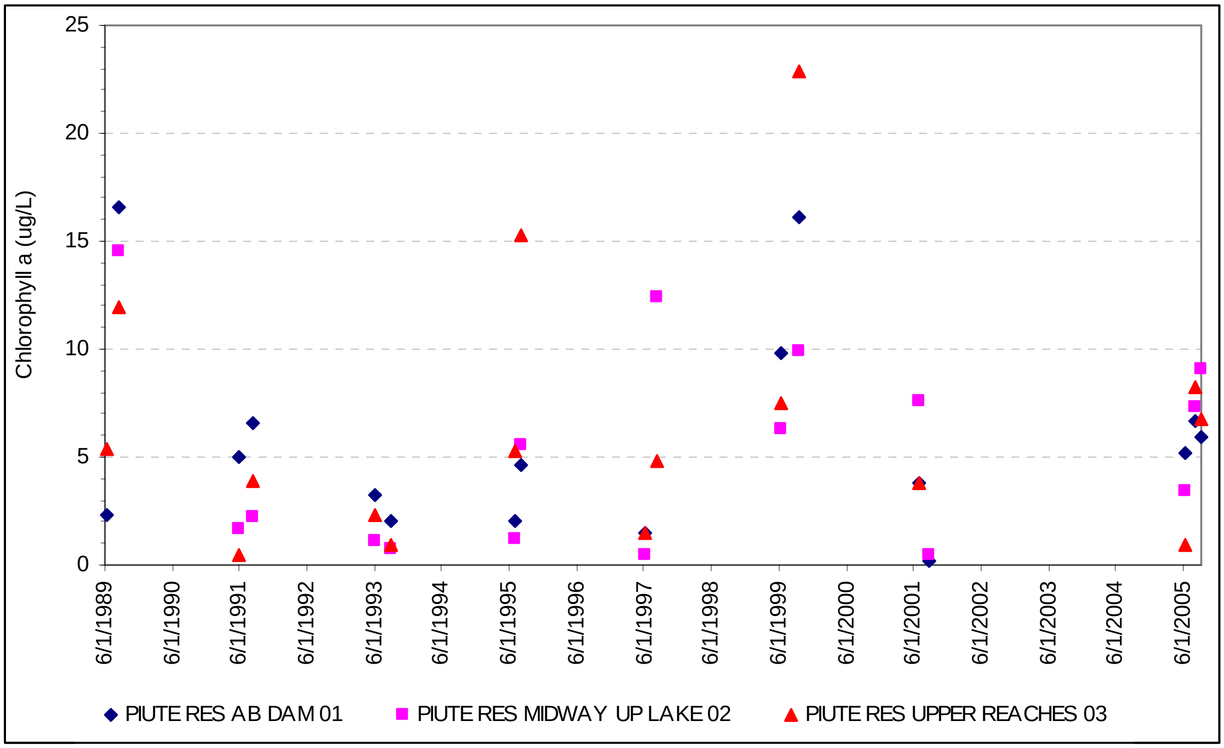

Figure 2.2. Chlorophyll-a data for Piute Reservoir

2.4.7. Secchi Depth

Secchi depth is a measurement of surface water transparency and is measured by lowering a disk with alternating black and white sections into the water. The secchi depth is the depth at which the disk is no longer visible. High Secchi depth readings indicate that the water is relatively clear and will allow sunlight to penetrate to greater depths than low readings, which indicate turbid water.

Secchi depth measurements taken in Piute Reservoir since 1999 are summarized in Table 2.7 and Figure 2.3. The table shows that values range from 0.3 meters to 5.0 meters with an average depth of approximately 2.0 meters. Secchi depth measurements and how they relate to water quality will be discussed in more detail in section 2.4.10.

The Secchi depths recorded for Piute Reservoir (Figure 3.9) show an increasing trend over time during the summer growing season, in most cases. Data collected in 2006 are slightly lower than in past years and are likely related to higher chlorophyll *a* values during this same sampling period. Low secchi depth values also reflect non-algal turbidity associated with dissolved organic carbon or carbonate alkalinity (Carlson 1992).

Table 2.7. Piute Reservoir Secchi Depth Summary.

Site Name	Start	End	n	Min (meters)	Average (meters)	Max (meters)
PIUTE RES AB DAM 01	7/5/2001	9/6/2005	6	0.4	2.3	4.0
PIUTE RES AB DAM 01	8/15/1979	9/14/1999	14	0.4	2.1	5.0
PIUTE RES MIDWAY UP LAKE 02	7/5/2001	9/6/2005	6	0.3	2.0	4.1
PIUTE RES MIDWAY UP LAKE 02	8/10/1989	9/14/1999	11	0.8	1.6	3.1
PIUTE RES UPPER REACHES 03	7/5/2001	9/6/2005	6	0.9	1.7	2.6
PIUTE RES UPPER REACHES 03	8/10/1989	9/14/1999	11	0.2	1.1	2.8

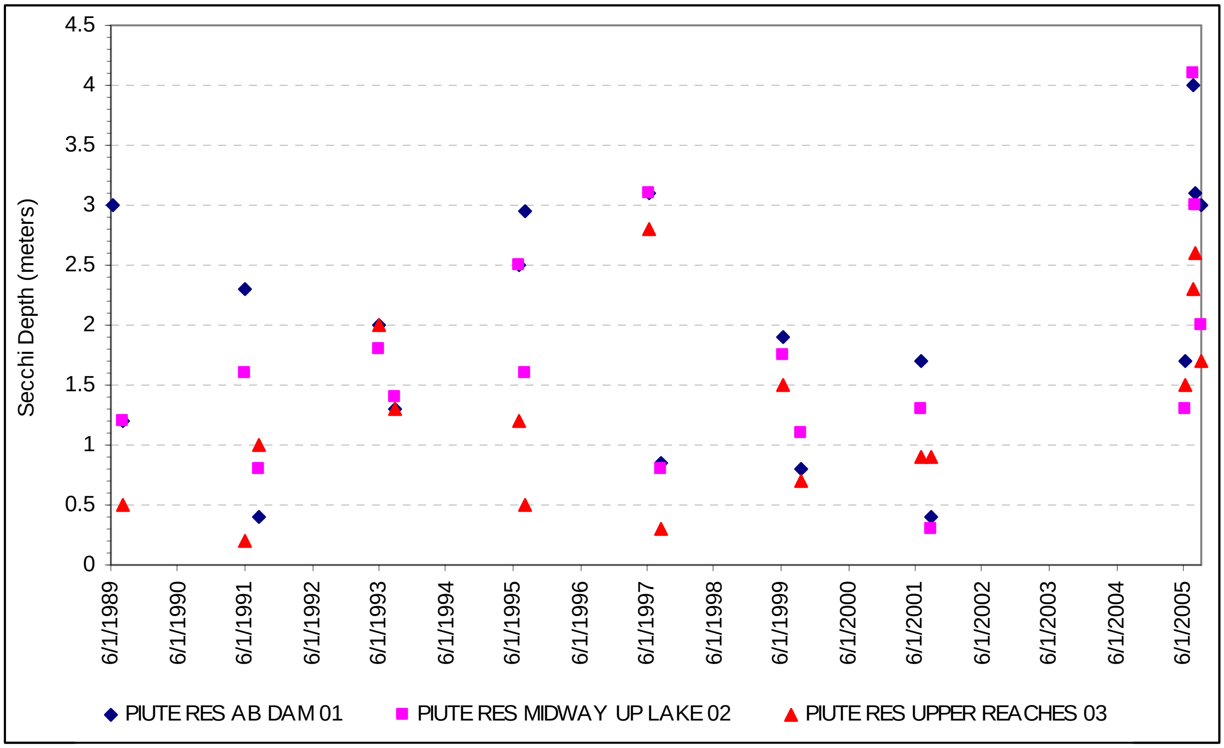

Figure 2.3. Secchi depth measurement for Piute Reservoir since 1999.

2.4.8. Water Column Data Assessment

This section discusses depth profile characteristics for dissolved oxygen, temperature, and pH as well as an assessment of viable fish habitat. Depth integrated profile data for temperature, pH, and dissolved oxygen collected by UDWQ were evaluated using the percentage-based criteria established by the State of Utah specifically for dissolved oxygen. Depth integrated data are available for the dam site, mid- reservoir site, and the upper reservoir site for the months shown in Table 2.8. Additional profiles were also collected at each site in 1991, 1993, and 1997 and were referenced to gain a historic perspective on profile trends.

Table 2.8. Depth Integrated Profile Sampling Frequency.

	2001	2003	2005	2007
May				
June			x	
July	x		x	x
August	x			
September			x	

A summary of depth profile plots for dissolved oxygen, temperature and pH is displayed for all Piute Reservoir sampling stations in Figure 2.4, Figure 2.5, and Figure 2.6. The figures demonstrate the proportion of the sampled profiles with less than 4 mg/L dissolved oxygen, temperature greater than 20 degrees C, as well as the percentage of the water column where State water quality standards are met (Viable Habitat). As demonstrated in the figures (and Table 2.2), dissolved oxygen below 4 mg/L occurs in much less than 50 percent of the water column. Dissolved oxygen conditions are also typically better at the upper reservoir site (Figure 2.6) than both the mid lake and dam sites, which is likely a result of shallower depths and complete mixing from the wind and tributary inflows. The figures show that surface water temperature exceeds the standard for the 3A beneficial use in most profile samples. As discussed in Section 2.4.4, these exceedances were determined to be the result of natural solar radiation.

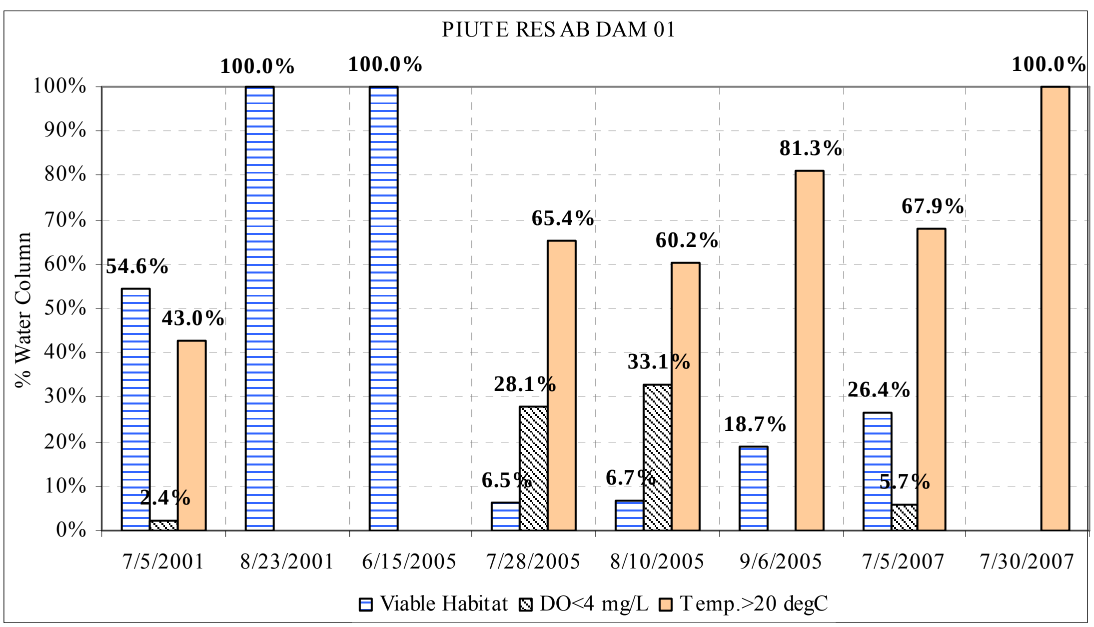

Figure 2.4. Depth Integrated Profile Summary for Piute Reservoir Above the Dam.

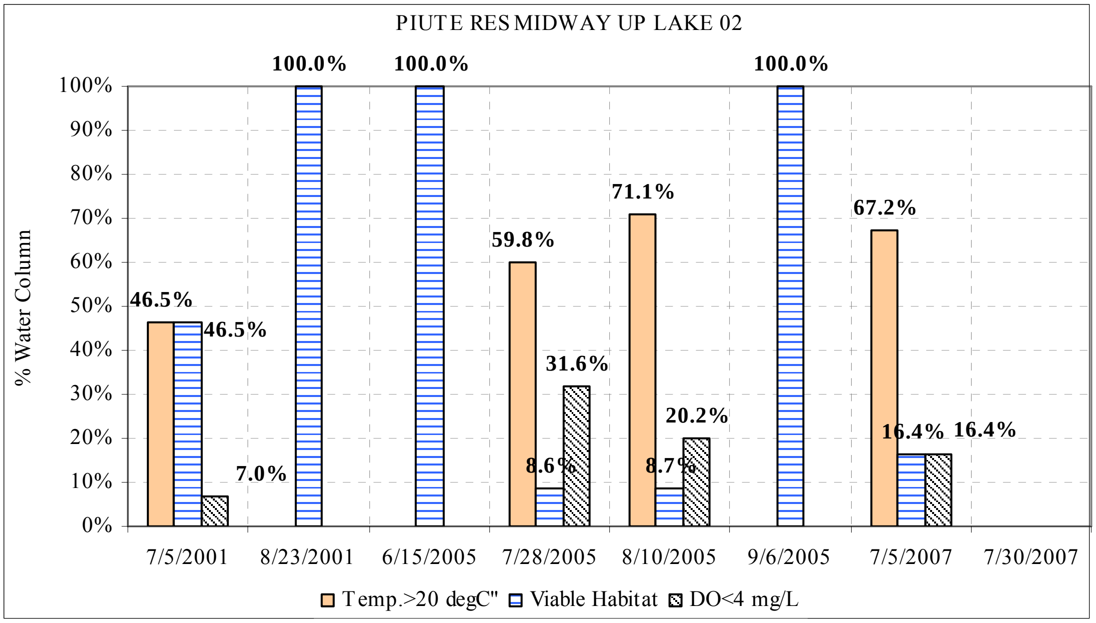

Figure 2.5. Depth Integrated Profile Summary for Piute Reservoir at Mid-Lake.

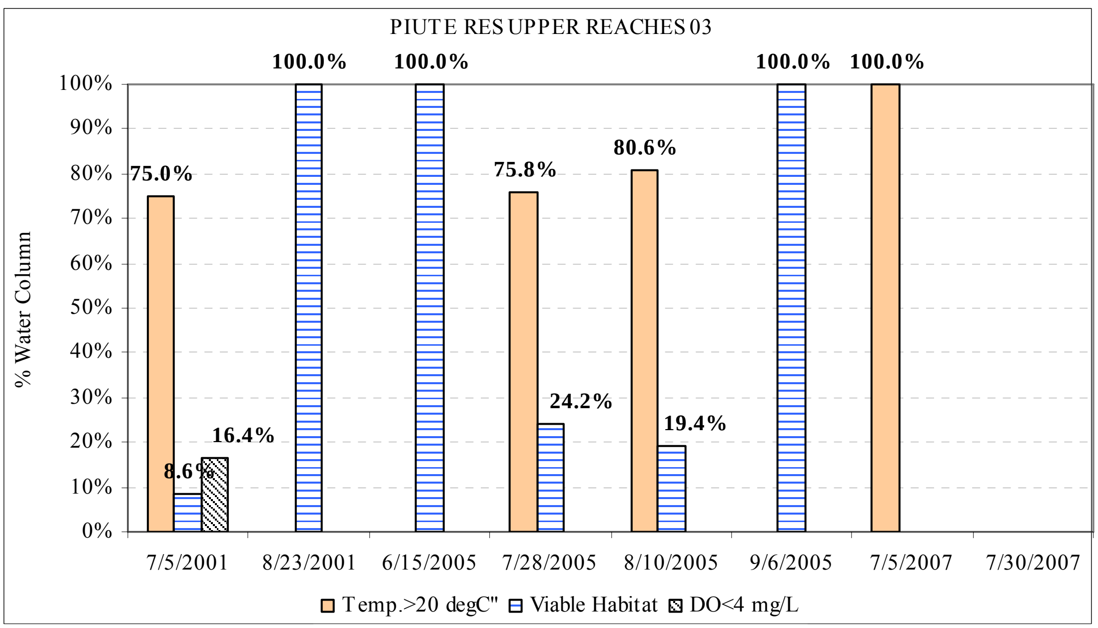

Figure 2.6. Depth Integrated Profile Summary for Piute Reservoir in the Upper Reaches.

Figure 2.7, Figure 2.8, and Figure 2.9 present typical DO, pH, and temperature profiles during critical summer conditions at the three reservoir sampling locations. The plots show surface of the reservoir on top of the plot while depth increases down the vertical axis.

Figure 2.8 shows stratification occurring in the profile at the Dam Site and Mid-Reservoir Site, respectively. A thermocline, the location in the profile where temperature changes by more than 1 ^{o}C within a 1 meter depth, occurs at 10 meters at the dam site and at 7 meters at the mid-reservoir site. The thermocline in Piute Reservoir prevents mixing and allows the depletion of dissolved oxygen in the lower depths of the reservoir as decomposition consumes oxygen from the water column. Stratification in Piute Reservoir typically occurs in mid June when surface water temperature increases and creates a sufficient thermal gradient throughout the profile to prevent mixing. Stratification usually occurs between 7 to 10 meters deep and persists until late July to mid-August. Mixing or fall turnover in the reservoir is primarily a function of reservoir level and the occurrence of intense late summer thunderstorms. Once the reservoir is drawn down to approximately 7 to 8 meters, the temperature throughout the water column is similar enough to allow mixing to occur. Additionally, intense thunderstorms accompanied by high winds provide sufficient wind energy to assist in mixing the water column.

Figure 2.9 shows typical profile conditions for the upper reservoir site. This site is usually shallow enough to prevent summer stratification and is usually well mixed throughout the profile. The well mixed profile is also a function of the site's proximity to the reservoir inflow; water movement from the inflow allows for physical mixing. Additionally, none of the current or historical profiles at this location indicated DO depletion in the lower depths of the profile.

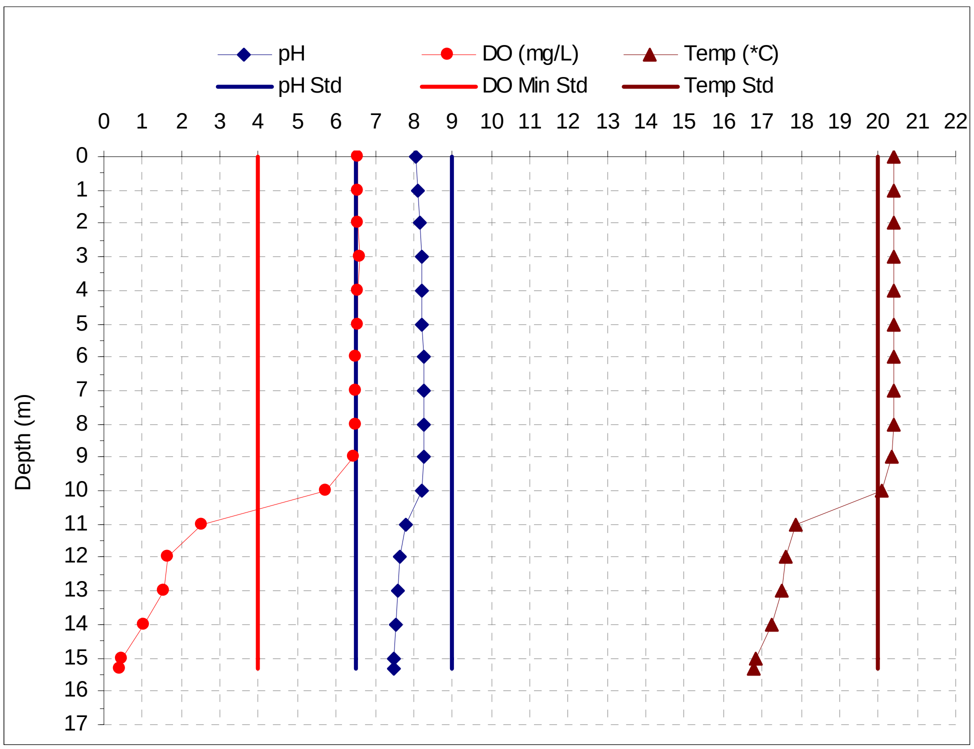

Figure 2.7. Typical Depth Integrated Profile Sample at the Dam Site During Critical Conditions (7/28/2005).

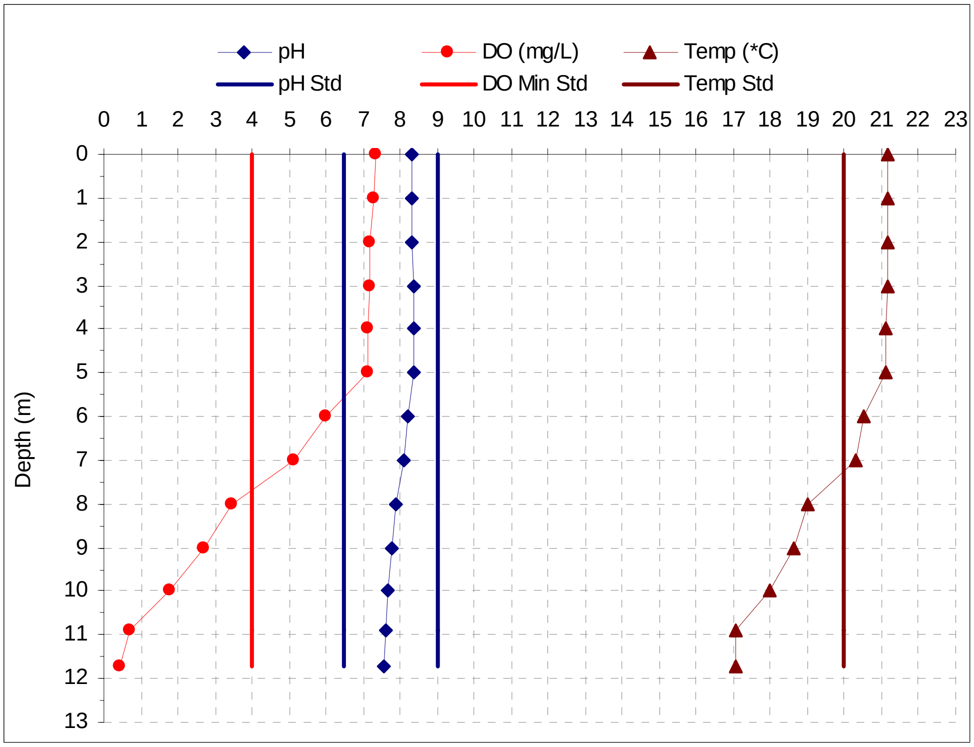

Figure 2.8. Typical Depth Integrated Profile Sample at the Mid-Reservoir Site During Critical Conditions (7/28/2005).

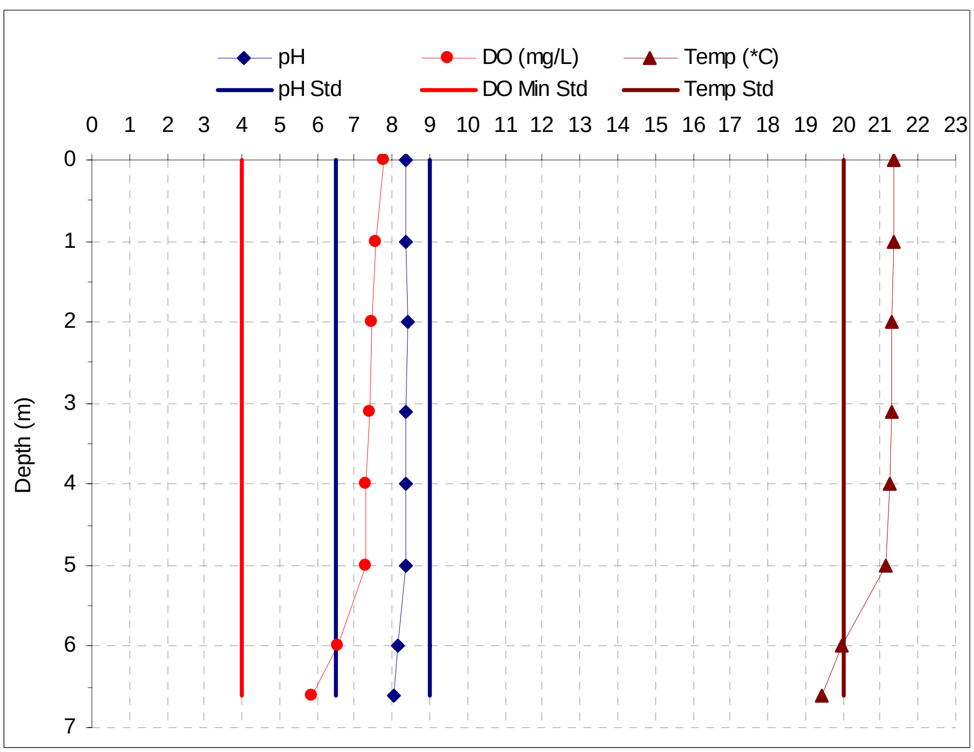

Figure 2.9. Typical Depth Integrated Profile Sample at the Upper Reservoir Site During Critical Conditions (7/28/2005).

2.4.9. Diurnal DO Data

Hourly depth integrated diurnal samples for temperature, DO, DO saturation, and pH are available for a four day period from July 30, 2007 to August 3, 2007 at the Piute Reservoir dam site. Samples were collected at 1.5 meters, 3.5 meters, 5.5 meters, and 7.5 meters, although samples for the 1.5 meter location were lost due to equipment failure (Table 2.8). Total depth at the site was 8.5 meters. Site observations during the sampling event include a visual observation of a large algal bloom as well as frequent intense thunderstorms. Additionally, this sample was collected approximately 2 weeks after de-stratification.

Table 2.8 demonstrates that values for the four parameters fluctuate with depth and through time. Temperature throughout the profile for the entire sample period is above the 3A standard, but generally decreases through time. Temperature also becomes more uniform throughout the profile on 8/2/2007 due to influence of a large storm and wind mixing.

Dissolved oxygen concentration and saturation follow a similar trend as temperature. Assuming that dissolved oxygen concentrations for the 1.5 meter sample (missing data) followed the same trends as the 3.5 meter and 5.5 meter samples, greater than 50 percent of the water column had concentrations greater the 4 mg/L. Both the 1.5 meter and 3.5 meter sample were determined to be in the photic zone and diurnal oxygen fluctuations should be similar in both samples.

A noticeable exception occurred on 8/2/2007 where dissolved oxygen concentrations decreased throughout the profile and less than 50 percent of the profile was above 4 mg/L. This observation corresponds very well to the timing of a large storm and increased mixing of the water column and is not a result of oxygen depletion from increased algal productivity and nighttime respiration. Dissolved oxygen saturations are also low during this period and further indicate that productivity was low. Therefore, the low dissolved oxygen concentrations in the upper portion of the water column are most likely the result of mixing of surface waters with bottom water containing low oxygen concentrations, which decreased oxygen concentrations throughout the water column. Dissolved oxygen saturation is greater than 110 percent at various times throughout the sampling period, which supports the visual observation of heavy algal blooms at the beginning of the sampling period.

pH is relatively stable throughout the sampling period at all profile depths; however, values are noticeably lower in the 7.5 meter sample. This difference is most likely due to the changes in water chemistry as a result of low dissolved oxygen. The stability of values in the 3.5 meter sample suggests that productivity does not influence pH during this sampling period.

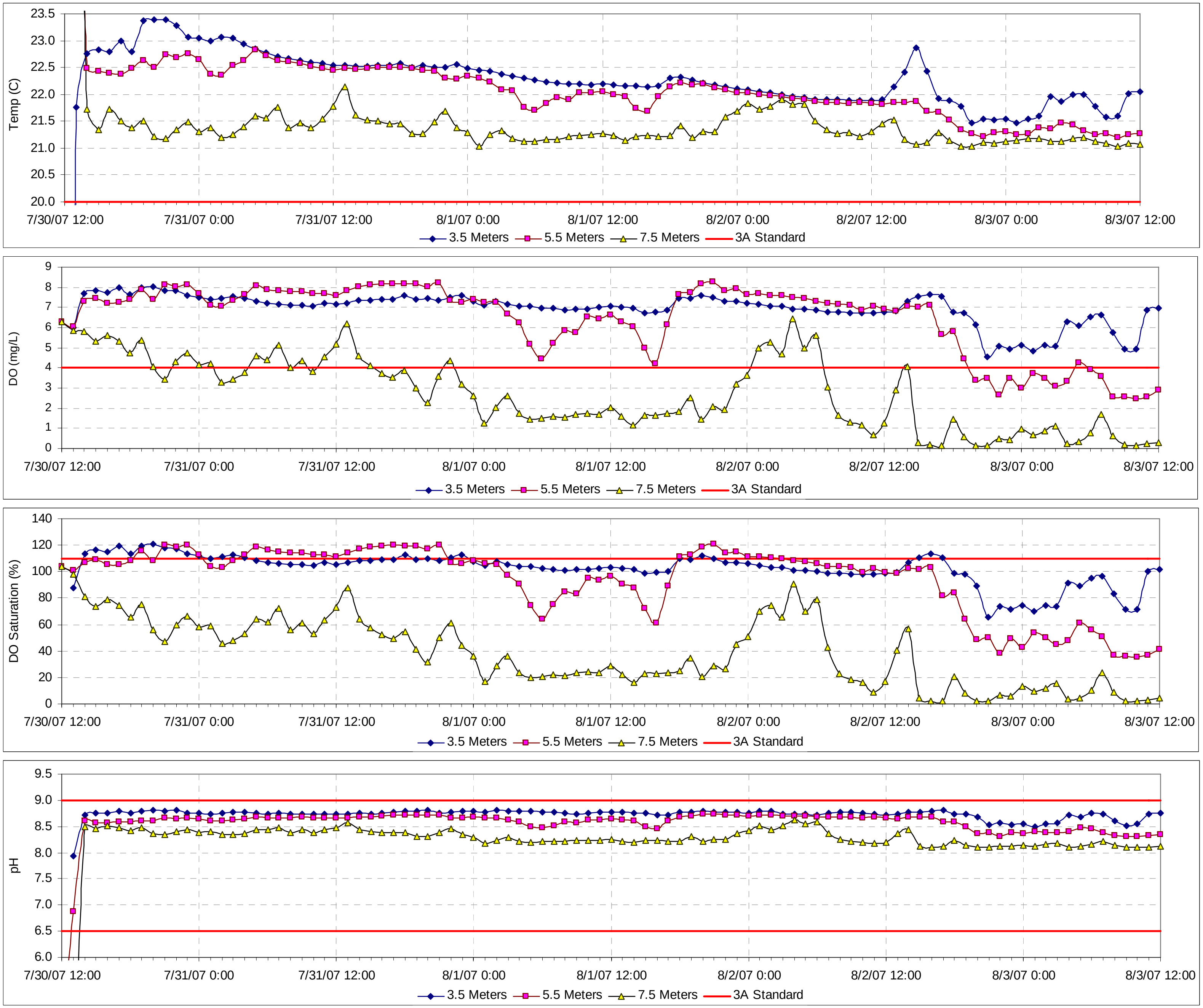

Figure 2.10. Diurnal Profile Data for the Piute Reservoir Dam Site.

2.4.10. Trophic State Index

Trophic state index (TSI) is a measurement of the biological productivity or growth potential of a body of water. The basis for trophic state classification is an estimation of algal biomass present in the water body. The calculation of a TSI generally includes the relationship between chlorophyll, where chlorophyll *a* is used as a measure of algal biomass. Secchi depth and total phosphorus TSI values are used as a surrogate to predict chlorophyll production. (Carlson and Simpson 1996):

chlorophyll *a*: $TSI_{CHL} = 9.81 \ln(CHL) + 30.6$

Secchi depth: $TSI_{SD} = 60 - 14.41 \ln(SD)$

total phosphorus: $TSI_{TP} = 14.42 \ln(TP) + 4.15$

Oligotrophic water bodies have TSI values less than 30 and are generally transparent, have low algal population densities, and have adequate dissolved oxygen throughout the water column (Table 2.9). Mesotrophic water bodies with TSI values between 40-50 are moderately clear, and have an increasing chance of hypolimnetic anoxia in summer. Eutrophic water bodies with TSI values of 50–70) commonly experience more turbidity, higher algal population densities than oligotrophic water bodies, low hypolimnetic dissolved oxygen levels in mid- to late-summer, and often experience excessive macrophyte growth. Eutrophic water bodies are more supportive of warm water fisheries than cold water fisheries. Hypereutrophic water bodies have TSI values greater than 70, have heavy algal blooms, dense macrophyte growth, extensive dissolved oxygen problems throughout the water column, and often have fish kills.

Table 2.9. Trophic State Index Categories.

TSI	Trophic Status and Water Quality Indicators
< 30	Oligotrophic; clear water; high DO throughout the year in the entire hypolimnion
30–40	Oligotrophic; clear water; possible periods of limited hypolimnetic anoxia (DO =0)
40–50	Mesotrophic; moderately clear water; increasing chance of hypolimnetic anoxia in summer; cold-water fisheries “threatened”; supportive of warm water fisheries
50–60	Mildly eutrophic; decreased transparency; anoxic hypolimnion; macrophyte problems; generally supportive of warm-water fisheries only
60–70	Eutrophic: Blue-green algae dominance; scums possible; extensive macrophyte problems
70–80	Hypereutrophic: Heavy algal blooms possible throughout summer; dense macrophyte beds;
> 80	Hypereutrophic: Algal scums; summer fish kills; few macrophytes due to algal shading; rough fish dominance
Source: From Carlson and Simpson, 1996.	

Mean TSI values for Piute Reservoir are displayed in Table 2.10. TSI values for chlorophyll *a* range from 42 at the mid-reservoir site to 45 at the dam site. Based on mean chlorophyll *a* measurements, Piute Reservoir is classified as mesotrophic; however, total phosphorus and secchi TSI values indicate the reservoir is mildly eutrophic. A discussion of these differences is presented below. Figure 2.11, Figure 2.12, and Figure 2.13 display a temporal distribution of TSI values for data collected since 1990. TSI values for each component do not show a significant trend through time. Like mean TSI values, the figures also show that chlorophyll *a* TSI values are lower than their secchi depth and total phosphorus counterparts in almost all samples.

Table 2.10. Mean TSI Values in Piute Reservoir.

Site Name	Chlorophyll *a* TSI	Secchi Depth TSI	Total Phosphorus TSI
Dam Site	45	52	54
Mid-Reservoir	42	54	57
Upper Reservoir	44	60	57

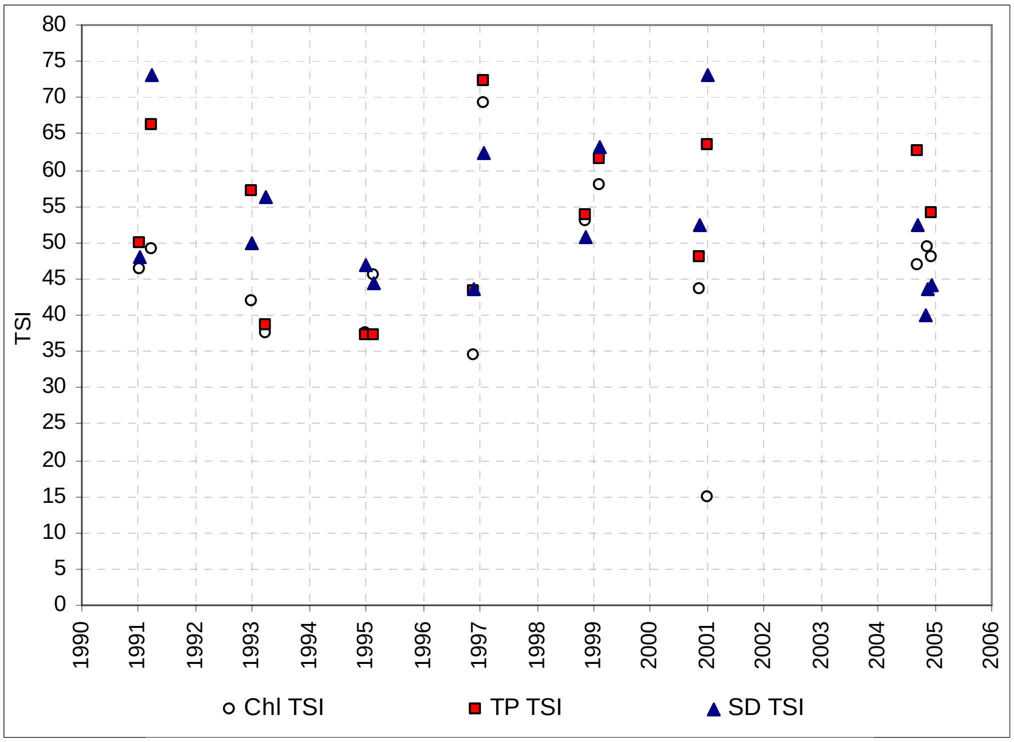

Figure 2.11. Trophic State Index Trend Data for the Piute Reservoir Dam Site.

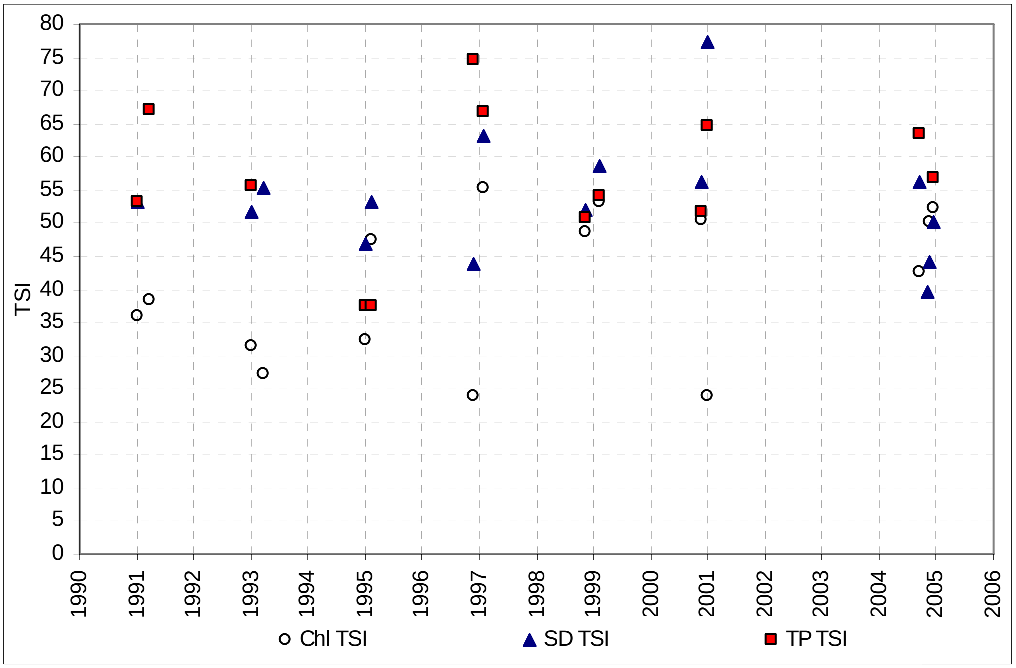

Figure 2.12. Trophic State Index Trend Data for the Piute Reservoir Mid-Reservoir Site

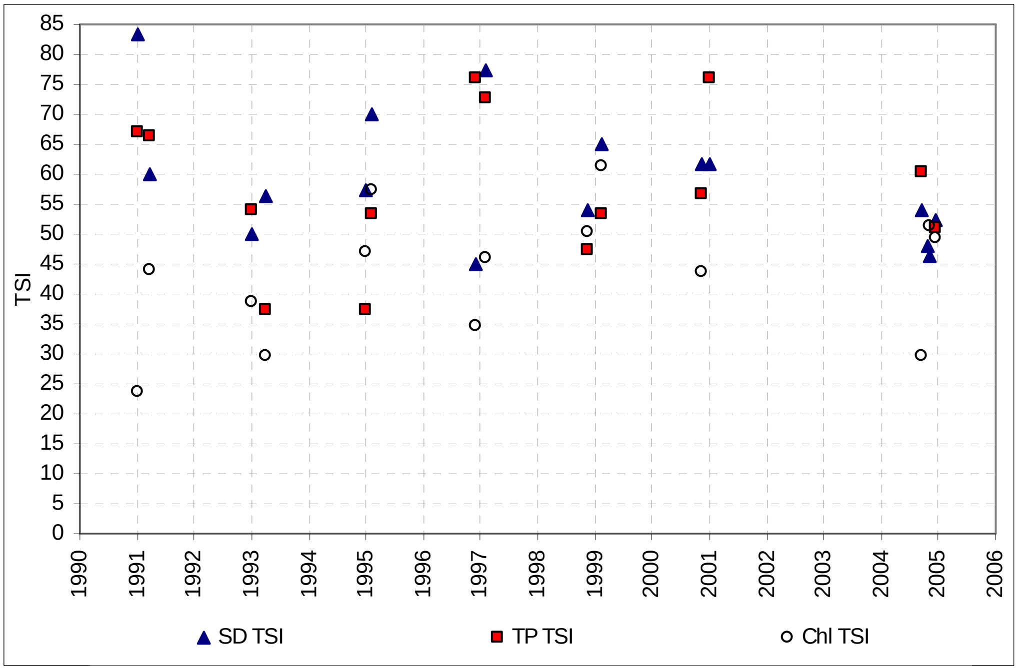

Figure 2.13. Trophic State Index Trend Data for the Piute Reservoir Upper Reservoir Site.

Determining the relationship between TSI values is helpful in identifying factors that limit algal biomass. Although every water body is unique, a number of common relationships between Secchi depth, chlorophyll *a*, and total phosphorus have been identified (Carlson and Simpson 1996). Figure 2.14, Figure 2.15, and Figure 2.16 display a multivariate comparison of each TSI component. The following describes how to interpret the information presented in the plots.

Points plotting to the left of the vertical axis indicate reduced transparency from non-algal factors including clay particles, dissolved organic matter, or reduced transparency resulting from carbonate alkalinity (Carlson 1992). Points to the right of the vertical axis indicate transparency is greater than predicted by chlorophyll TSI, which can occur when large particulate matter like blue-green algae or other organic matter dominate. Additionally, in situations where chlorophyll TSI is under predicted by phosphorus TSI (points plotting below the horizontal axis), something other than phosphorus is limiting chlorophyll abundance, whereas points above this axis indicate that chlorophyll production is limited by phosphorus concentrations. The diagonal line extending from the lower left quadrant to the upper right quadrant indicate the level of agreement between secchi depth TSI and total phosphorus TSI. Points plotting to the left of the origin indicate situations where TP and sechhi depth are well correlated, but chlorophyll is not.

The routine occurrence of chlorophyll *a* TSI values less than secchi depth and total phosphorus TSI values are as depicted in Figure 2.14, Figure 2.15, and Figure 2.16. These figures indicate that chlorophyll production is limited by something other than phosphorus availability, turbidity is reduced due to suspended particulates rather than chlorophyll *a*, and that chlorophyll is under-predicted by both secchi depth and phosphorus.

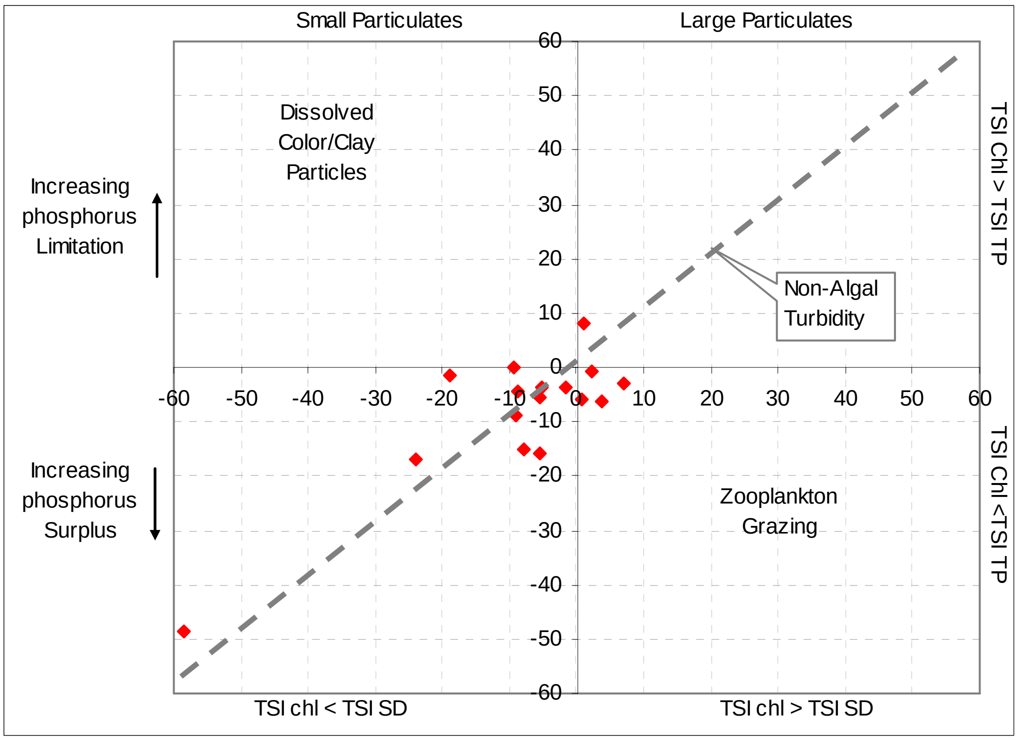

Figure 2.14. TSI Relationships for the Piute Reservoir Dam Site.

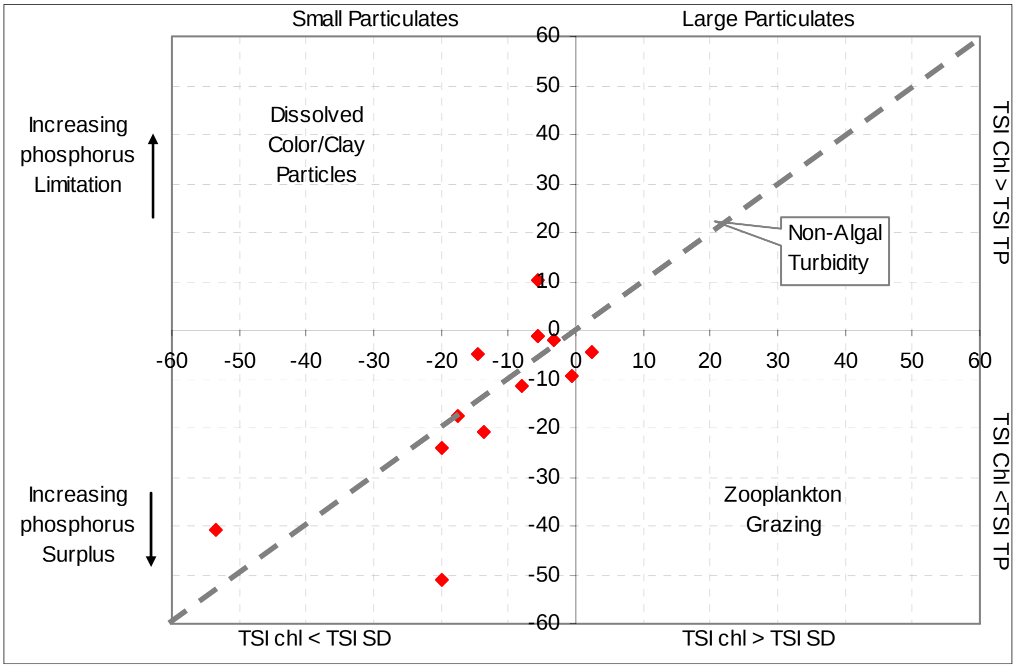

Figure 2.15. TSI Relationships for the Piute Reservoir Mid-Reservoir Site.

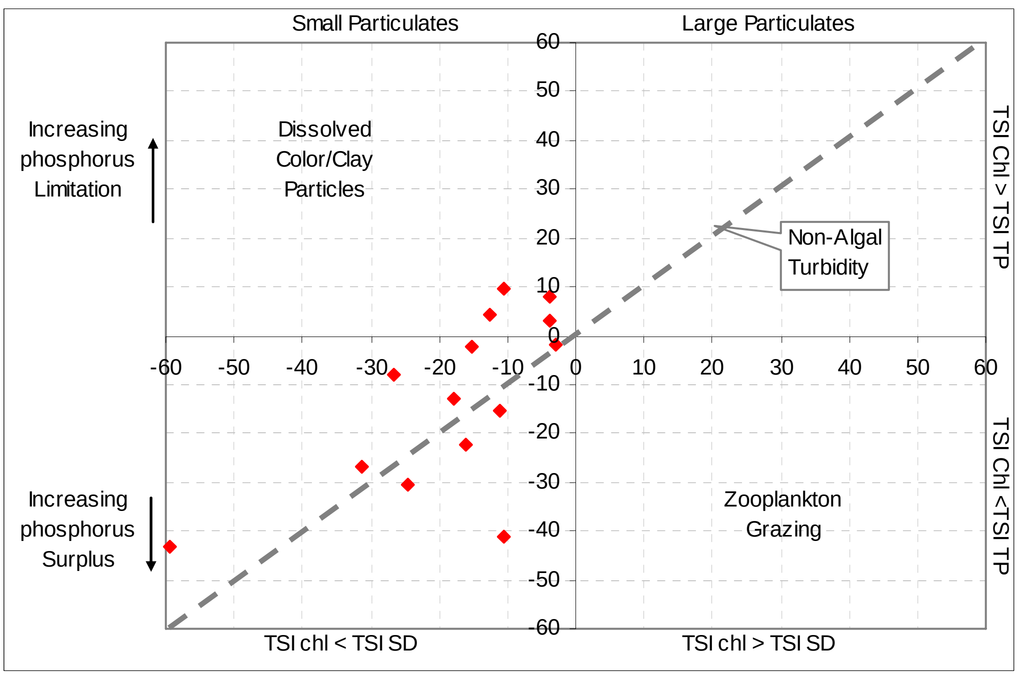

Figure 2.16. TSI Relationships for the Piute Reservoir Upper Lake Site.

2.4.11. Fishery Management

The Utah Division of Wildlife Management (DWR) manages Piute Reservoir as a put and take fishery for rainbow trout and small mouth bass. Water levels play a significant role in the viability of the reservoir's trout fishery (UDWR, 2006). On average, Piute Reservoir is nearly drained one out of every six years, which makes maintaining a long term fishery difficult. Additionally, when reservoir levels remain high for more than a few years, trout populations are inhibited by increasing competition with nongame species. DWR can easily remove nongame fish during periods with low reservoir levels, but if water levels remain high, it is not economically feasible. As a result, DWR is establishing a small mouth bass population to improve fishing conditions during periods with low water levels and elevated nongame competition. However, DWR maintains that when reservoir water levels are optimal, trout populations thrive and fishing conditions are some of the best in the state (UDWR, 2006).

No fish kills have been reported in Piute Reservoir (DEQ 2008).

2.4.12. Phytoplankton composition

The presence of blue-green algae, or cyanobacteria, has been associated with the occurrence of toxins and mortality in local animal populations. Although cyanobacteria may be of low toxicity, cyanotoxins can become concentrated in the environment or through bioaccumulation where cyanobacterial growth occurs. Cyanobacteria can dominate nitrogen-limited systems due to their ability to fix atmospheric nitrogen. As a result, cyanobacteria can increase where low nitrogen limits the growth of other algal species (Sharpley et al. 1984, 1995; Tiessen 1995).

The relative densities of algal species and diversity of the algal community both serve as surrogate measures of water quality by identifying overall species diversity, excessive algal growth or eutrophication, and the presence and relative abundance of toxic blue-green algae.

Detailed plankton data are available for the dam site at Piute Reservoir for September 14, 1999 and August 23, 2001 (Rushforth and Rushforth 2000, Rushforth and Rushforth 2002). Algal taxa present at these times were identified and grouped by taxon to show green algae (chlorophyta), blue-green algae (cyanophyta), diatoms (bacillariophyta) and others.

In the 1999 and 2001 sampling, green algae dominated at 49.3% and 53.1 % relative density, respectively, of the total algal population. Diatoms represented a smaller population at 11.3% and 46.9%, respectively of the total. Blue-green algae were not detected in 2001; however, a population was present in 1999, representing 37.0% of the total phytoplankton population.

2.4.13. Existing Watershed TMDLs

The watershed contributing to Piute Reservoir consists of two major drainages; the East Fork Sevier River and the Sevier River. Both watersheds have EPA approved TMDLs in place for total phosphorus. The TMDL endpoint for these watersheds is an in-stream total phosphorus concentration of 0.05 mg/L, which equates to a 45 percent reduction and a 55 percent reduction for the East Fork Sevier River and the Sevier River, respectively.

Current flow, total phosphorus concentrations, and load conditions for the East Fork Sevier River and The Sevier River at Kingston, UT are presented in Figure 2.17, Figure 2.18, and Figure 2.19. The figures demonstrate that Piute Reservoir receives approximately 60 percent of its inflow from the Sevier River, most of which is delivered between October and June. The East Fork Sevier River delivers the majority of summer volume to the reservoir via water release from Otter Creek Reservoir (Figure 2.17).

Total phosphorus concentrations are generally higher in the Sevier River inflow than the East Fork Sevier River except during the summer months. Lower phosphorus concentrations and flow during the summer in the Sevier River are the result of a complete upstream diversion for irrigation use. (Figure 2.18).

Figure 2.18 and Table 2.11 demonstrate that of the 17,805 kg/yr total phosphorus delivered to Piute Reservoir, approximately 65 percent (11,617 kg/year) is from the Sevier River. The East Fork Sevier River delivers the majority of the summer load for an annual total of approximately 6,188 kg/year (35 percent of the total load).

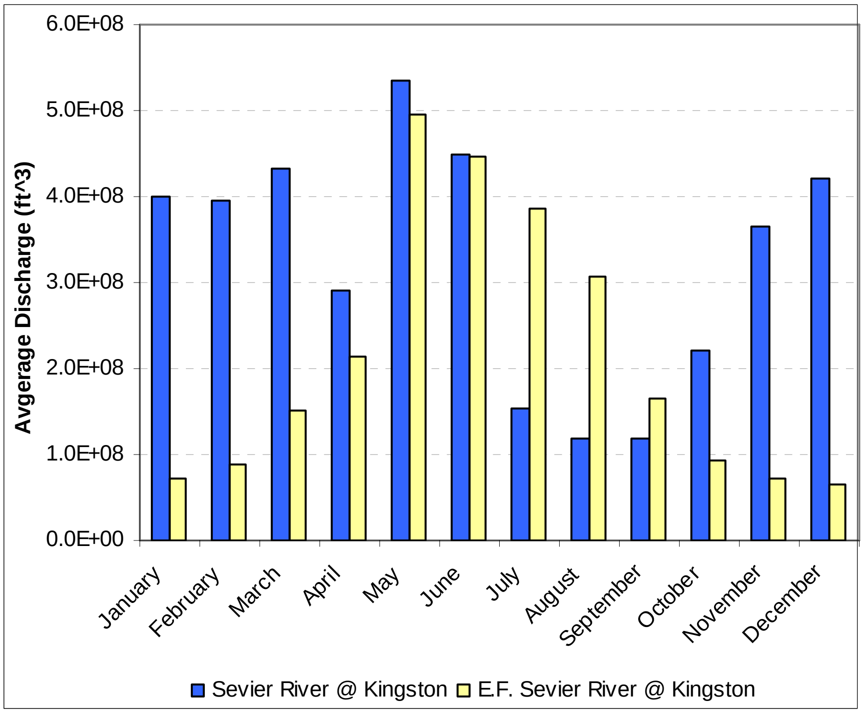

Figure 2.17. Average Total Monthly Inflow to Piute Reservoir.

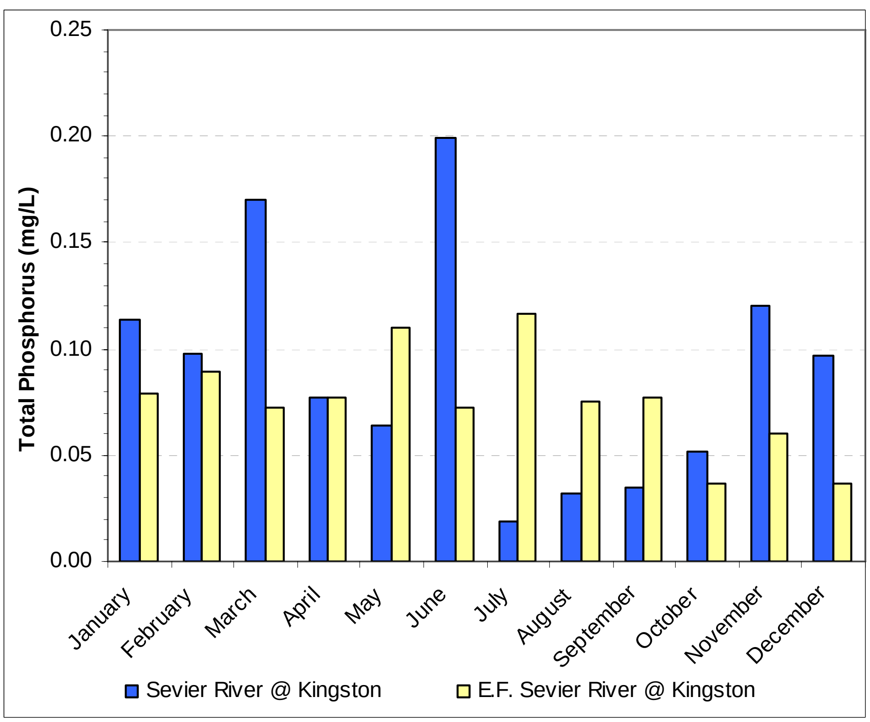

Figure 2.18. Average Monthly Inflow Total Phosphorus Concentrations

Figure 2.18 and Table 2.11 also demonstrate the effect of expected phosphorus reductions into Piute Reservoir as a result of upstream TMDLs for total phosphorus. When the upstream TMDL targets are achieved, total phosphorus load to the reservoir is expected to be reduced from 17,805 kg/year to 8,515 kg/year for a load reduction of approximately 48 percent. This load reduction is expected to significantly decrease in-reservoir total phosphorus concentrations.

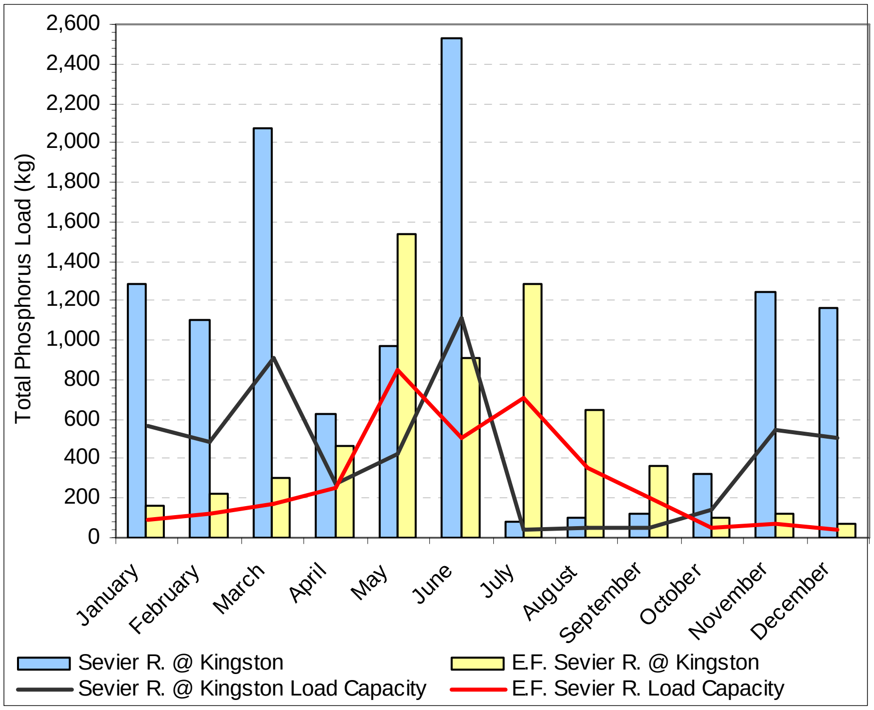

Figure 2.19. Average Total Monthly Total Phosphorus Load and Loading Capacity.

Table 2.11. Average Total Phosphorus Load and TMDL Targets.

	Current Conditions					Expected Load Reductions		
	Sevier R. @ Kingston		E.F. Sevier R. @ Kingston		Total to Piute Reservoir	Sevier R. @ Kingston	E.F. Sevier R.	Piute Reservoir
Month	**TP (kg)**	**% Total**	**TP (kg)**	**% Total**	**TP (kg)**	**TP (kg)**	**TP (kg)**	**TP (kg)**
January	1,280.1	88.7%	162.9	11.3%	1,443.1	563.3	89.6	652.9
February	1,101.0	83.2%	222.8	16.8%	1,323.8	484.5	122.5	607.0
March	2,077.3	87.1%	307.2	12.9%	2,384.5	914.0	169.0	1,083.0
April	631.6	57.5%	466.9	42.5%	1,098.6	277.9	256.8	534.7
May	966.8	38.6%	1,540.1	61.4%	2,506.9	425.4	847.1	1,272.5
June	2,531.1	73.5%	911.8	26.5%	3,442.8	1,113.7	501.5	1,615.1
July	82.9	6.1%	1,280.5	93.9%	1,363.4	36.5	704.3	740.8
August	105.6	14.0%	649.4	86.0%	755.0	46.5	357.2	403.6
September	117.2	24.5%	360.7	75.5%	477.9	51.6	198.4	250.0
October	322.3	76.9%	96.7	23.1%	419.0	141.8	53.2	195.0
November	1,242.4	91.1%	121.0	8.9%	1,363.3	546.6	66.5	613.2
December	1,158.6	94.4%	68.3	5.6%	1,226.8	509.8	37.6	547.3
Total	**11,616.9**	**65.2%**	**6,188.3**	**34.8%**	**17,805.2**	**4,976.9**	**3,403.6**	**8,515.0**

Significant BMP implementation efforts are already in progress in both watersheds and include stream bank restoration and re-vegetation, riparian exclusion, off stream stock watering, and range improvement practices. The effects of these projects are expected to be evident in the short-term, while full realization of environmental benefits will occur through long-term implementation efforts.

3.0 WATER QUALITY SUMMARY

3.1. Compliance with Water Quality Criteria

No observed exceedances of the 3A dissolved oxygen criteria have occurred in Piute Reservoir and more than 50 percent of the water column meets dissolved oxygen criteria of > 4.0 mg/L during all months at the three reservoir sites. Chlorophyll a values were also supportive of literature recommendations for support of coldwater fisheries with only 6.8 percent of the observations exceeding the recommended concentration. Additionally, no pH exceedances occurred in the dataset and detailed analysis revealed that pH does not respond to productivity, suggesting that algal productivity is not excessive in the reservoir.

3.2. Explanation of Exceedances

3.2.1. Total Phosphorus

Total phosphorus concentrations at all sampling locations in the reservoir routinely exceed the State's indicator value of 0.025 mg/L. However, elevated phosphorus concentrations do not appear to influence productivity to an extent to cause depletion of dissolved oxygen through decomposition of organic matter and respiration during the night. As discussed in the evaluation of TSI values in section 2.4.10, this is likely the result of particulate-bound phosphorus unavailable for algal growth.

3.2.2. Temperature

Results of a reservoir heat budget conducted by the Utah Division of Water Quality determined that temperature impairment to the cold water fishery in Piute Reservoir is due to natural solar radiation and significant decreases would not be obtained by implementation of best management practices (BMPs). Piute Reservoir was removed from the 303(d) list based on the results of this analysis.

3.2.3. Diurnal Profile Sampling

Some observations in the diurnal dataset were low enough to deplete DO in more than 50 percent of the water column; however, an analysis of climatalogical data during the sampling period indicated that low dissolved oxygen was the result from normal reservoir mixing rather than elevated productivity. The occurrence of DO depletion occurs simultaneously with an intense storm event. The storm event combined with shallow reservoir depths made mixing of surface and bottom water possible. Bottom water containing low dissolved oxygen concentrations mixed with surface water and effectively lowered surface oxygen concentrations. This mixing is considered a natural event for reservoirs of this nature. The influence of decreased dissolved oxygen with mixing is not expected to persist and surface water concentrations will gradually increase back to normal.

3.3. Trophic State

Analysis of the trophic state of Piute Reservoir indicates the reservoir is generally mesotrophic. Occurrences of reduced turbidity measured in terms of secchi depth generally indicate a non-algal source of light interference most typically associated with fine particulates. Additionally, phosphorus is generally unavailable for algal production and supports the conclusion that total phosphorus concentrations above the 0.025 mg/L indicator value are not adversely affecting the health of the fishery.

3.4. Watershed TMDLs

EPA approved TMDLs are in place and currently in the implementation phase for both the Sevier River and East Fork Sevier River watersheds. These watersheds are the primary inflows to the reservoir and watershed wide BMP implementation will further improve water quality conditions in Piute Reservoir. The combined result of these TMDLs is expected to translate into an approximate 48 percent reduction of total phosphorus into the reservoir. With current water quality conditions fully supporting the cold water fishery beneficial use in Piute Reservoir, additional phosphorus removal provides assurance of long term beneficial use support.

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