Bear Creek Watershed Report 2001:

Water Quality Monitoring, Summary Data and Trends

Bear Creek Watershed Association

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I. INTRODUCTION

The Bear Creek Watershed Association (Association) is the designated water quality management agency for the Bear Creek Watershed as recognized by the Denver Regional Council of Governments in *the Metro Vision 2020 Clean Water Plan* (DRCOG 1998). Water quality data was originally collected as part of an intense one-year *Bear Creek Reservoir Clean Lake Study* (DRCOG 1989). A generally continuous collection of surface quality data has been done in the watershed and reservoir beginning in 1990. Data collection has included specific chemical, physical and biological parameters.

The Bear Creek Control Regulation (Regulation #74) defines the water quality goal, wasteload allocation for total phosphorus, monitoring program and other control strategies for the Bear Creek Watershed. The Association is responsible for implementing the control regulation. The Association also produces a summary data report for the Water Quality Control Commission and Water Quality Control Division. The report characterizes water quality monitoring activities, data tabulation, and general trends in the Bear Creek Watershed including water quality and wastewater management efforts.

The long-term management strategies of the association have improved water quality at the reservoir and within the watershed. The trophic status of the reservoir has shifted from hypertrophic-eutrophic toward the eutrophic-mesotrophic boundary. All major wastewater treatment plants are in compliance with the control regulation and meet specific wasteload allocations. Several minor plants have shown compliance problems and/or lack of reporting to the Association. Overall, the point source nutrient loading to the reservoir is well controlled. Nonpoint source reductions of total phosphorus will be a major focus in the near future. Activities of the association are limited due to funding and resource constraints.

Association management program

The Association includes the City of Lakewood, Town of Morrison, Clear Creek County, Jefferson County, Park County, Evergreen Metropolitan District, West Jefferson County Metropolitan District, Genesee Water and Sanitation District, Kittredge Sanitation and Water District, Willowbrook Water and Sanitation District, Forest Hills Metropolitan District, Jefferson County Schools, Conifer Center Sanitation Association, West/Brandt Foundation (also called Singing River Ranch), Brook Forest Inn, Bear Creek Development Corporation (Tiny Town), Bear Creek Cabins and Geneva Glen.

The Association provides the framework and opportunity for joint participation in planning, coordinating and review activities for the purpose of implementing a continuing area wide water quality and wastewater management program for the Bear Creek Watershed. Membership entities are general-purpose governments, special districts and all other National Pollutant Discharge Elimination System (NPDES) dischargers within the Bear Creek Watershed as permitted by the Water Quality Control Division. The association's memorandum of understanding and by-laws describe the

roles, responsibilities and meeting requirements of the management agency, operating agencies and general-purpose governments as related to water quality management activities in the Bear Creek Watershed.

The management agency implements water quality and management strategies, decides on the need for and specific characteristics of wastewater treatment processes and details implementation within specified parameters (Table 1). A watershed association approach provides an opportunity to coordinate water quality activities at a local level. The association provides three primary benefits:

1. Ensures an effective watershed level water quality management program consistent with the *Bear Creek Reservoir Control Regulation* and the *Metro Vision 2020 Clean Water Plan*;

2. Ensures cost effective local wastewater management systems within the parameters of the *Metro Vision 2020 Clean Water Plan* and wastewater discharge permits; and

3. Identifies activities that meet water quality compliance.

Table 1 Water Quality Management Activities

Management Activity	Status
Wastewater Management	
Compliance by wastewater treatment facilities and control regulation	Major facilities met permit limits; small facility reporting problem.
Wastewater utility planning	Development and review of wastewater utility plans & management strategies; coordination; information exchange
Aspen Park Wastewater Service Strategy	Developed special strategy for wastewater service and system of treatment works for Aspen Park/Conifer area
Reservoir and Park Management	
Hypolimnetic aeration in reservoir; system operating during growing season	City of Lakewood manages system; provides an annual report to Association; Planned for new aeration system
Park facilities support recreational uses	Management program
Water Quality Monitoring	
Long-term trend monitoring program for reservoir inputs, reservoir and output	Monitoring program with periodic review by Association and WQCD; annual data report; model support; trend studies
Turkey Creek groundwater study	Jefferson County study complete; implementation of strategies
CDOT construction-monitoring program	Ongoing effort by CDOT; reports to Association
Data Management	
Maintain water quality data in STORET	Access data-set ready for upload into STORET
Watershed Management	
Construction project review and recommendations	Reviewing construction actions and providing appropriate comments; develop and review site-specific BMPs
Membership involvement and review; Management program cost effectiveness	Monitoring program review; on-going efforts in evaluating membership involvement and public processes
Re-affirmed mission & goal	Evaluation; workshop for public input into mission and goals

Wastewater treatment facilities

Operating agencies in the watershed include the Town of Morrison, Evergreen Metropolitan District, West Jefferson County Metropolitan District, Genesee Water and Sanitation District, Kittredge Sanitation and Water District, Forest Hills Metropolitan District, Jefferson County Schools, Conifer Center Sanitation Association, West/Brandt Foundation, Brook Forest Inn, Bear Creek Development Corporation, Bear Creek Cabins and Geneva Glen.

The total phosphorus wasteload allocation for all point sources in the Bear Creek Watershed is 5,255 pounds per year. The reporting point source total annual phosphorus discharges are shown Table 2. The Association believes the intent of the control regulation is clear in requiring all treatment facilities to be in compliance and report this information to the Association for incorporation into the annual report. Major reporting treatment facilities are well within their wasteload allocations. The lack of reporting to the Association is problematic and hinders the effective development of wastewater management strategies.

Beginning in 2001, the Bear Creek Watershed Association reviewed wastewater management strategies for the Aspen Park/ Conifer Village Center. Based on available options and preferred strategies, the Association adopted on March 13, 2002 and modified by the Association on May 8, 2002 a preferred wastewater service strategy for existing and new developments within the Aspen Park/ Conifer Village Center. This wastewater management strategy defines both near-term implementation actions and a long-term strategy. Details for wastewater treatment systems will be incorporated into wastewater utility plans subject to full approval processes at the local and regional levels. The strategy supports three wastewater treatment facilities in the vicinity of the Conifer/ Aspen Park Village Center: Jefferson County High School (existing), Conifer Sanitation Association North Turkey Creek Plant (existing), and the South Turkey Creek Regional Plant (proposed).

Status of total maximum annual load (TMAL)

The Bear Creek Reservoir Control Regulation (Regulation #74, Appendix A) incorporates the total maximum annual load that controls wasteload allocations for point sources and the allowable nonpoint source load. The total maximum annual load will result in the Bear Creek Reservoir meeting all designed uses and classifications. The total maximum annual load describes prohibitions, standards, concentrations, and effluent limitations on the extent of specifically identified pollutants that may discharge into the watershed. The elements of the Bear Creek total maximum annual load as approved by Region VIII Environmental Protection Agency and the Water Quality Control Commission are shown in Table 3.

Table 2 Treatment Facility Annual Phosphorus Poundage

Treatment Plant	TMAL Phosphorus Pounds/ year	2001 Phosphorus Pounds/ year
Evergreen Metropolitan District	1,500	**627**
West Jefferson County Metro District	1,500	**904**
Genesee Water and Sanitation District	1,015	**372**
Town of Morrison	600	**115**
Kittredge Sanitation and Water District	240	**77**
Forest Hills Metropolitan District	80	**50**[1]
Jefferson County Schools - Conifer High School	125	**3**
Conifer Center Sanitation Association	40	**4**
West/Brandt Foundation - Singing River Ranch	30	**NR**[2]
Mary Ann Gallagher - Brook Forest Inn	5	**NR**[2]
Bear Creek Development Corp. - Tiny Town	5	**NR**[2]
Jefferson County Schools – Mt. Evans Outdoor School	5	**2**
Bear Creek Cabins (Bruce & Jayne Hungate)	5	**3**[3]
Geneva Glen	5	**NR**[4]
Reserve Pool	100	**100**
Total Phosphorus Wasteload (Pounds/Year)	**5,255**	**2,157**

1 Forest Hills Metro District has trade agreement with West Jefferson County Metro District and is in compliance with permit.

2 NR - No Report Provided to Association. The Association recommends a non-reporting facility be issued a notice of noncompliance with the Bear Creek Reservoir Control Regulation.

3 The Bear Creek Cabins exceeded total phosphorus monthly allocations 5 times in two years and may have exceeded the annual total phosphorus allocation. The wastewater flow projections reported in the Discharge Monitoring Reports are suspect as low and don't reflect occupancy. The Association recommends the facility be issued a notice of noncompliance.

4 The Geneva Glen treatment plant is not discharging, but no report provided to the Association.

Table 3 Bear Creek Watershed TMAL Elements

Allocation	Endpoints	Target
Point Source Wasteload Allocation	Total phosphorus effluent poundage limit	The total wasteload allocation for all point sources of phosphorus in the Bear Creek Watershed is 5,255 pounds per year. Each individual discharger is limited to an annual wasteload of total phosphorus (pounds per year), except under trading provisions. Reserve pool maintained for future dischargers.
	Total phosphorus effluent concentration limit	Point source discharges can't exceed a total phosphorus effluent concentration of 1.0 mg/l as a 30-day average, except under trading provisions.
Margin of Safety (MOS)	Implicit MOS	A margin of safety is built into the wasteload and nonpoint source allocations as an implicit MOS.
Nonpoint Source Load Allocation	Reservoir narrative standard	Jefferson County, Clear Creek County, Park County, municipalities, and districts in the Bear Creek Watershed will implement best management practices for control of erosion and sediments.
	Monitoring trophic status indicators	At a minimum, local entities in the watershed will ensure that water quality monitoring is conducted on Turkey Creek, Bear Creek, and in Bear Creek Reservoir on a monthly basis to measure the phosphorus loading reaching the reservoir and other factors which affect the water quality, as well as the attainment of beneficial uses for the reservoir, including meeting the reservoir narrative standard. Data results must be reported to the Water Quality Control Commission and Water Quality Control Division.

Colorado Department of Transportation independent monitoring program

The Colorado Department of Transportation (CDOT) conducts a special surface water quality-monitoring program along the U.S. 285 corridor through the Turkey Creek drainage. Phased construction activities have resulted in ongoing highway construction. CDOT does independent water quality monitoring to evaluate the effectiveness of BMPs being used during construction. CDOT continues involvement with the Association through the regular meeting program.

Turkey Creek, a major tributary to Bear Creek, flowing directly into Bear Creek Reservoir. Water-quality concerns in the Reservoir and downstream in the South Platte River have heightened sensitivity to activities in the Turkey Creek watershed that

potentially impact water quality. U.S. Highway 285 is a major route into the Denver metropolitan area from the west. Growth and development in the area served by U.S. Highway 285 has resulted in increased traffic volumes and created the need for expansion of the roadway. The Colorado Department of Transportation has underway with a significant construction effort along parts of Highway 285 that transect the Turkey Creek drainage.

Following a 4-year (1995-98) cooperative monitoring program between DRCOG and CDOT, Exponent and TDS Consulting, CDOT contractors, are in their fourth year of a multi-year effort of monitoring water quality at several locations in Turkey Creek and evaluating the effectiveness of construction-related BMPs implemented by CDOT associated with the U.S. Highway 285 project. The monitoring program also provides data reflecting the impacts of increased residential and commercial development throughout the watershed. Intermittent CDOT presentations before the Bear Creek Watershed Association (BCWA) during 2001 and 2002 have described results of the monitoring program, the dynamic aspects of the program required to adapt to the progression of construction, and some of the information benefits it has provided to date to CDOT and BCWA interested parties.

During 2001, particular focus of CDOT monitoring results (12 sites; 12 field surveys) was made in the Windy Point area (concluding Phase-IV work), in the general area of the Meyer Ranch Jefferson County Open-Space Park and Aspen Park (active Phase-V construction), and the Kennedy Gulch area (highway intersection under construction just west of the Turkey Creek watershed, Phase V). In general, average streamflows were less than for the preceding 4-year historical period (1995-1998) as well as for the recent (1999) period. In contrast, the 2001 streamflows were slightly higher than during 2000 throughout the Turkey Creek watershed. Annual average total suspended solids (TSS) concentrations were generally higher compared to historical and recent periods. This was attributable to below-normal precipitation conditions prevailing during 2001 as well as localized, short-term highway-construction and associated impacts. Sampling-survey results at several monitoring sites skewed the average sediment-related constituent concentrations for 2001, because of streamflows generated due to an intense, short-duration thunderstorm event on 7/23-24/01.

The 2002 CDOT monitoring program is continuing, and plans are being made to extend the program through calendar year 2003. An addition, CDOT continues its involvement with the BCWA with monitoring-program status updates periodically at regular monthly meetings.

II. WATER QUALITY MONITORING AND MANAGEMENT PROGRAM

The monitoring program characterizes water quality inflow into Bear Creek Reservoir from Bear Creek and Turkey Creek, outflow from Bear Creek Reservoir as a tail-water discharge and downstream water quality. The reservoir is monitored at a single representative station located in the central pool beyond the Bear Creek and Turkey Creek inlets. The monitoring program was reviewed in 2001 with an update to the

quality assurance plan associated with the *2002-2005 Bear Creek Watershed: Sample Analysis Plan (SAP) And Quality Assurance Project Plan (QAPP)* (Bear Creek Watershed Association 2001). This monitoring plan document provides the basis for all monitoring activities in the Bear Creek Watershed.

Monitoring sites

The five routine monitoring stations and reservoir station are as follows (*2002-2005 Bear Creek Watershed: Sample Analysis Plan (SAP) And Quality Assurance Project Plan (QAPP),* Bear Creek Watershed Association 2001):

1. Mainstem of Turkey Creek prior to discharge into Bear Creek Reservoir, within Bear Creek Park, adjacent to the City of Lakewood Maintenance Yard;

2. Mainstem of Bear Creek prior to discharge into Bear Creek Reservoir, within Bear Creek Park, adjacent to the bridge at the western edge of the park;

3. Tail-water discharge from Bear Creek Reservoir in the concrete channel which starts the lower Bear Creek;

4. Mainstem of Bear Creek about 1-mile below Bear Creek Reservoir; and

5. Bear Creek Reservoir, center of main pool beyond the Bear Creek and Turkey Creek Inlets.

Parameters and sampling program

The monitoring program provides necessary data to make statistical water quality trend assessments and verify the effectiveness of control and alternative management programs. The minimum required physical, chemical and biological components listed in the control regulation and shown in Table 4.

Sample Frequency

The routine watershed-monitoring program focuses on inputs to and outputs from Bear Creek Reservoir. There are 16 reservoir and stream samples taken per calendar year with biweekly monitoring in May, June, July and August, and monthly for other months. There may be some sample periods in the winter where Bear Creek Reservoir cannot be sampled due to poor ice conditions. The stream sampling program is conducted without reservoir sampling. The stream input and output-sampling program targets data collection for all months within a calendar year. A maximum of 16 stream data sets will be collected per year. If a winter reservoir monitoring set cannot be taken due to unsafe conditions, then the reservoir monitoring set will be added at a later time period to the annual monitoring program, which will result in a total of 16 monitoring sets per calendar year within the reservoir. The E. coli sample frequency is listed in Table 1.

Table 4 Water Quality Parameters

2002-2005 Water Quality Parameters			
Parameter (units)	**Watershed Inflows**	**Reservoir**	**Reservoir Outflow/ Downstream**
Physical/Field			
Discharge (cu m/s)	X		X
Specific Conductance (umhos/cm)	X	X (Profile)	X
Secchi (meters)		X (Single Measurement)	
Dissolved Oxygen (mg/l)	X	X (Profile)	X
Temperature (C)	X	X (Profile)	X
Total Suspended Sediments (mg/l)	X	X (3 Depths)	X
pH (standard unit)	X	X (3 Depths)	X
Biological			
E. Coli (cts/100ml)	X (April to October)	X (March to November)	X (April to October)
Chlorophyll a (ug/l)		X (Surface Sample)	
Phytoplankton		X (Surface Sample)	
Zooplankton		X (Vertical Tow)	
Nutrients			
Ammonia (ug/l)	X		X
Nitrate (ug/l)	X	X (3 Depths)	X
Total Particulate Phosphorus (ug/l)	X	X (3 Depths)	X
Total Dissolved Phosphorus (ug/l)	X	X (3 Depths)	X
Ortho-Phosphorus (ug/l)	X	X (3 Depths)	X
Total Phosphorus (ug/l)	X	X (3 Depths)	X

Trophic Indicators

The reservoir-monitoring program provides data for use in assessing compliance with the reservoir narrative standard. Therefore, monitoring parameters are also trophic state indicators. The watershed program evaluates nutrient loading trends and balances for nitrogen and phosphorus species. Secchi depth and total suspended solids characterize the clarity of the water column. Algal productivity is measured by chlorophyll a samples and phytoplankton characterization. Since the growing season is critical for reservoir compliance as defined in the Bear Creek Reservoir Control

Regulation (Regulation #74), then monitoring program targets additional sampling during this season.

Stormwater management

The association is concerned with the quality of dry-weather and stormwater runoff associated with significant development sites. Significant development sites are generally related to urban development construction activities. The association has developed a project specific monitoring guidance report (BCWA 1996c). However, the Association has no direct responsibility for regulating development activities or implementing site-specific water quality or stormwater control facilities. The association works with its members through local review processes to ensure that development follows the watershed water quality management strategy using the best available management practices. The association reviews BMPs and makes recommendations as requested by local governments.

City of Lakewood reservoir aeration program

The City of Lakewood maintains a reservoir aeration program. This aeration system increases the amount of dissolved oxygen throughout the water column. The program helps support the fishery goal of the Association for the reservoir. This aeration effort has proven to be a successful management practice and the continued operation is necessary to maintain quality in the reservoir. The current aeration system will be replaced with a more efficient system that is designed to de-stratify the reservoir water column and introduce more uniform aeration within the reservoir main pool. The City of Lakewood has received bids and should implement the new aeration system before the 2003 summer season.

Onsite system management plan

Water quality impacts are occurring from onsite wastewater systems in a number of specific areas in the Bear Creek Watershed. However, the presence and nature of these problems is not been well verified or rigorously documented in the watershed. In fact, few well-documented studies have been done in Colorado that directly link water quality or health risks with onsite wastewater systems. Examples of identified impacts include elevated nitrate and/or bacteria levels in ground water used for drinking water, and nutrient loadings adversely affecting surface waters. Researchers from Colorado State University identified many mountain homes potentially using bacterial laden well water caused by misplacement of leach fields *(How Safe Is Mountain Well Water,* CSU 1972). Other studies done by the Colorado State University and local health department document elevated nitrates in groundwater for specific locations.

Although few site-specific studies have been completed, it appears that substantial cumulative loadings of nutrients to Bear Creek Watershed waters are likely occurring in some areas where there are a significant total number and density of onsite wastewater

systems. There are areas of known nitrate contamination and increased nitrate levels in ground water in areas of high density (lots less than one acre) and a significant number of homes.

In some surface water basins, phosphorus loadings from onsite wastewater systems are a potentially significant water quality factor. Phosphorus loading into Bear Creek Reservoir has caused adverse water quality impacts that have led to the development of a control regulation to control phosphorus loadings. Water quality monitoring in the Bear Creek Watershed over a 15-year period has shown that there is a phosphorus-loading problem in Bear Creek Reservoir. Screening surveys completed by the Association show elevated levels of phosphorus in areas with a higher density of on-site wastewater systems, such as the community of Idledale (Bear Creek Watershed Association, 1998; 1997 Bear Creek Watershed Association Annual Report; Bear Creek Watershed Association, 1997a, *Management Program Review and 1990-1995 Water Quality Summary*).

The Association recognizes the need for a comprehensive septic management plan for the watershed that addresses the nutrient loading issue. The county members of the Association should take the lead in developing a septic management program. The Denver regional Council of Governments is in the process of developing a septic management plan guidance document. Once this guidance document is accepted the Council's Board of Directors, the guidance can be used to assess the septic management program needs of the watershed.

III. WATERSHED AND RESERVOIR TRENDS

Reservoir tropic status

Bear Creek Reservoir has a water quality goal established by the Water Quality Control Commission instead of a numeric standard. The reservoir goal, as defined by the site-specific narrative standard, listed in the Watershed Control Regulation (WQCC 1996) reads as follows:

> *Concentrations of total phosphorus in Bear Creek Reservoir shall be limited to the extent necessary to prevent stimulation of algal growth to protect beneficial uses. Sufficient dissolved oxygen shall be present in the upper half of the reservoir hypolimnion layer to provide for the survival and growth of cold-water aquatic life species. Attainment of this standard shall, at a minimum, require shifting the reservoir trophic state from a eutrophic and hypereutrophic condition to a eutrophic and mesotrophic condition, based on currently accepted limnological definitions of trophic states*.

The annual monitoring program characterizes reservoir quality in relation to the narrative goal. The use of trophic indicators is one method to determine compliance with the control regulation. The reservoir program evaluates seasonal as well as long-term changes in the following three categories:

1. Nutrient (nitrogen and phosphorus) concentrations and trends;

2. Indicator biological characteristics (phytoplankton and zoology);

3. Characterization of mass loading into reservoir.

Two models are used to evaluate the current trophic state: Walker (annual and seasonal); and Carlson (annual and seasonal). Both models use the total phosphorus, Secchi depth and chlorophyll-α levels for the evaluation. The two models differ in that Walker's trophic status index bases the scale on chlorophyll-α levels rather than Secchi depth levels to correct for non-algal light-attenuating factors. Carlson's trophic state index is based on phosphorus limited northern temperate lakes. The Carlson trophic status index shows the reservoir tropic index has shifted toward the eutrophic-mesotrophic boundary, but remains a eutrophic waterbody (Figure 1). Like Carlson's trophic status index, Walker's trophic status index was also developed based on data from northern temperate lakes.

The Walker seasonal trophic status index evaluation shows a similar trend to Carlson (Figure 2). Although nutrient total loading was reduced in 2001, the trophic index shows a slight decrease in overall quality. The trophic state in the reservoir remains in flux and additional monitoring at the current level of effort is still required. Based on the historical trend analysis and all water quality models, the reservoir is shifted toward the desirable mesotrophic-eutrophic system from the eutrophic-hypereutrophic condition measured during the *Bear Creek Reservoir Clean Lake Study*. Over the recent period of data record, the overall trend in reservoir trophic status classification is a eutrophic state.

Figure 1 Carlson trophic status index

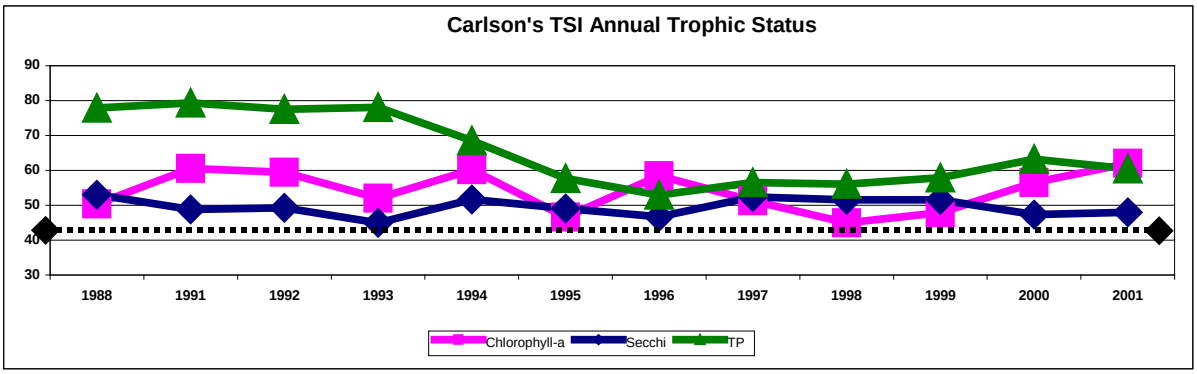
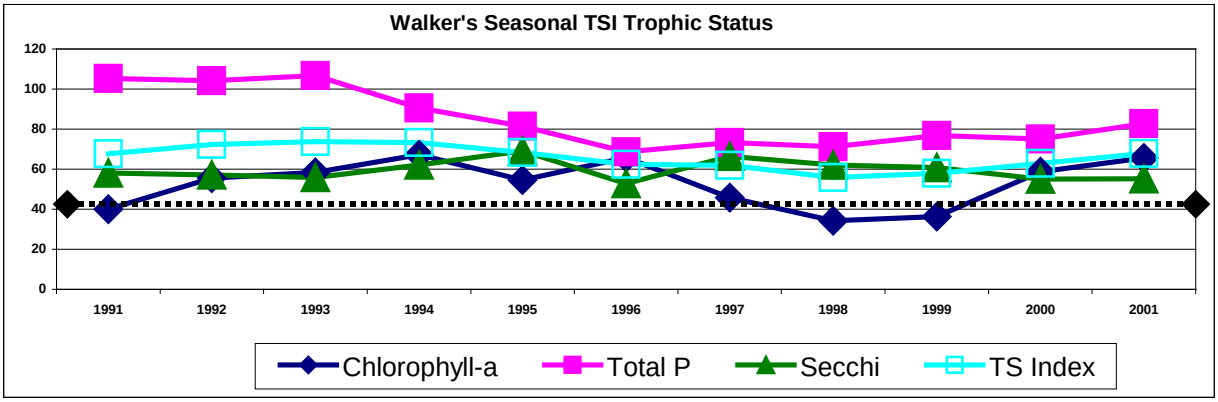


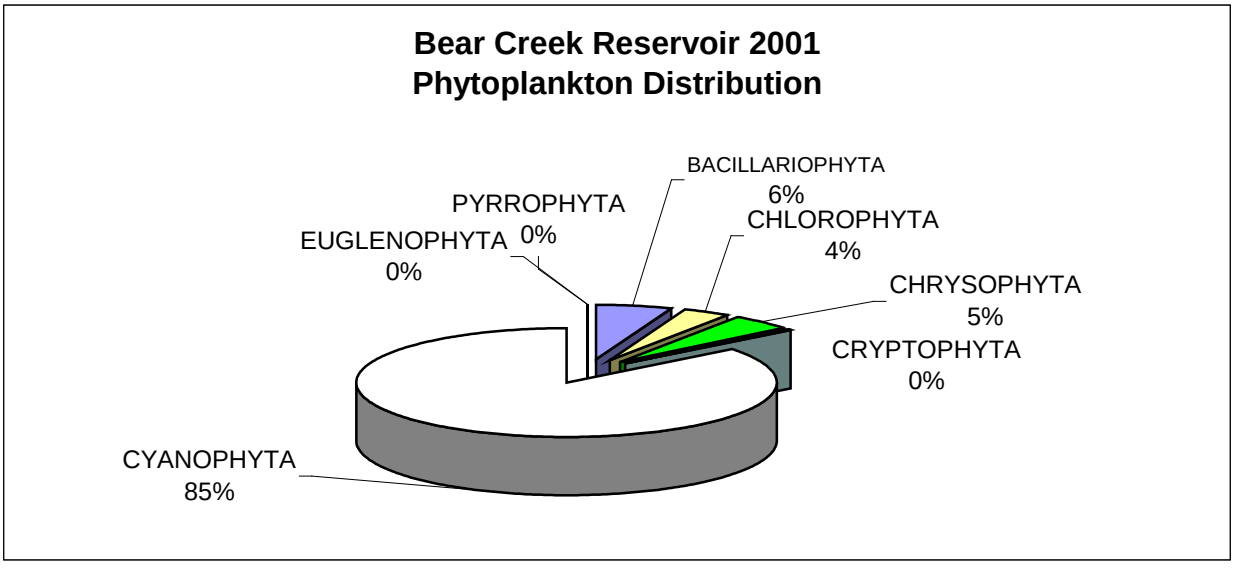
Figure 2 Walker Seasonal trophic status index



Phytoplankton distributions

The biological integrity of Bear Creek Reservoir can be assessed by monitoring changes in plant (phytoplankton) communities. The increased abundance within a reservoir of certain types of algae or plants (e.g., blue-green algae or Cyanophyta) indicate declining water quality. In 2001, the blue-green species made up on the average 85% of plants present in the reservoir. Fifteen species of blue-green algae were found in the reservoir with a maximum total density of 401,880 cells/ml in the September 2001 sample data, which was classified as a visual algal bloom. No fish kills or problems were reported for the reservoir in September or any other month. The diatoms (Bacillariophyta and Chrysophyta) made up 11% of the remaining species. Certain species of diatom can be problematic from a water supply perspective.

Figure 3 Phytoplankton Distributions in Reservoir



Zooplankton distributions

A more detailed evaluation of zooplankton species presence was assessed from June through August. Species were counted as present without density determinations. The zooplankton species found in the reservoir are divided among three major groups of copepods, cladocerans and rotifers, which is typical of front-range reservoirs. Zooplankton are common in the upper regions of the reservoir where assemblages include 16 species of rotifers, six species of cladocerans and eight species from the class Copepoda. Copepods are usually a dominant group in the reservoir. The microcrustacean class Ostracoda is missing from the reservoir, but has been found in other front-range waterbodies. Most species of three functional groups make their living grazing algae from either the water column or off surfaces. Zooplankton is a vital link for passing energy up the food chain to fish.

Table 5 Zooplankton Species Summer 2001

COPEPODA	CLADOCERA	ROTIFERA
Acanthocyclops vernalis	***Alona sp.***	***Asplanchna girodi***
Aglaodiaptomus clavipes	*Bosmina longirostris*	*Brachionus urceolaris*
Diacyclops thomasi	*Chydorus sphaericus*	*Collotheca sp.*
Eucyclops spp.	*Daphnia mendotae*	*Conochilus unicornis*
Leptodiaptomus siciloides	*Daphnia pulex - group*	*Euchlanis dilatata*
Mesocyclops edax	*Leptodora kindti*	*Kellicottia longispina*
Skistodiaptomus pallidus		*Keratella cochlearis*
Tropocyclops prasinus		*Keratella quadrata*
		Lecane (L.) spp
		Lecane (M.) sp.
		Lepadella sp.
		Polyarthra vulgaris
		Pompholyx sulcata
		Synchaeta pectinata
		Trichocerca sp.
		bdelloid

Monitoring program

The 2001 monitoring program tropic indicators for the reservoir are shown in Table 6. The annual monitoring program characterizes reservoir quality in relation to the narrative goal. The use of trophic indicators is one method to determine compliance with the control regulation. Reservoir water quality models use total phosphorus, Secchi depth and chlorophyll-α levels as indicators of reservoir health.

The biological integrity of Bear Creek Reservoir is assessed by monitoring changes in plant (phytoplankton) and animal (zooplankton) communities. The increased abundance within a reservoir of certain types of algae or plants (e.g., blue-green algae

or Cyanophyta) indicates declining water quality. Reservoir loading for total phosphorus, nitrate and suspended sediments are also good trophic measures. The water quality goal for the watershed is to obtain a mesotrophic/eutrophic state in the reservoir. Implementation of the watershed management program has impacted water quality in the reservoir and generally helped improve the overall reservoir quality. However, algal production was significantly increased under the drier hydrologic conditions monitored during 2001, even though the total phosphorus loading was lower than historic trends. The growing season Chlorophyll-a concentration is indicative of declining quality or hypertrophic conditions. The data suggests an internal loading problem that can be reduced through an improved reservoir aeration system.

Figures 4-8 shown some water quality trends for selected parameters from the 2001-monitoring program. The discharge rates for Turkey Creek were extremely low throughout 2001 (Figures 4 and 5). A total phosphorus flux from bottom sediments occurred from June through November (Figure 6). This nutrient loading contributed to algal blooms of bluegreen algae that occurred during summer months.

The dissolved oxygen profiles show low oxygen levels are still occurring in bottom waters of the reservoir late in the growing season (Figure 7). The dissolved oxygen concentrations in the water column are profiled in 1-meter intervals at the central sampling site. Dissolved oxygen is a reservoir trophic indicator measure, where dissolved oxygen concentrations below 5 mg/l can indicate a potential water quality and biological problem. Low dissolved oxygen concentrations can stress aquatic life species. The lower the dissolved oxygen concentration, the greater the potential stress.

Oxygen levels that remain below 1-2 mg/l for a few hours can result in fish kills. Since fish within the reservoir can migrate to better-oxygenated water, the amount of water column with low dissolved oxygen is an important tropic indicator. Low dissolved oxygen concentrations occur below 4 meters (about 14 feet) beginning in June and extends through November. Generally, dissolved oxygen zeros out between 10-13 meters (33-43 feet). The re-establishment of an aeration system in the reservoir is necessary to address this water quality problem and reduce the potential for stress of the aquatic species.

Large suspended sediment loading occurred at two distinct periods (Figure 8). The Association has been monitoring construction activities associated with the Willow Springs North development site. The Willow Springs North development on the lower Turkey Creek drainage is a major source of sediments reaching Bear Creek Reservoir. The excessive erosion caused by site development and subsequent sediment loading into Turkey Creek is having a measurable water quality impact on the reservoir. Consequently, the Association, as the water quality management agency, requested Jefferson County require additional mitigation measures to reduce on-site erosion and downstream sedimentation. This development site continued as a major source of sediments in the 2001-monitoring program. Little action has been taken to fix this water quality problem.

Reservoir loading for total phosphorus, nitrate and suspended sediments are shown in Figures 9, 10 and 11, respectively. Wastewater treatment plants and a combination of nonpoint sources within the watershed produce the total phosphorus load. The total phosphorus load in 2001 from all sources reaching the reservoir was 1,314 pounds at a total inflow of 13,510 acre-feet. Although the point source discharges of total phosphorus were in excess of 2,000 pounds, the water diversions above the reservoir are removing a portion of this phosphorus load before it reaches the reservoir. This is the lowest total phosphorus loading recorded for the reservoir by the Association. The nitrate and suspended sediment loading were also well below historic conditions. There were no nutrient or sediment loading problems in 2001.

The pH values in the water column are profiled in 1-meter intervals at the central sampling site (Figure 12). Water column pH can be a reservoir trophic indicator measure, where pH values above 9.0 indicate a potential water quality and biological problem. The pH scale measures relative quantities of the hydroxyl and hydrogen ions on a scale of 0 to 14. Where the hydrogen ion predominates in acidic solutions [measured as 0 on the scale] and hydroxyl ions predominate in very alkaline solutions [measured as 14 on the scale]. At around pH 7 the numbers of both species present are equal and the water is said to be neutral.

The pH scale is a logarithmic measurement of the concentration of hydrogen ions, which means that each one unit change in the scale equals a ten-fold increase or decrease. Plant photosynthesis is the main cause of high pH and diurnal pH fluctuations. High alkalinity water [pH > 9.0] can cause direct physical damage to fish skin, gills and eyes. Prolonged exposure of aquatic life to sub-lethal pH levels can cause severe stress or result in death of species with a narrow pH tolerance. The elevated pH measurements in the reservoir need careful monitoring with a determination of cause and affect.

Table 6 Bear Creek Reservoir 2001 - Selected Trophic Indicators

Bear Creek Reservoir 2001 - Selected Trophic Indicators	
Trophic Indicator	**Value in Reservoir**
Average Growing Season Chlorophyll-a [ug/l (surface waters only)]	23.5
Peak Chlorophyll-a [ug/l]	69.7
Average Total Phosphorus [ug/l]	49.8
Peak Total Phosphorus	150.1
Peak Ortho Phosphorus	97.2
Secchi Depth [meters]	2.3
Peak Total Suspended Sediments	35.6
Phytoplankton Species Co-dominant Species	Diatom - *Stephanodiscus hantzschii*
	Green – *Chlorella minutissima*
	Chrysophyta - *Chromulina mikroplankton*
	Bluegreen - Aphanizomenon flos-aquae
	Bluegreen - *Woronichinia compacta*

Bear Creek Reservoir 2001 - Selected Trophic Indicators	
Trophic Indicator	**Value in Reservoir**
	Bluegreen - *Microcystis aeruginosa*
Peak Phytoplankton Density	401,880 cells/ml (September)

Figure 4 Instantaneous Discharge Rates

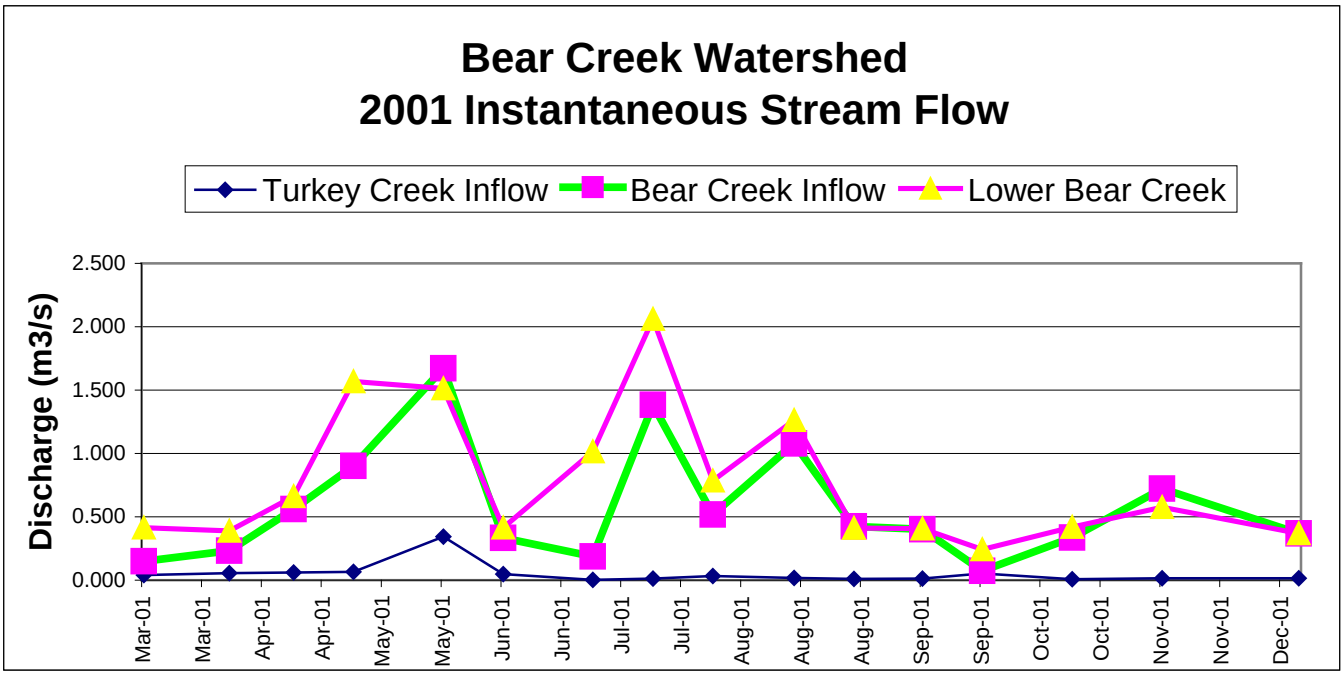


Figure 5 Estimated Inflows from Turkey Creek and Bear Creek

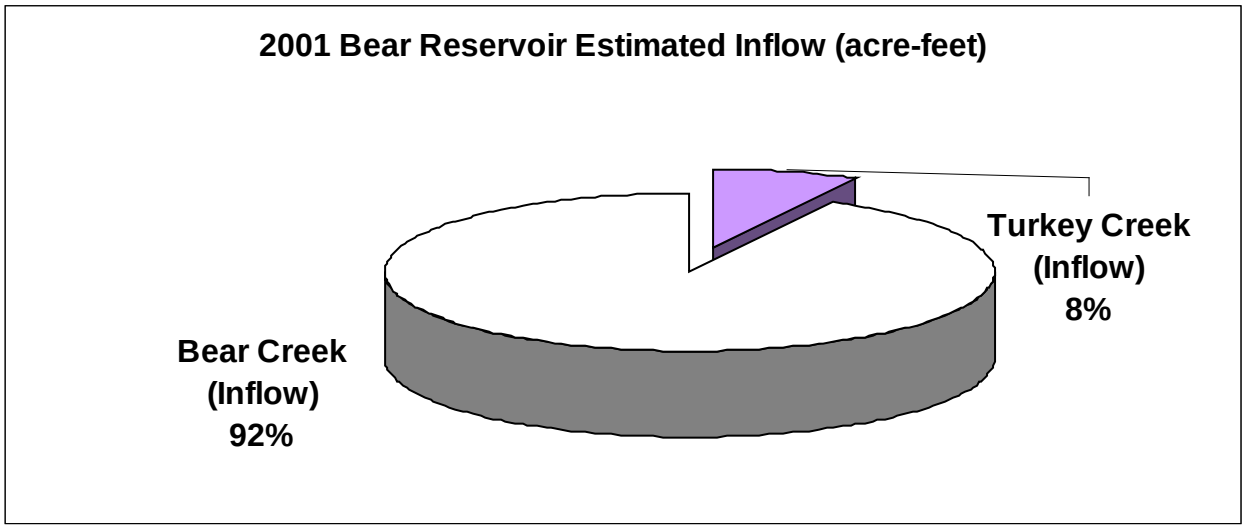


Figure 6 Total Phosphorus Trends

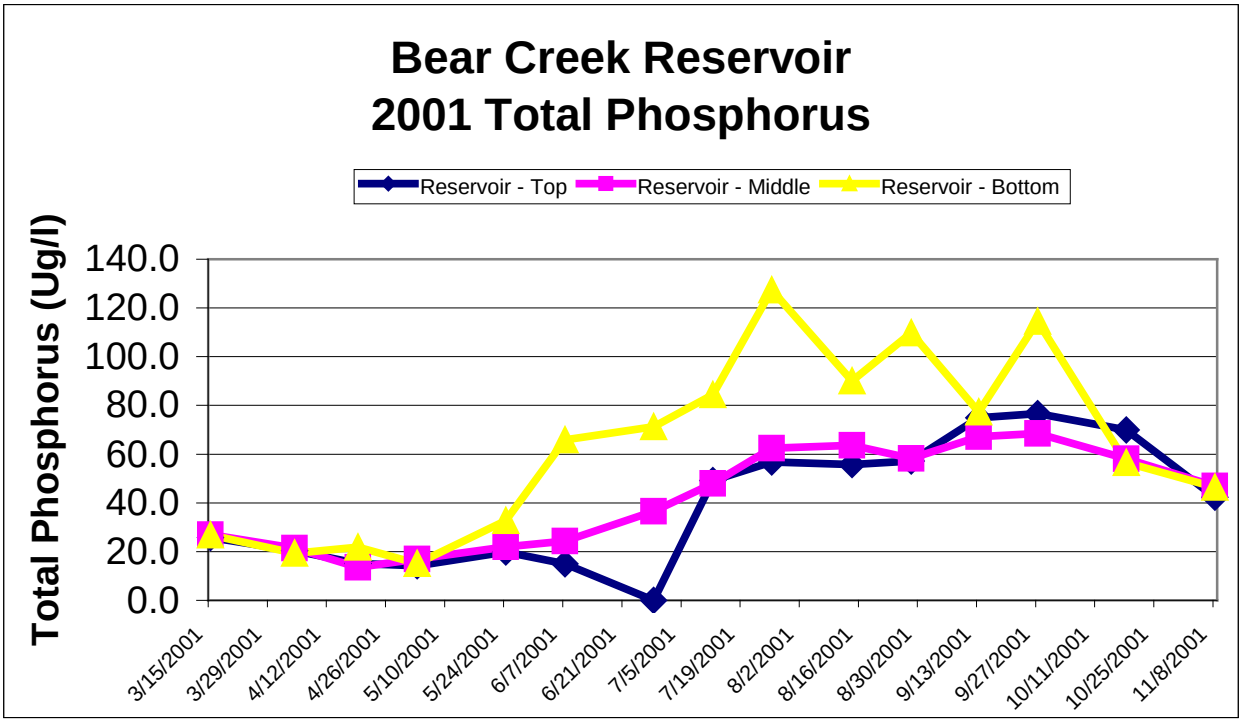


Figure 7 Dissolved Oxygen Profiles

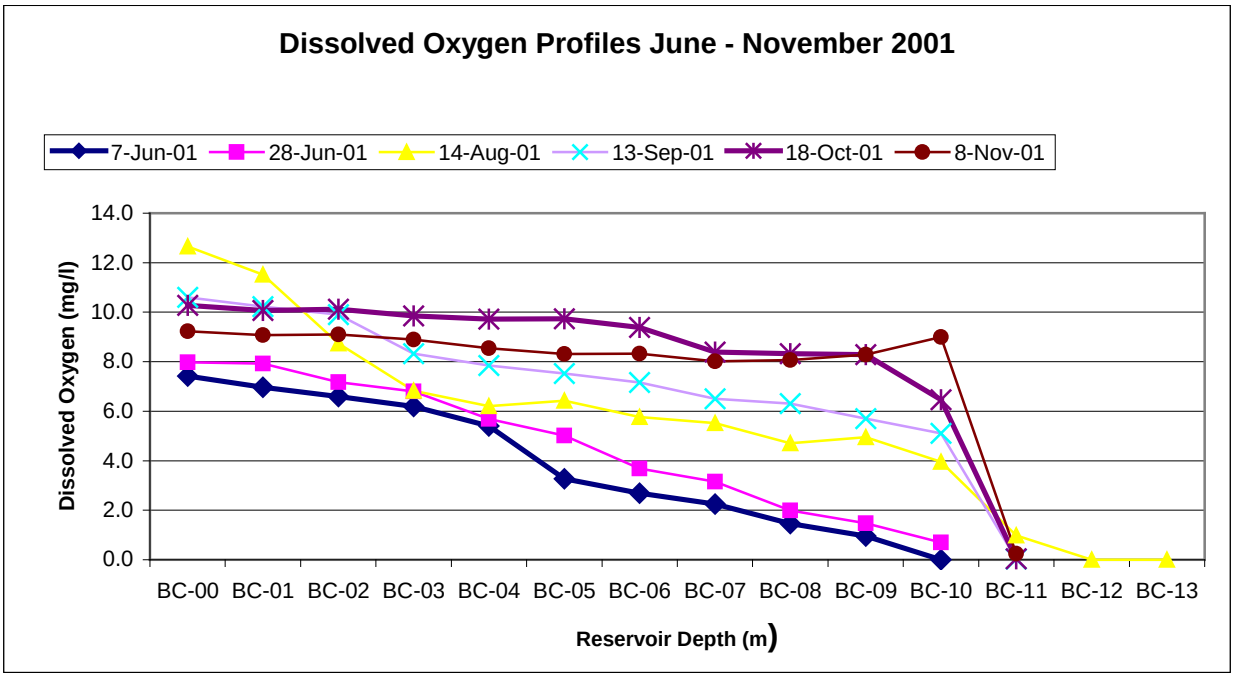


Figure 8 Total Suspended Solids Trends

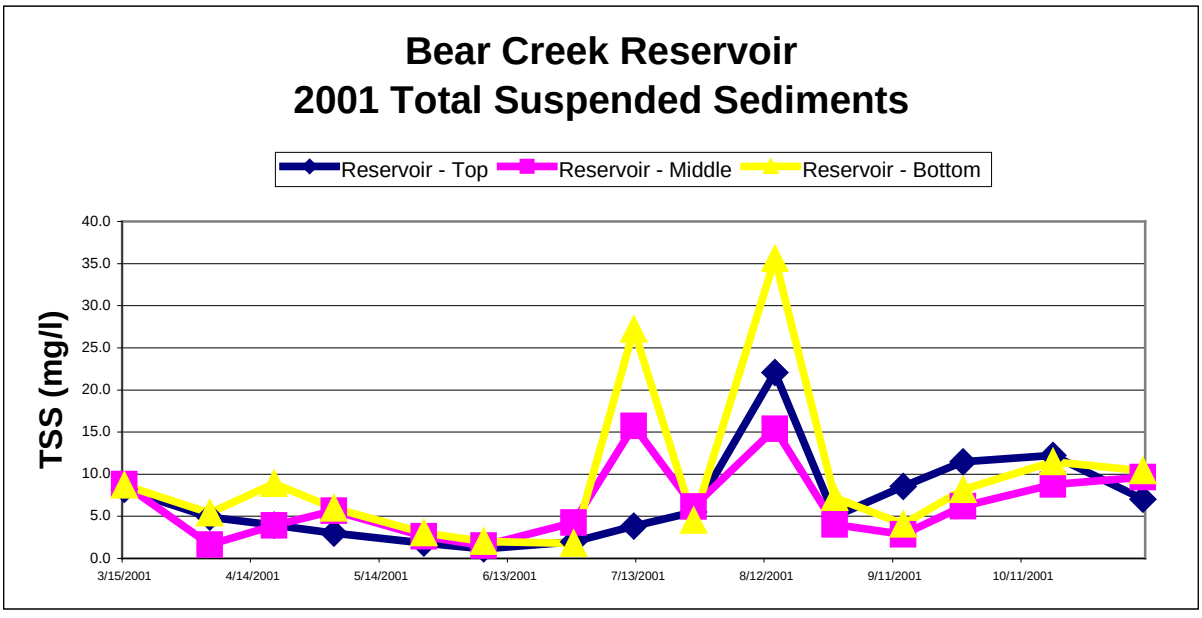


Figure 9 Total Phosphorus Loading

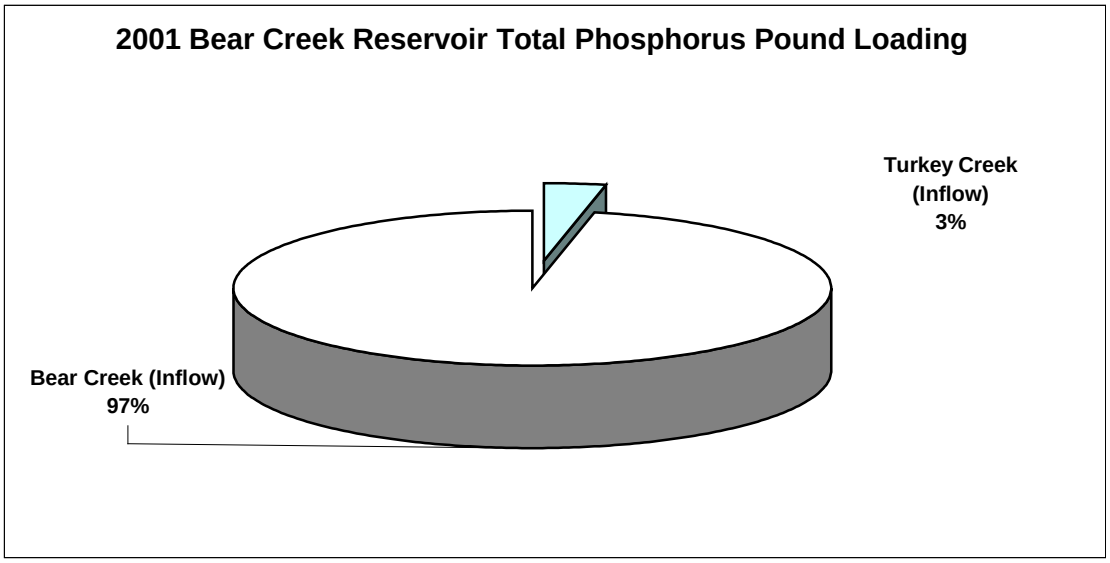


Figure 10 Nitrate Loading

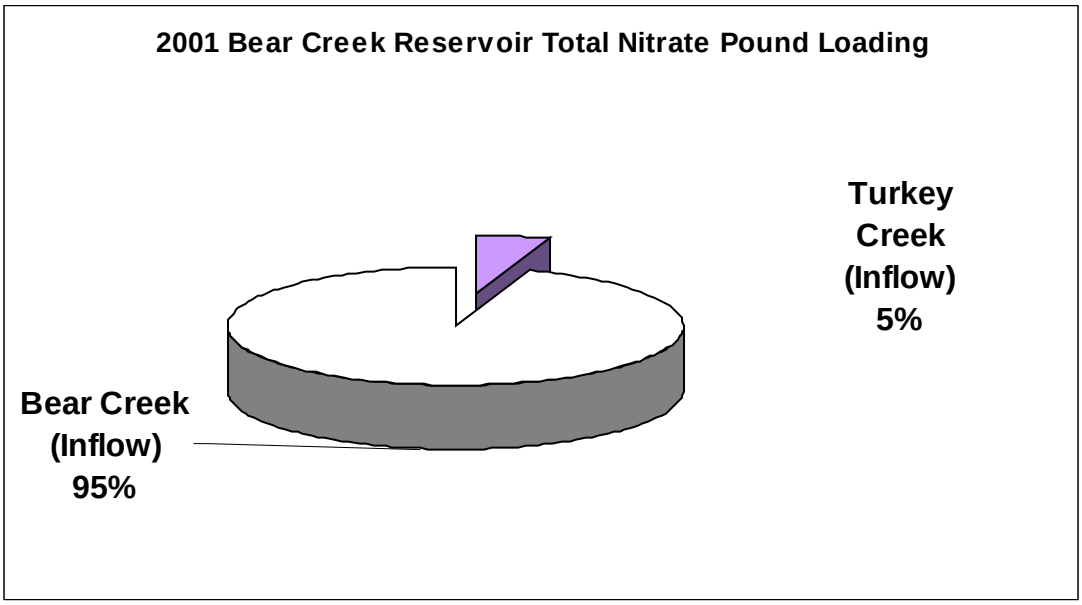


Figure 11 Suspended Sediment Loading

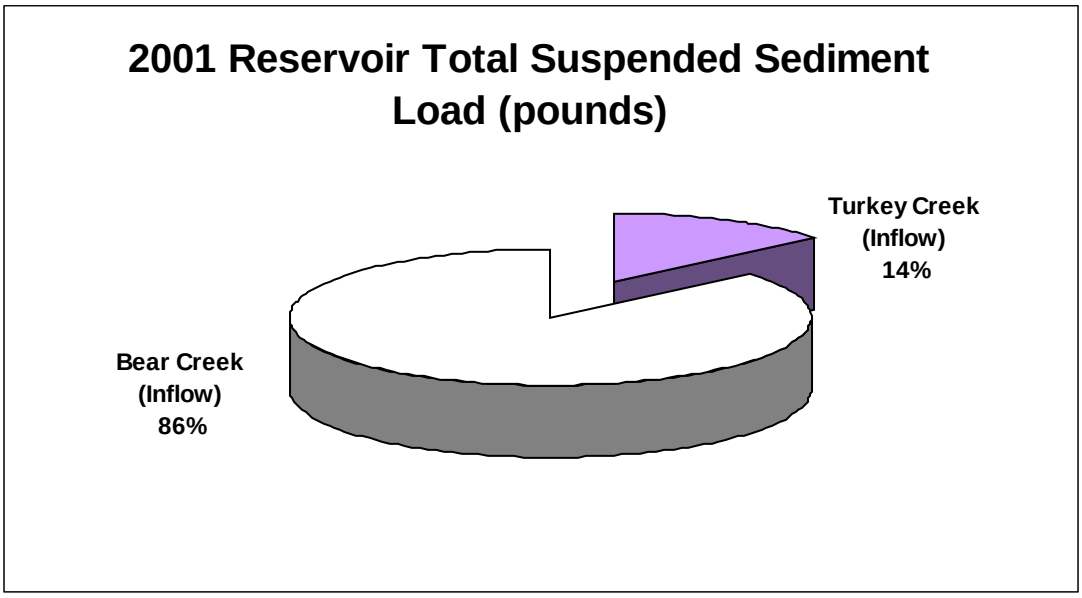
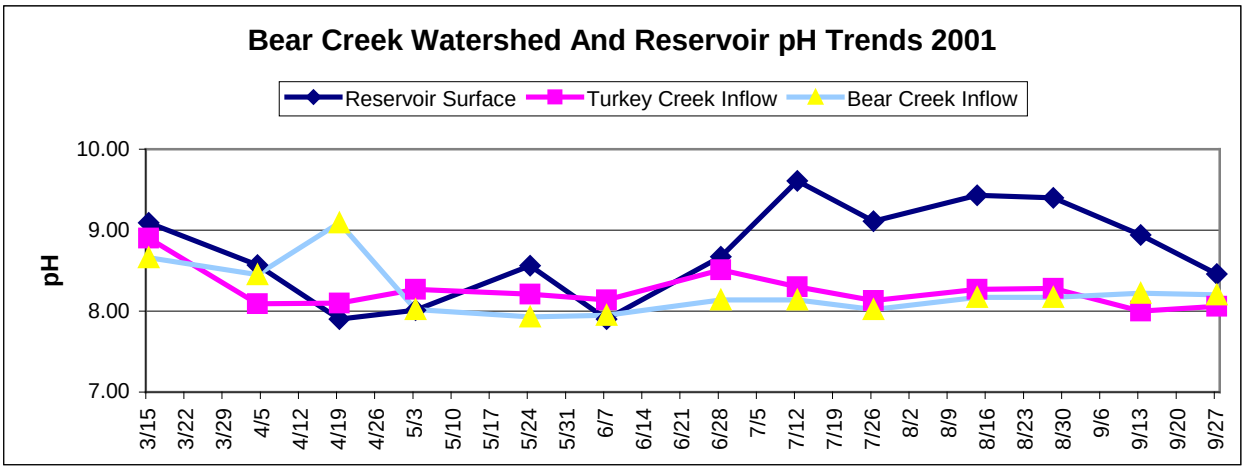


Figure 12 Bear Creek Reservoir 2001 pH Trends



Long-term water quality trends

The water quality goal for the watershed is to obtain a mesotrophic/eutrophic state in the reservoir. Implementation of the watershed management program has had a significant impact on the water quality in the reservoir. Figures 12-17 and Table 7 characterize selected water quality trends. The reservoir program evaluates seasonal, annual and long-term changes in nutrient (nitrogen and phosphorus) concentrations, chlorophyll-a, total suspended sediments and Secchi depth. The reservoir trends from 1991 through 2001 are summarized in Table 7.

The total suspended sediment load in the reservoir has been generally constant over the monitoring periods with periodic storm events dumping large volumes of sediment into the reservoir. The average depth of the reservoir has declined by over 3 meters (10-11 feet) since 1991.

The control program for the watershed targets the reduction of total phosphorus reaching the reservoir on an annual basis. The data supports the success of this management effort. While the nitrogen data has fluctuated over the years, no clear pattern has emerged. However the surface Chlorophyll concentration increased dramatically in 2000 and 2001. This suggests an internal nutrient loading problem triggering algal blooms. Additionally, the algal blooms appear to correlate with drier hydrologic conditions. Future monitoring and some special studies (if this trend continues through 2002) will address the algal production problem in the reservoir.

Table 7 Bear Creek Reservoir Mean Annual Concentrations 1991-2001

Bear Creek Reservoir Mean Annual Concentrations 1991-2001													
		Mean Annual Concentrations											
Parameter	Site	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	91-00 Mean
Chlorophyll-a (ug/L)	Reservoir 0-2.5 m	17.7	26.0	13.7	29.7	9.4	17.1	8.2	4.9	6.2	23.9	24.6	16.5
	Reservoir 5-10 m	19.8	15.5	5.9	17.0	6.2	10.3	2.4	5.4	5.5	8.9	6.3	9.4
	Water Column Mean	18.7	20.8	9.8	23.4	7.8	13.7	5.3	5.2	5.9	14.1	14.6	12.7
Nitrate-Nitrogen (ug/L)	Reservoir 0-2.5 m	442	289	504	382	474	578	393	388	224	431	401	410
	Reservoir 2.5-10 m	381	282	451	356	502	589	365	372	220	443	395	396
	Reservoir 5-10 m	341	228	333	308	503	561	341	342	231	483	390	369
	Water Column Mean	388	266	429	349	493	576	366	367	225	441	387	390
Total Phosphorus (ug/L)	Reservoir 0-2.5 m	144	146	175	83	34	29	38	33	34	59	42	74
	Reservoir 2.5-10 m	138	140	164	79	37	33	45	40	37	57	42	74
	Reservoir 5-10 m	270	201	240	99	52	66	86	69	54	56	64	114
	Water Column Mean	184	162	193	87	41	43	56	47	42	60	50	88
Total Suspended Solids (mg/L)	Reservoir 0-2.5 m	6	7	4	9	6	4	12	6	7	6	7	7
	Reservoir 2.5-10 m	8	6	6	8	7	4	15	8	9	5	7	8
	Reservoir 5-10 m	19	8	5	9	13	7	22	12	12	8	10	11
	Water Column Mean	11	7	5	9	9	5	16	9	9	6.4	8	8.6
Secchi Depth (m)	Reservoir	2.17	2.1	2.84	1.79	2.14	2.51	1.7	1.8	1.8	2.4	2.3	2.1

Figure 13 Nitrate Input and Outflow Trends

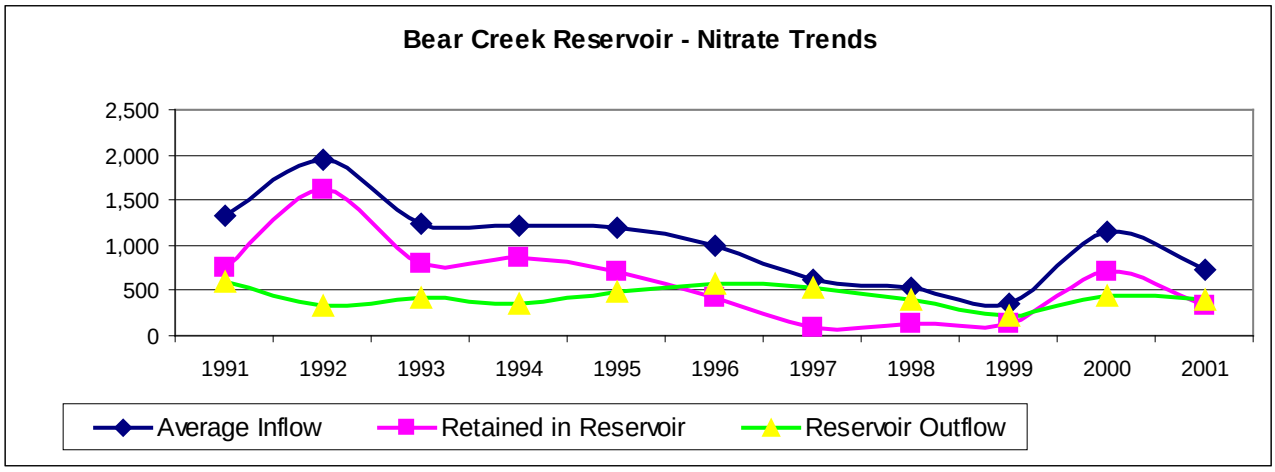


Figure 14 Reservoir Average Nitrate Trend

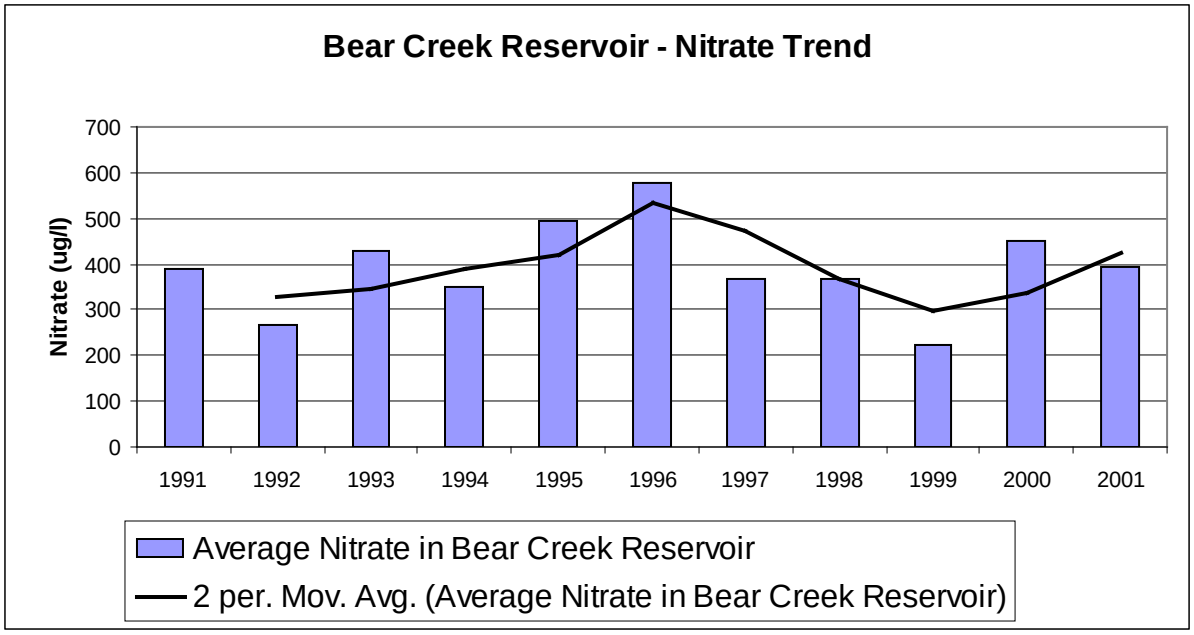


Figure 15 Total Phosphorus Averages

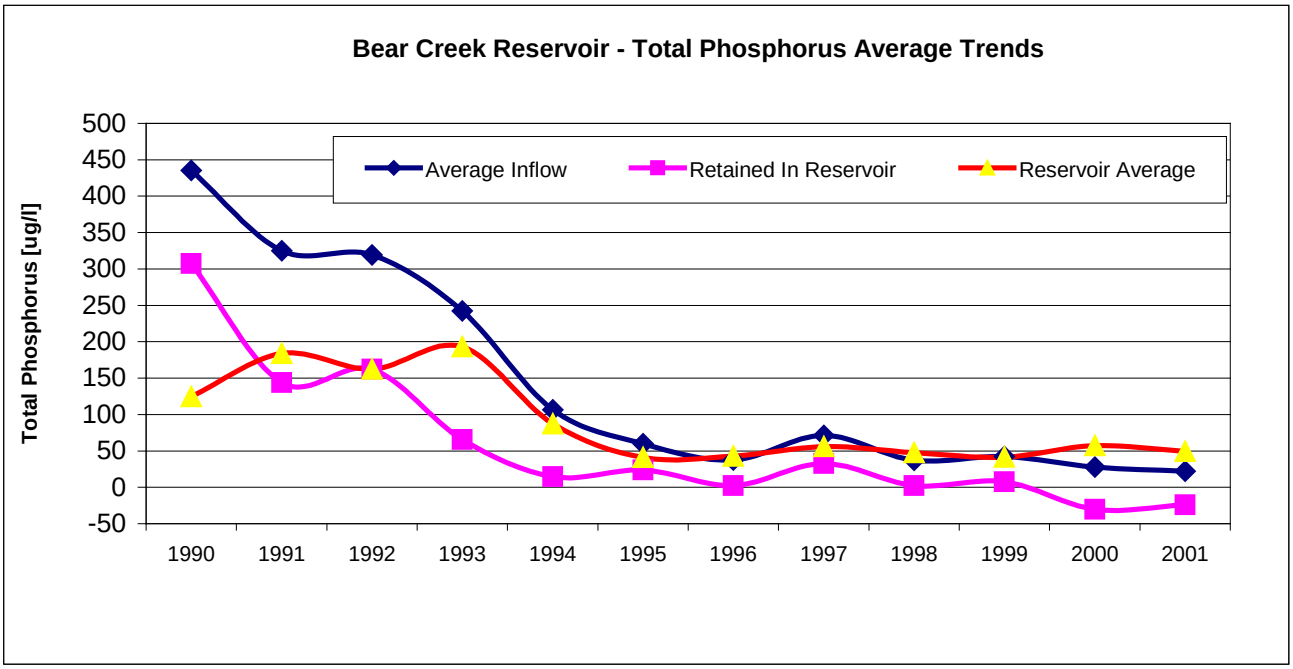


Figure 16 Reservoir Total Phosphorus Trend

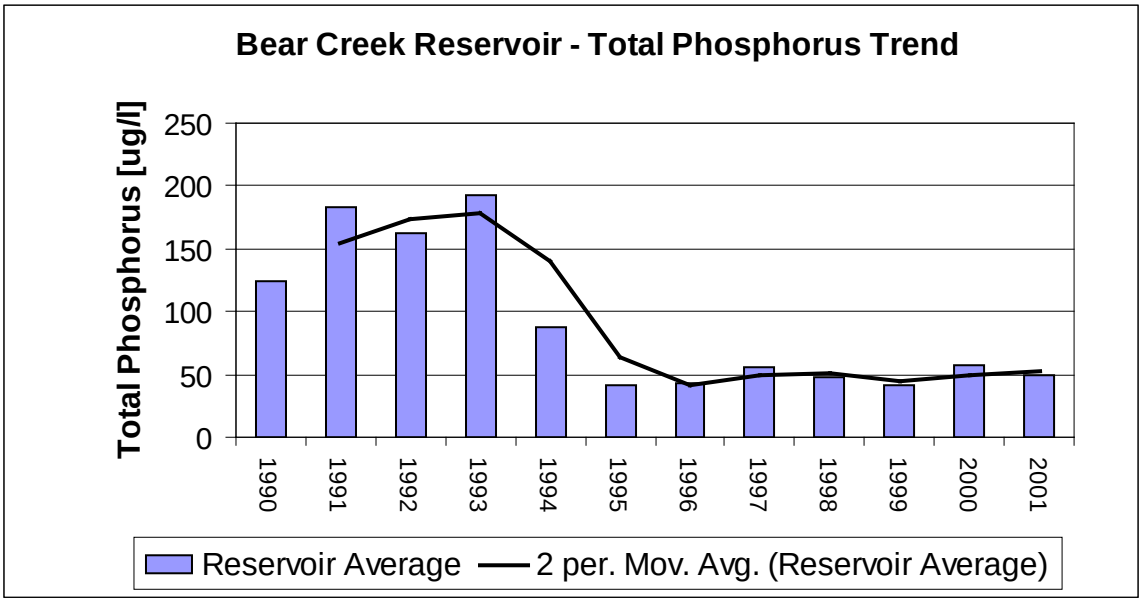


Figure 17 Total Phosphorus Inflow Trend

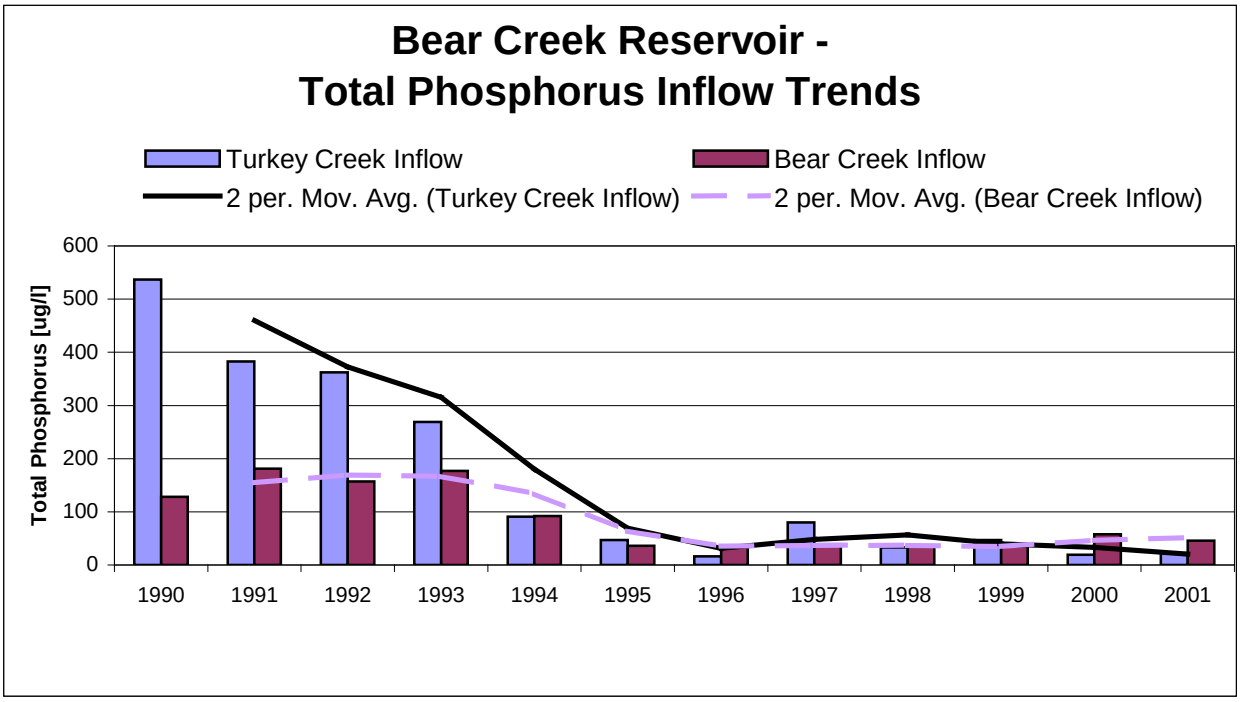
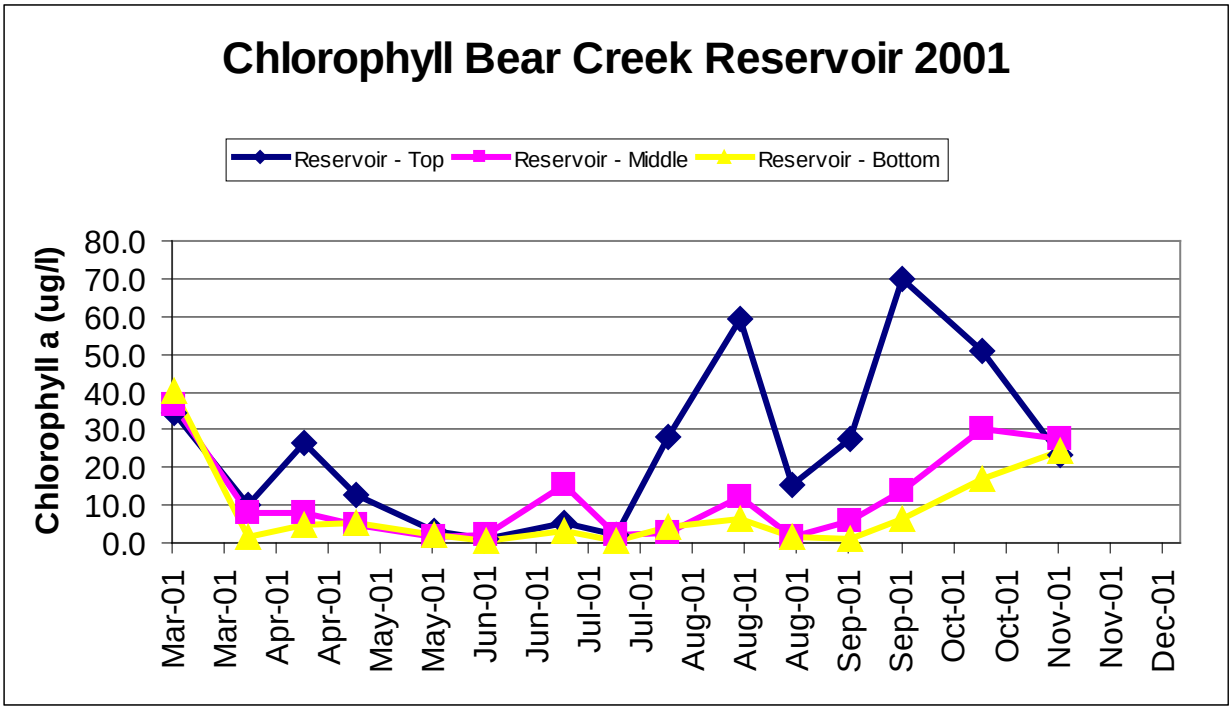


Figure 18 Reservoir Chlorophyll Trend



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