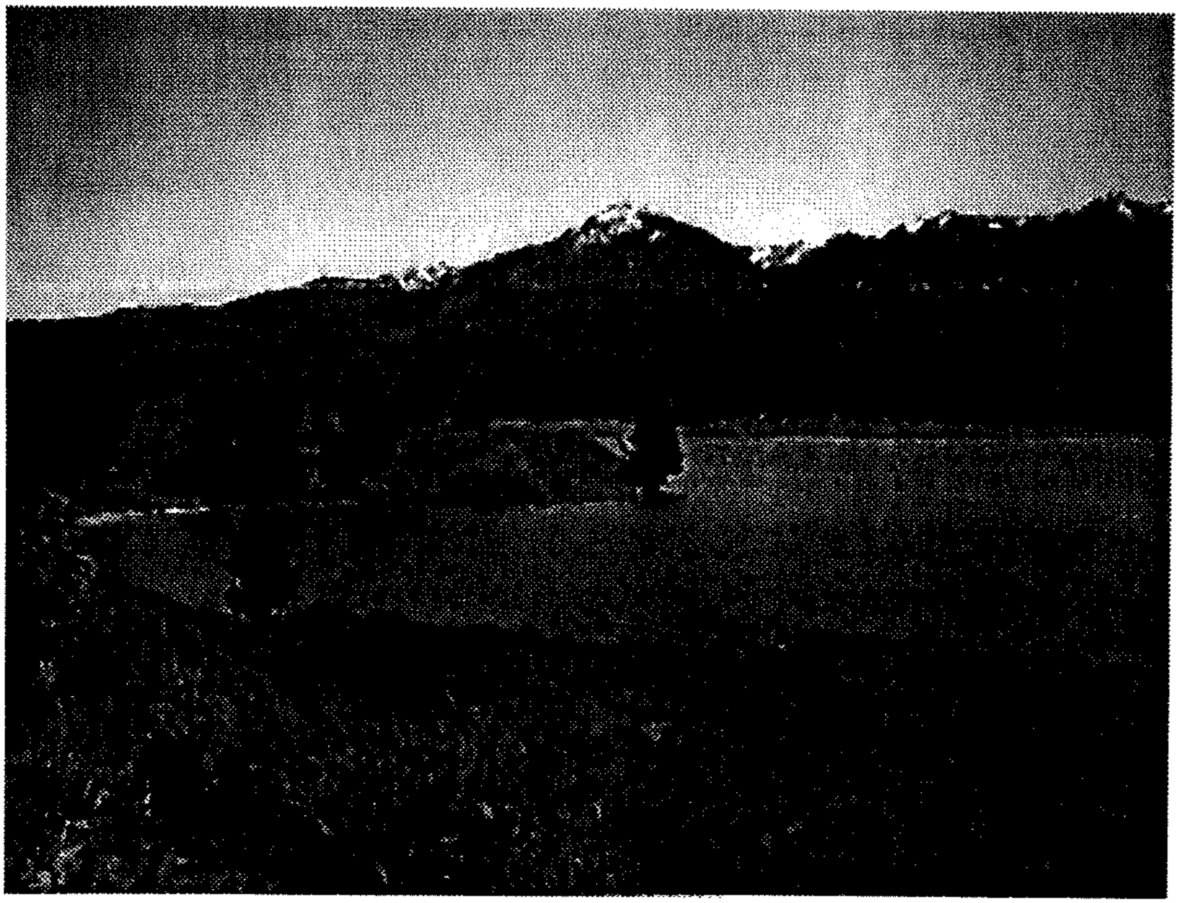
Cascade Reservoir
Phase II
Watershed Management Plan



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Cascade Reservoir
Phase II
Watershed Management Plan

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The Forestry, Agriculture, and Urban/Suburban Source Plans are available as a separate appendix volume to this document from the Idaho Division of Environmental Quality. To

request a copy of this appendix volume contact the DEQ - Boise Regional Office at 1445 North Orchard, Boise, ID 83706-2239 (208-373-0550) or the DEQ - Cascade Satellite Office at PO Box 247, Cascade, ID 83611 (208-382-6808).

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Foreword

The Phase I and Phase II Watershed Management Plans prepared for the Cascade Reservoir Watershed are part of an ongoing process for improvement of water quality in the reservoir and its tributaries. The Phase I management plan identified in-reservoir water-quality standards for reduction of algal growth, point and nonpoint sources of nutrient loading, subwatershed specific load allocations and reductions required to meet the in-reservoir water-quality standards. The Phase II management plan further refines the parameters defined by the Phase I in the areas of point and nonpoint sources of nutrient loading, subwatershed-specific load allocations and load reductions required. The Phase I and Phase II management plans were developed by the Idaho Division of Environmental Quality (DEQ), Boise Regional Office, and are consistent with Idaho Code 39-3611, which details the "Development and Implementation of Total Maximum Daily Loads or Equivalent Processes". The overall goal of this process is to restore and maintain water quality in Cascade Reservoir and its tributaries to a level that protects designated beneficial uses.

As stated in the Phase I management plan: "It is important to note that correction of water-quality problems in Cascade Reservoir will not happen overnight. Successful implementation of this plan requires a coordinated effort of planning and best management practice implementation involving concerned government agencies and land owners in the watershed over the next several years."

Acknowledgments

Hundreds of hours have been expended in the preparation of this document by volunteers, agency personnel and many others. We gratefully acknowledge the time and effort that have been dedicated by so many individuals and organizations whose help and support have been indispensable. Their continuing support is very much appreciated, indeed, critical to the success of this project.

We would like to acknowledge efforts of the Boise and Payette National Forests, Boise Cascade Corporation, the Idaho Soil Conservation Commission, the Idaho Department of Agriculture, the Idaho Department of Fish and Game, the Idaho Department of Lands, the Idaho Department of Water Resources, the Natural Resources Conservation Service, the Bureau of Reclamation, the Valley Soil and Water Conservation District, Valley County, the City of Cascade, the City of McCall and the Cascade Reservoir Association for their participation in meetings, contributions of important background information and their assistance with management and implementation of the project.

On behalf of the DEQ, we wish to expressly acknowledge the Cascade Reservoir Coordinating Council, the Technical Advisory Committee and all the Source Plan workgroups for their support in this effort.

Finally, we thank the citizens of the State of Idaho and surrounding states for their support of the recreational attributes of Cascade Reservoir, and their expressed concern and participation in its restoration.

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1.0 Executive Summary

Cascade Reservoir Water-Quality Concerns:

Segment Identifier:	PNRS# 884, HUC 17050123
Pollutants of Concern:	Nutrients, Dissolved Oxygen, pH
Uses Affected:	Fishing, Swimming, Boating, Agricultural Water Supply
Known Sources:	Point Sources - Waste-Water Treatment Plant and Fish Hatchery Non Point Sources - Agriculture, Forestry, Urban/suburban, Internal Recycling, Septic Tanks

Cascade Reservoir is located in the Payette River Basin of southwestern Idaho. Major tributaries to the reservoir include the North Fork Payette River (NFPR), Mud Creek, Lake Fork, Boulder Creek, Gold Fork River and Willow Creek, all of which discharge into the northern end of the reservoir. The overall watershed is divided into seven separate subwatersheds on the basis of drainage areas to these tributaries: NFPR, Mud Creek, Lake Fork, Boulder/Willow Creek, Gold Fork River, Cascade and West Mountain.

The Cascade Reservoir Watershed encompasses approximately 357,000 acres located in a moderately high elevation valley between West Mountain and the Salmon River Mountains. The watershed contains two major drainages: Big Payette Lake drainage area, located in the northern end of the watershed, and the direct drainage area to Cascade Reservoir (the area included in this watershed management plan) which covers approximately 300,980 acres. A major portion of the watershed is steeply-sloped forested land, while the area immediately adjacent to the reservoir and major tributaries is predominantly shallow-sloped agricultural land. Elevation of the valley floor and reservoir is approximately 4850 feet. Only minor changes in local relief occur on the valley floor, while elevation increases sharply once into the forested lands. Anthropogenic features such as ponds, irrigation ditches and diversions dominate the flow of water within the watershed. Predominant stream-flow within the watershed is north to south along the length of the valley.

Cascade Reservoir was created in the spring of 1949 with the completion of Cascade Dam, an earthen structure 107 feet high and 785 feet long, which was constructed across the NFPR, north-northwest of the present day location of the City of Cascade. Congress authorized construction of the reservoir to provide storage for irrigation and power generation at Black Canyon Dam on the main stem Payette River near Emmett, Idaho. Full storage was reached in 1957. The reservoir is 21 miles long, 4.5 miles wide at the widest point and is relatively shallow, measuring 26.5 feet in average depth. Cascade Reservoir is operated by the U.S. Bureau of Reclamation (BOR) in correlation with two other reservoirs (Deadwood and Black Canyon) to meet irrigation, hydropower, flood control, recreation and wildlife habitat needs. Maximum storage capacity is 703,200 acre-feet. A 50,000 acre-foot minimum pool has been congressionally authorized, and although the BOR has the authority to lower the reservoir to this level, an administrative decision was made by the BOR in 1984 that a 300,000 acre-foot minimum pool would be maintained. This decision was based on an Idaho Department of Fish and Game study that evaluated the minimum pool required to provide adequate over-winter habitat for fish within the reservoir (Reininger, 1983).

Under section 303(d) of the Clean Water Act (CWA), Cascade Reservoir has been identified as water-quality limited due to excessive phosphorus loading to the reservoir from the surrounding watershed. Nuisance algae growth resulting from nutrient loading has impaired beneficial uses of the reservoir, specifically, fishing, swimming, boating and agricultural water supply. The plan developed for achieving water-quality improvements in Cascade Reservoir has three phases:

Phase I .... Initial water-quality assessment and nutrient reduction goal, approved by EPA May 13, 1996.

Phase II .... Further evaluation of phosphorus reduction goals and alternatives, to be completed by December 31, 1998.

Implementation Plan A subwatershed-specific outline of projects that have been and will be initiated to effect required water-quality improvements within Cascade Reservoir. Will be completed within 18 months of the Phase II document (~June 2000).

Phase III .... Plan evaluation and monitoring summary to determine if modification of management practices is necessary to attain water-quality goals within the reservoir.

Phase I was implemented in January of 1996. The Phase II Watershed Management Plan (Phase II) has been compiled with the purpose of refining and augmenting information available in the Phase I plan. The purpose of both the Phase I and the Phase II management plans is to improve water quality in Cascade Reservoir through the joint efforts of concerned government agencies and land owners. Both the Phase I and the Phase II management plans utilize a watershed management approach to address water-quality concerns, as pollutant sources distributed throughout the watershed drain into the reservoir and impact water quality. This Watershed Management Plan constitutes the functional equivalent of a total maximum daily load (TMDL) (EPA, 1991) and is consistent with Idaho Code 39-3601.

1.1 Public Involvement

As public involvement is viewed as critical for the entire TMDL process, a structured citizen involvement program was established that included a watershed advisory group (WAG), a technical advisory committee (TAC) and other specific work groups. The Cascade Reservoir Coordinating Council (CRCC) functions as the WAG for this TMDL process. Its membership includes nine local representatives appointed by the Boise Regional Office of Division of Environmental Quality (DEQ) from all major sectors of the local community. CRCC members work directly with their respective interest groups to provide direction to DEQ in developing and implementing a watershed management plan, and help identify funding needs and sources of support for specific projects that may be implemented.

The TAC is responsible for reviewing proposed projects to ensure they are consistent with phosphorus reduction goals, are scientifically sound and that monitoring follows scientifically accepted procedures. The membership of the TAC includes scientific and engineering representatives from local, state and federal agencies, industry and municipal staff.

Work groups were formed to generate a "source plan" for each of the designated nonpoint source categories (forestry, agriculture, and urban/suburban) which would assess nonpoint source phosphorus loading. These groups represent a variety of interests common to the source-plan specific land-use activities. The source plans generated were used as data sources for the Phase II document.

1.2 Water-Quality Concerns and Status

The water quality of Cascade Reservoir has been identified as impaired under section 303(d) (1998) of the CWA, due to violations of water-quality standards for dissolved oxygen, nutrients and pH. The reservoir was listed as a high priority for TMDL development.

Beneficial uses for Cascade Reservoir include domestic and agricultural water supply, cold water biota, salmonid spawning, and primary/secondary contact recreation. Those uses that have been found to be at risk are agricultural water supply (toxic algal blooms), cold water biota (depressed dissolved oxygen (DO) and warm temperatures) and primary and secondary contact recreation (toxic algal blooms).

Applicable Water-Quality Standards and Criteria

Numerical standards for pH (6.5 to 9.5 standard units), temperature (Cold Water Biota: 22 °C daily maximum, 19 °C maximum daily average; Salmonid Spawning: 13 °C daily maximum, 9 °C maximum daily average, during time periods designated for salmonid spawning and incubation) have been established by the State of Idaho (IDAPA 16.01.02), and dissolved oxygen in lakes and reservoirs (≥6 mg/L at all times, except for the bottom 20% of water depth in lakes and reservoirs where depths are thirty-five (35) meters or less, and hypolimnion waters in stratified lakes and reservoirs). These parameters represent regulatory standards for Cascade Reservoir.

Narrative criteria for nutrients state that waters should be free from excess nutrients that can cause visible slime or other nuisance aquatic growths impairing designated beneficial uses (IDAPA 16.01.02.200.06). Coliform bacteria standards have also been established for primary and secondary contact recreation (IAPA 16.01.01.250).

Historical data

Approximately 30 years of water-quality data is available for Cascade Reservoir and the surrounding watershed. Initial monitoring consisted of the evaluation of fish-habitat by Idaho Department of Fish and Game (IDFG) and water-quality parameters by the BOR. Further studies of water quality in Cascade Reservoir (Clark and Wroten, 1975; Klahr, 1988; Klahr, 1989; Entranco, 1991; Ingham, 1992; Worth 1993 and 1994) have indicated significant impairment resulting from excess nutrients entering the reservoir through tributary and diversion inflow, and overland runoff.

In 1975, Clark and Wroten reported that water quality within the reservoir was good yet slightly eutrophic, noting that ortho-phosphate was conducive to algae growth. Later reports demonstrated that phosphorus was entering the reservoir from point and nonpoint sources (primarily spring runoff and irrigation returns). Continued inputs of phosphorus and fluctuations in water level within the reservoir have led to eutrophic conditions.

Routine, scheduled monitoring was started by DEQ and other agencies for specific inlake sites in 1992, and in 1993 for all major tributaries. In 1993, pollutant loads and an unusual runoff pattern combined to produce dense mats of blue-green algae on the reservoir. In September, 23 cattle died as a result of ingesting toxins produced by the blue-green algae (Long Valley Advocate, 1993). As a result, health advisories were issued by DEQ discouraging contact with the reservoir water. Unfortunately, 1994 was a low water year. The high pollutant loads in 1993, combined with the reduced reservoir volume and lows flows of 1994 resulted in decreased dissolved oxygen levels due to algal growth and decay, warmer water temperatures produced by low water levels and increased sediment phosphorus release. This series of events resulted in a substantial fish kill affecting nearly all species of fish, and impacted beneficial uses for both 1993 and 1994.

Data collected for water years 1995 and 1996 (both slightly above average precipitation) indicate increased flow volume and subsequent increases in water quality, although the listed standards and criteria were not achieved. Fisheries within the reservoir rebounded to some extent but have not regained their pre-1993 status.

Water-quality data reveal that a significant phosphorus load is carried in the increased flows present during spring runoff. Poor conditions within the watershed, especially within the riparian areas, may be contributing to this situation. As spring flows increase, degraded riparian areas contribute to increased phosphorus loads with accelerated runoff due to inadequate sediment and ground-water holding capacities.

There are several major indicators of water-quality impairment for Cascade Reservoir. Algae blooms represent the most obvious visual indication of poor water quality. In mid to late summer, dense algae blooms are noticeable on the water surface. As a visual indicator, algae blooms are occurrences of concern to the local population and to the transient tourist population utilizing the reservoir. Additional key indicators of water-quality impairment within the reservoir are increased nutrient and decreased dissolved oxygen concentrations. Both of these analytical indicators are directly related to the algal growth. Nutrients (most notably phosphorus) represent a primary algal food source and dissolved oxygen is depleted as algae die, sink below the surface and decompose. During the summer months, substantial oxygen depletion occurs in the lower depths of the reservoir as the algae settle within the water column.

Because of the direct relationship between algal growth, depleted dissolved oxygen and high total phosphorus concentrations within the water column, the reduction of total phosphorus input to the reservoir is being specifically targeted as a mechanism for overall water-quality improvement. Historical monitoring data for total phosphorus measurements represent the most complete and reproducible data set available for the watershed. For this reason, total phosphorus measurements were targeted for both load estimation and reduction allocations. Ortho- and bioavailable phosphorus represent the portion of phosphorus readily available for uptake by aquatic organisms. Total phosphorus is a measurement of all phosphorus that may *ever* be available for biological uptake, thus offering an estimation of long-term availability within the watershed. Total phosphorus loading modifications have been addressed through the load allocations and reductions discussed below. Dissolved oxygen and pH modifications will be addressed through activities implemented for phosphorus load modification resulting in reduced algal growth.

It should be noted that because of the complex hydrology within the watershed and the lack of available data on bedload sediment and delivery, only suspended loads were evaluated for the purpose of this document. Interpretation of the values presented and the conclusions drawn should be made with these considerations in mind.

1.3 Pollutant Source Inventory

As part of the plan to improve the water quality in Cascade Reservoir, phosphorus contributions from point and nonpoint sources have been evaluated.

Point Source Pollution

There are two point sources of pollution to Cascade Reservoir, the McCall wastewater treatment plant (WWTP) and the IDFG fish hatchery in McCall. Both sources discharge nutrients and other pollutants directly to the NFPR upstream of Cascade Reservoir under NPDES permits. For the purposes of this document, the major pollutants of concern associated with the WWTP and IDFG fish hatchery discharge are nutrients, predominantly phosphorus. Since 1988, annual total phosphorus loading from the McCall WWTP effluent has remained relatively stable, ranging from 3815 kg to 4751 kg annually. Following changes in feeding management practices at the IDFG fish hatchery, total phosphorus loads have fallen from 726 kg/year (average) to 218 kg (average) total phosphorus annually.

Nonpoint Source Pollution

Major nonpoint sources of phosphorus within the watershed include forestry, agricultural and urban/suburban management practices, and internal recycling of nutrients within the reservoir. Due to the complexity inherent in the evaluation of nonpoint sources, each of these major categories was evaluated separately.

Forestry Management Sources

A total of 184,092 acres are included in the forestry land-use designation of the watershed, representing 66.6% of the total land area. Forestry management practices include timber harvest and related activities such as road construction and use and livestock grazing on forested allotments. The major pollutant associated with forestry management practices is sediment which may contain phosphates and carry adsorbed nutrients. Traditional timber harvest activities can result in increased sediment loads within the watershed due to construction of roads, erosion of road surfaces, landslides on destabilized slopes and erosion of harvest areas. Recreational use of existing forest roads also contributes to the overall sediment load. The geology of forested lands within the Cascade Reservoir Watershed is conducive to erosion and sediment production. Predominant lithology is granite and related basaltic rocks that are decomposing to unstable, easily transportable sediments. Nearly all forested areas within the watershed have an extensive network of roads which increases sediment yields. Local lithology also contributes to landslides. Most slides are due to natural causes but some are management induced.

Impacts from grazing practices include increased sediment and nutrient loading due to erosion of stream bank areas destabilized by animal impacts and waste deposition. As grazing animals frequent streambank areas due to easy access to water, wastes are often deposited directly in the stream channel. Grazing often results in decreased stubble height and damage to riparian areas due to removal of vegetation and hoof action on stream bank sediments.

Agricultural Management Sources

A total of 66,344 acres were identified under agricultural land-use within the watershed, representing 24% of the total land area. Irrigated pasture land (used for grazing cattle) accounts for the majority of the agricultural land-use acres. Pollutants associated with agricultural practices are sediment and nutrients present in both dissolved and sediment-bound forms. Related impacts are alteration of stream flows and temperatures.

Impacts from grazing practices include direct and indirect effects related to sediment and pollutant loading. Local streams represent the major source of water for livestock and a secondary source of forage. Access to streams is generally unrestricted. The shearing action of hooves on stream banks destabilizes the soil and increases the potential for significant erosion. Grazing cattle also remove or substantially reduce riparian vegetation, thus decreasing stability of stream banks and reducing depositional areas for sediment already within the water column (Platts and Nelson, 1995). Grazing practices also contribute to nutrient loading through the deposition and transport of animal wastes. Manure concentration per unit of land is relatively small but the total grazed-land area is very large and correlates well with major water bodies, resulting in a greater potential for direct transport.

Related impacts include increased water temperatures in the tributaries due to removal of stream side vegetation, allowing greater dissolution of adsorbed phosphorus, sheet and rill erosion from storm events and subsurface compaction of soils. Vegetation in over-utilized pasture areas is commonly insufficient to retain sediment within overland flow and deposited manure is easily transported directly into or down stream within existing stream and irrigation channels (NRCE, 1996).

Practices like sub-flood irrigation that create a substantially increased subsurface flow can also lead to increased phosphorus loading as irrigation recharge and surface runoff created by sub-flood irrigation practices are diverted to local streams or returns as shallow ground-water. These waters generally contain high concentrations of phosphorus and nitrogen compared to ambient concentrations of local streams (Klahr, 1988). These same irrigation systems funnel and accelerate delivery of runoff from snow-melt during spring thaw. In addition, inefficient irrigation water management practices can reduce stream flows unnecessarily, resulting in increased water temperatures.

Impacts from cropping within the watershed are relatively minor due to the small acreages dedicated to crop production. These impacts include those detailed for sub-flood irrigation in the section above and the impacts of fertilizers applied in the production of grains and to establish growth in newly seeded pastures. Fertilizer is reportedly not frequently applied to pastures once growth is established.

Urban/Suburban Sources

Urban/suburban land-use totals 25,945 acres within the watershed, representing 9.4% of the total land area. The major urban/suburban centers in the Cascade Reservoir watershed are the incorporated cities and city impact areas of Cascade (population ~1120), Donnelly (population ~200) and McCall (population ~2600). A significant increase in population occurs during summer months when part-time residents and tourists frequent the area. Most of the City of Cascade is located outside the hydrologic drainage of the Cascade Reservoir. Runoff from Donnelly discharges into Boulder Creek and Willow Creek. Approximately half of the City of McCall is within the drainage of the North Fork of the Payette River. Pollutant sources of concern associated with urban runoff include nutrients, sediment from erosion of conveyance systems, oils, pesticides and bacteria.

Subdivisions aggregated around the north end, on the west side and in the southwest reach of the reservoir have been identified as potential nutrient source locations due to inadequate retention time and treatment of septic tank effluent. Both locations are dominated by high ground-water tables, evidence of ground-water contamination, high septic tank density and poor soil types.

Potential impacts from recreational activities are varied, ranging from increased erosion potential caused by irresponsible off-road vehicle use to direct contamination of surface water by personal water craft or accidental fuel spills. Pollutants of concern generated by recreational use of the watershed include (but are not limited to) hydrocarbons from outboard motors, organic material from fish cleaning, potential bacterial contamination from human waste (improper sanitary disposal) and addition of nutrients, grease and oils from parking lot runoff at camp grounds and boat ramps. Sediments are also contributed by erosion of banks around popular beach areas and camping sites.

Internal Recycling and Reservoir Water Levels

Phosphorus contained in reservoir bed sediments represents a significant loading source to the water column. Increased phosphorus release from bed sediments has been observed under anaerobic conditions. Low dissolved oxygen levels lead to sediment release of bound phosphorus in this manner. Availability of sediment-bound phosphorus and potential leaching into surface water can also be affected by operational conditions controlling the water depth over the reservoir sediments. Fluctuating water levels that periodically expose lake sediments or alter the aerobic/anaerobic conditions at the sediment/water interface affect the sink/source characteristics of these sediments. Under annual drawdown conditions, sediment phosphorus availability may be increased, further contributing to the enrichment of the water column and increased algal productivity.

Data gaps have been identified within NFPR and Cascade subwatersheds. While accurate calculation of total measured annual phosphorus loading for NFPR is possible from monitoring data, the total amount of phosphorus attributable to bank erosion is currently under study. No consistent monitoring data is available for the Cascade subwatershed. Load and reduction allocations have been estimated using available information on land-use practices and comparing specific land-use acreages and flow volumes to other, similar subwatersheds for which comprehensive monitoring is available.

1.4 Water-Quality Targets

Load capacity has been assessed on the achievement of inlake water-quality targets based on numerical standards for phosphorus (0.025 mg/L inlake total phosphorus concentration), chlorophyll a (10 μg/L inlake chlorophyll a concentration) and dissolved oxygen (concentrations exceeding 6 mg/L at all times, with the exceptions listed previously). These targets, based on water-quality modeling efforts for Cascade Reservoir, were set to achieve full support of designated beneficial uses (specifically fishing, swimming, boating and agricultural water supply). Pollutant loads are allocated as kg/year total phosphorus. Load capacity was divided among load allocations, waste-load allocations and a margin of safety.

1.5 Load Capacity

To evaluate load capacity for the reservoir, monitoring data was used to calibrate and validate two computer models specific to Cascade Reservoir. The revised Cascade Reservoir 1-D Model (Worth, 1997; Chapra, 1990) and the BETTER Model (Bender, 1997) were used to simulate changes in reservoir total phosphorus and chlorophyll a concentrations in response to changes in total phosphorus contributed by the subwatersheds. The results of the computer modeling were used to determine the level of phosphorus loading resulting in acceptable water-quality concentrations. The maximum acceptable total phosphorus loading value generated was about 70% of the averaged total phosphorus loading measured by instream tributary monitoring, thus requiring a 30% overall load reduction. To further assure attainment of water-quality standards inlake and to account for the precision of monitored values, and confidence intervals on estimated values and assumptions made, a 7% margin of safety (MOS) was established, making the total required reduction 37%.

1.6 Estimates of Existing Pollutant Loads

An annual phosphorus load allocation was established for Cascade Reservoir using measured total phosphorus loads for water years 1993 through 1996. External contributions of total phosphorus (measured in kg/yr) from point and nonpoint sources were evaluated to determine current loading and establish a quantitative value from which appropriate reduction levels could be assessed. The water years evaluated represent both above average and below average precipitation levels. Existing monitoring data was combined with modeling results to allow reasonably accurate estimates of the subwatershed loads generated by each of the major land-use categories (forestry, agriculture and urban/suburban). The loads estimated by this modeling process were then summed to provide a total estimated load contribution specific to each subwatershed. The relative percentage of the total estimated management load was determined for each land use within the watershed. This percentage (combined with the appropriate percentage of the natural load identified for that subwatershed) was applied to the total measured load for each subwatershed. In this manner, it was possible to account for differences in load contribution specific to land use within a subwatershed.

Estimated nonpoint source runoff accounts for the majority of phosphorus input to the reservoir, averaging 83% in an assessment of current and historical monitoring data. Estimated point source loading averages 9.5%. Phosphorus contribution from septic tank effluent was estimated at 5.5% of the total load. Contributions of phosphorus from direct rainfall were based on precipitation data, applying a phosphorus content of rainfall (assumed equal to 0.05 mg/L) and multiplying by the volume of direct rainfall/snowfall in the water budget. Actual measurements of phosphorus content in rainfall have not been obtained and could be underestimated in the loading budget. Internal recycling was estimated as representing roughly 8,700 kg total phosphorus annually. However, it should be noted that seasonal and annual variance associated with nonpoint sources and internal recycling are likely to be significant, and actual contributions are expected to vary considerably under differing limnological conditions.

Calculations of natural contribution were made specific to slope and vegetative cover throughout the subwatersheds. The natural contribution from shallow-sloped acreages (<12%) was assessed as the sum of sheet and rill erosion and snow-melt based erosion. The natural contribution of total phosphorus from steeply-sloped acreages ($\geq$12%) was calculated using a combination of long-term monitoring data available in subwatersheds with little or no recent management activities and computer modeling by both Boise Cascade Corporation and the US Forest Service for estimation of erosion based sediment loads. Both soil creep and mass-wasting events (e.g. landslides) were accounted for. Additionally, a sediment transmittance factor for Little Payette Lake and the background contribution from Big Payette Lake were assessed.

1.7 Load Allocations

As part of this plan to improve the quality of water in Cascade Reservoir, the 37% total phosphorus reduction identified is anticipated to result inwater-quality improvements that attain the desired water-quality objectives of 0.025 mg/L total phosphorus and 10 µg/L chlorophyll a in the reservoir. Reductions required are based on assessment of the maximum inlake load that can be sustained without beneficial use impairment. Reductions were assessed at the level required to achieve the inlake water-quality objectives for phosphorus concentration.

To accomplish this overall reduction, point-source reductions totaling 7% of the total phosphorus load, and nonpoint-source reductions totaling 30% of the total phosphorus load (management load plus natural and/or background load) have been calculated on both a subwatershed and a subwatershed land-use basis. In the NFPR, the subwatershed load allocation reflects full (100%) removal of the City of McCall's WWTP, the changes in feeding management practices already in place for the IDFG fish hatchery, and a 30% reduction of all nonpoint sources. In all nonpoint-source reduction allocations, a 30% reduction of the total load (management load plus natural and/or background load) is possible from management sources alone. Attainment of the 30% overall nonpoint-source reduction may be difficult in some subwatersheds (i.e. Gold Fork) where natural phosphorus loads represent the majority of the total load. It should be understood that an overall reduction of 30% of the nonpoint-source total phosphorus load (management load plus natural and/or background load) is required to reach water-quality standards. It is recognized that efficient use of management efforts and available implementation monies should be of primary concern. Therefore, it is reasonable to expect that the 30% nonpoint source reduction goal may be reached by implementation measures resulting in greater than 30% in some subwatersheds to offset less than 30% reductions in others.

1.8 Compliance Strategy

Success in reducing the current annual load of total phosphorus will be measured by comparing individual subwatershed allocations with the measured contributions monitored at or near the mouth of major tributaries.

DEQ will rely upon existing authorities and voluntary implementation of additional phosphorus reduction measures to achieve the goals and objectives of this plan. Attainment of water-quality objectives and full support of beneficial uses for Cascade Reservoir, as demonstrated by this plan, will require a significant long-term coordinated effort from all pollutant sources throughout the watershed.

For point source discharges of pollutants subject to NPDES permits, DEQ will ensure achievement of water-quality goals established in this plan through water-quality certifications provided in Section 401 of the CWA.

For nonpoint sources, the feedback loop will be used to achieve water-quality goals. DEQ and other involved agencies will conduct instream and/or qualitative effectiveness monitoring throughout the watershed to evaluate the overall effectiveness of best management practices (BMPs) and other restoration projects in reducing phosphorous loading. If BMPs and other restoration projects prove ineffective they will be modified to ensure effectiveness of existing and future projects. Any modifications to required BMPs will be subject to state rule-making requirements. DEQ will work closely with the CRCC, applicable resource agencies and affected parties to review the existing regulatory authorities and determine if there is a need for additional requirements for nonpoint sources activities to achieve the goals of the plan.

DEQ's regulatory and enforcement authorities are generally set forth in the Idaho Environmental Health and Protection Act of 1972, as amended (See Idaho Code Sections 39-101 *et. seq.*).

Within 18 months of the approval of the Phase II Watershed Management Plan, an implementation plan will be prepared identifying specific areas and measures to be taken to reach the 37% reductions outlined above. Following the approval of the implementation plan, a Phase III document will be prepared (December 2003) using monitoring data to evaluate progress toward attainment of water-quality standards and support of designated beneficial uses. If goals are being reached, or if trend analysis indicates that improvements made are substantial enough to result in attainment of water-quality objectives within a reasonable time frame, the watershed management plan will be a success. If not, the plan will be revised and will outline new goals and a new implementation strategy.

2.0 Subbasin Assessment

Introduction

The Federal Water Pollution Control Act (FWPCA) is the primary federal legislation that protects surface waters such as lakes and rivers. This legislation, originally enacted in 1948, was further expanded and enhanced in 1972; at this time it became known as the Clean Water Act (CWA). The main purpose of the CWA is the improvement of water quality through restoration and maintenance of the physical, chemical and biological integrity of water systems. The CWA provided a mechanism whereby waters can be evaluated, beneficial uses determined and water-quality criteria established to protect designated uses.

In addition, section 303(d) of the CWA requires that every two years, each state submit a list to the EPA identifying waters throughout the state that are not achieving state water-quality standards in spite of the application of technology-based controls in National Pollutant Discharge Elimination System (NPDES) permits. The waters identified on the 303(d) list are known as "water-quality limited". For each water-quality limited segment, the CWA requires that a total maximum daily load (TMDL) be developed for all pollutants responsible for the impairment of protected uses. Once the state has identified the pollutant load discharged from both point and nonpoint source activities, controls can be implemented to reduce the daily load of pollutants until the water body is brought back into compliance with water-quality standards. Once developed, TMDLs are submitted to the EPA for approval. The Idaho Department of Health and Welfare, Division of Environmental Quality (DEQ) is directed by state statute (see Idaho Code § 39-3601 *et seq.*) to develop TMDLs.

Under section 303(d) of the CWA, Cascade Reservoir has been identified as water-quality limited due to excessive phosphorus loading to the reservoir from the surrounding watershed. Nuisance algae growth resulting from nutrient loading has impaired beneficial uses of the reservoir, specifically, fishing, swimming, boating and agricultural water supply. The plan, developed for achieving water-quality improvements in Cascade Reservoir, has three phases:

Phase I .... Initial water-quality assessment and nutrient reduction goal, approved by EPA May 13, 1996.

Phase II .... Further evaluation of phosphorus reduction goals and alternatives, to be completed by December 31, 1998.

Implementation Plan A subwatershed-specific outline of projects that have been and will be initiated to effect required water-quality improvements within Cascade Reservoir. Will be completed within 18 months of the Phase II document (~June 2000).

Phase III .... Plan evaluation and monitoring summary to determine if modification of management practices is necessary to attain water-quality goals within the reservoir.

Phase I was implemented in January of 1996. The Phase II Watershed Management Plan (Phase II) has been compiled with the purpose of refining and augmenting information available in the Phase I plan. The purpose of both the Phase I and the Phase II management plans is to improve water quality in Cascade Reservoir through the joint efforts of concerned government agencies and land owners. These efforts will include both planning for future growth and development and the implementation of best management practices (BMPs) on existing and new land uses.

The purpose of this document (in conjunction with the approved Phase I document, and the pending Implementation Plan and Phase III documents) is to address listed pollutants specific to Cascade Reservoir, namely nutrients (phosphorus), dissolved oxygen, and pH. This document is intended to be specific to Cascade Reservoir only. Because a watershed-based approach is being used to meet in-lake water-quality objectives, other tributaries and their drainage areas are included in the management plan as "inputs" to the reservoir. It is hoped that BMPs and other projects associated with the management plan will result in improved water quality in the listed stream segments associated with the watershed, but this document is not intended to address specifically those pollutants for which the associated tributaries are listed.

Both the Phase I and the Phase II management plans utilize a watershed management approach to address water-quality concerns, as pollutant sources distributed throughout the watershed drain into the reservoir and impact water quality. The watershed has been divided into seven separate subwatersheds in an effort to address water-quality concerns and community/land-use management practices on a more localized or site-specific scale. This Watershed Management Plan constitutes the functional equivalent of a TMDL (EPA, 1991) and is consistent with Idaho Code 39-3601.

2.1 Characterization of the Watershed

2.1.1 Physical and Biological Characteristics

Cascade Reservoir is located in the Payette River Basin of southwestern Idaho (Figure 2.1). The headwaters originate in Upper Payette Lake, which drains into Big Payette Lake, the outflow of which is the North Fork Payette River (NFPR). The NFPR flows in a southerly direction for approximately 30 miles before emptying into Cascade Reservoir. Below the reservoir, the NFPR discharges into the Main Payette River near Banks, Idaho, 35 miles downstream. Major tributaries to the reservoir include the NFPR, Mud Creek, Lake Fork, Boulder Creek, Gold Fork River and Willow Creek, all of which discharge into the northern end of the reservoir. The overall watershed is divided into separate subwatersheds on the basis of drainage areas to these tributaries. As listed in the Phase I document, there are twelve subwatersheds within the Cascade Reservoir Watershed, nine of which drain more or less directly into Cascade Reservoir. The latter are addressed in this plan and include the NFPR, Mud Creek, Lake Fork, Boulder Creek, Gold Fork River, Willow Creek, Kennally Creek, Cascade and West Mountain. Slight subwatershed boundary changes were made from those designated in Phase I because the availability of cartographic coverages at a finer scale allowed greater accuracy in delineation. As in Phase I, Kennally Creek is included in the Gold Fork

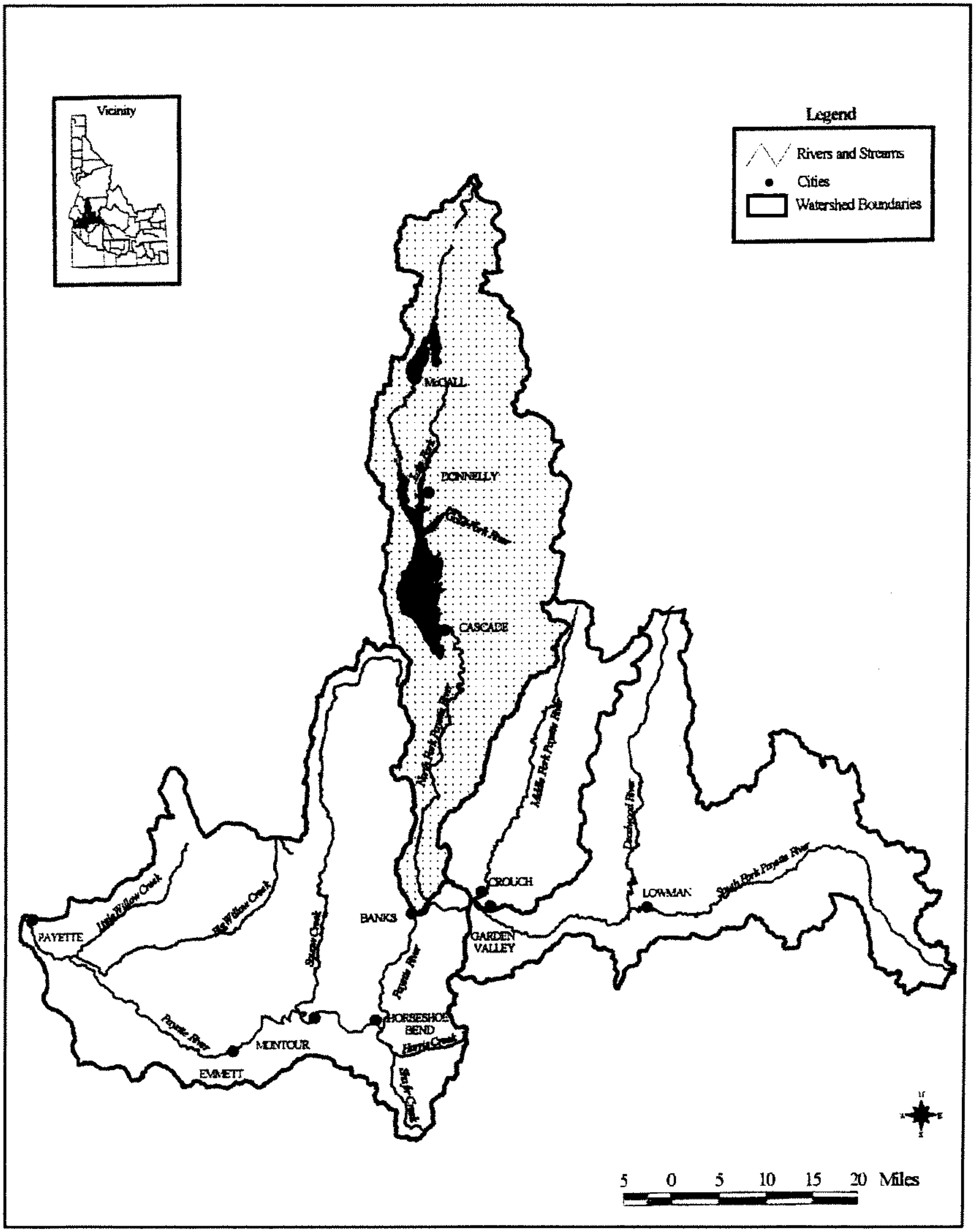


Figure 2.1 Payette River Basin map showing the location of the Cascade Reservoir Watershed.

River subwatershed because it drains into Gold Fork River, which in turn drains directly into the reservoir. Also as in Phase I, Lake Fork above Little Payette Lake has been combined with the lower portion of that subwatershed. Drainage area above Big Payette Lake is a separate subwatershed that has been addressed directly in an individual subwatershed management plan, the Big Payette Lake Management Plan (BPLWQC, 1997). The major difference in subwatershed designation between Phase I and Phase II is the combination of drainage areas for Boulder and Willow creeks. Designated as separate subwatersheds in Phase I, these areas were combined to form a single subwatershed for Phase II. This change was made because of the high degree of communication between the two tributaries due to the connectivity of irrigation diversions. Given these delineations, there are seven primary subwatersheds within the Cascade Reservoir Watershed as designated by this plan (Figure 2.2).

The Cascade Reservoir Watershed (part of HUC 17050123) encompasses approximately 357,000 acres located in a moderately high elevation valley between West Mountain and the Salmon River Mountains. Direct drainage area to Cascade Reservoir included in this watershed management plan covers approximately 300,980 acres. A major portion of the watershed is steeply-sloped forested land, while the area immediately adjacent to the reservoir and major tributaries is predominantly shallow-sloped agricultural land. Elevation of the valley floor and reservoir is approximately 4850 feet. Only minor changes in local relief occur on the valley floor, while elevation increases sharply once into the forested lands. The highest point in the watershed is 8322 feet elevation at Snowbank Mountain, southwest of the reservoir (BOR, 1991).

Cascade Reservoir was created in the spring of 1949 with the completion of Cascade Dam, an earthen structure 107 feet high and 785 feet long, which was constructed across the NFPR, north-northwest of the present day location of the City of Cascade. Congress authorized construction of the reservoir to provide storage for irrigation and power generation at Black Canyon Dam on the main stem Payette River near Emmett, Idaho. Full storage was reached in 1957. The reservoir is 21 miles long, 4.5 miles wide at the widest point and is relatively shallow, measuring 26.5 feet in average depth.

Climate

Temperatures within the watershed range from -40 °F to 100 °F. Seasonal temperatures show a winter average of 19 °F (January) and a summer average of 63 °F (July). The last freeze of the spring season usually occurs around the second or third week of June and the first freeze in the fall usually happens around the third week of August. Mean annual precipitation is 22 inches, roughly 65% of which falls in the winter (October through March) as snow (Rasmussen, 1981). Mean annual snowfall is 107 inches, with two to four feet on the ground throughout the winter season. The reservoir freezes over completely during the winter months. Full ice cover is usually in place by December and lasts until April. Spring weather is commonly cool and wet. Summers are warm and dry. Summer thunderstorms are common, but do not represent a primary precipitation source.

Hydrology

Hydrology of the Cascade Reservoir Watershed is composed of a variety of natural and anthropogenic (human-induced) features. Natural features include streams, lakes, springs and

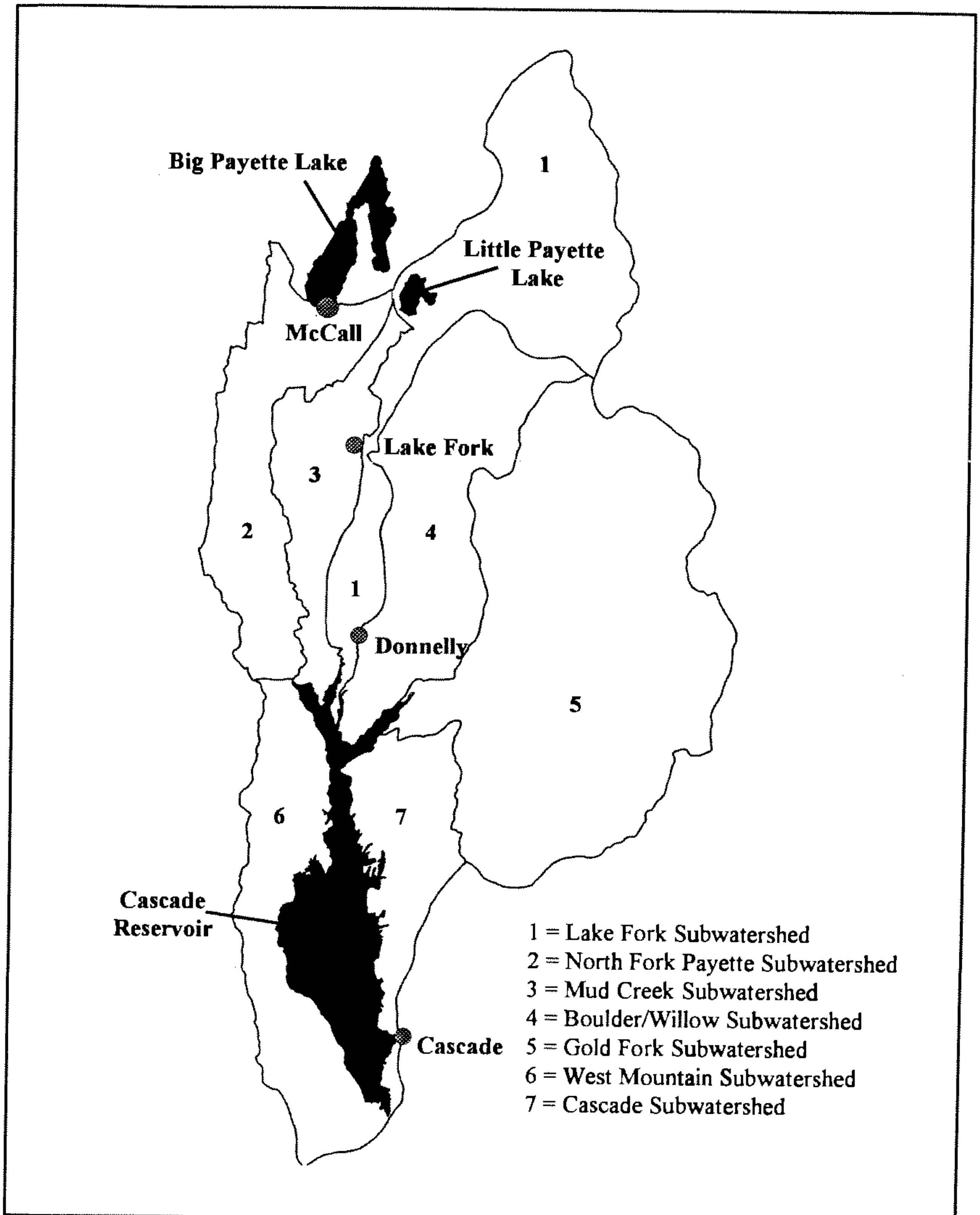


Figure 2.2 Subwatershed boundaries within the Cascade Reservoir Watershed.

wetlands. Anthropogenic features such as ponds, irrigation ditches and diversions dominate the flow of water within the watershed. Predominant stream-flow within the watershed is north to south along the length of the valley. Smaller streams (primarily along the west side of the reservoir) flow from the ridge-lines into the reservoir. The significant number of irrigation diversions and drainage canals within the watershed complicate the identification of flow and transport patterns.

Surface Hydrology. Cascade Reservoir is operated by the U.S. Bureau of Reclamation (BOR) in correlation with two other reservoirs (Deadwood and Black Canyon) to meet irrigation, hydropower, flood control, recreation and wildlife habitat needs. Maximum storage capacity is 703,200 acre-feet. A 50,000 acre-foot minimum pool has been congressionally authorized, and although the BOR has the authority to lower the reservoir to this level, an administrative decision was made by the BOR in 1984 that a 300,000 acre-foot minimum pool would be maintained. This decision was based on an Idaho Department of Fish and Game study that evaluated the minimum pool required to provide adequate over-winter habitat for fish within the reservoir (Reininger, 1983). Previous to the establishment of the 300,000 acre-foot minimum pool, average annual drawdown of the reservoir was 16 feet. This has since been reduced to 12 feet and has served to protect the existing fishery, maintain recreational access and reduce shoreline erosion caused by fluctuating water levels (BOR, 1991). Natural flows (~200 cfs) from the outlet of Cascade Reservoir are maintained during the winter months for power production at Black Canyon Dam. Storage for summer irrigation needs is initiated in the fall of the year and peaks in the early summer. Annual low water levels occur in October, high water levels occur in June. Water is released downstream to serve irrigators directly or to augment storage for Black Canyon Reservoir, where it can be further diverted or released as necessary. Irrigation releases usually start in May/June and end in November. If necessary, the level of Cascade Reservoir may be dropped preceding spring thaw as a flood control measure for downstream areas.

Stream flow within the watershed is characterized by three major events, snow-melt, rain-on-snow and seasonal thunderstorms. Snow-melt runoff is the predominant flow used to fill the reservoir. Natural stream and irrigation channels convey snow-melt runoff to the reservoir and other water bodies in two major events, valley melt (usually occurring in March and April) and mountain snow-melt (usually occurring in June and July) (USFS, 1998). During the irrigation season (June thru October), a significant portion of the total tributary flow is diverted for irrigation of pasture land and fields. The predominant irrigation practice within the watershed is sub-flood irrigation. Water from irrigation ditches is allowed to permeate the surrounding land, resulting in a heavily saturated layer of soil where the water table is at or only slightly below the soil surface. The return flows created by this practice are allowed to drain into existing tributaries or canals, which empty directly into the reservoir. Utilization of sprinkler irrigation systems is increasing slowly.

Ground-Water Hydrology. Ground water within the Cascade Reservoir Watershed can be divided into two major categories: "natural" ground water and irrigation recharge. Natural ground water refers to ground water that is present due to geological and hydrological processes. It occurs at a variety of subsurface levels, but is predominantly located 35 to 400+ feet below the ground surface. Irrigation recharge refers to sub-surface water present due to anthropogenic practices such as sub-flood irrigation. The water applied in such practices is often "perched" between the soil surface and one of several existing clay layers known as "hard-pan" or "clay-pan". These layers occur at various depths within the watershed, from 2 to 10 or more feet below the surface. Because of their relative impermeability they prohibit infiltration of the water to lower levels and promote an artificially raised water table. This water moves under hydraulic pressure toward low lying areas, discharging into existing stream channels through outlets in the stream banks and eventually into the reservoir itself. Vegetation types in sub-flood irrigated fields have been altered toward hydrophillic species throughout the lowlands of the watershed as a result of this artificially induced high water table. Ground-water contributions to Cascade Reservoir have been estimated at <5% of the total reservoir volume (USGS, 1998).

Geology

The Cascade Reservoir Watershed lies within the Idaho Batholith, a formation of crystalline igneous rock of volcanic origin. The Payette River Basin is located entirely within this formation, which covers approximately 20,000 square miles in north and central Idaho. Local lithology is predominantly granite (granite gneiss, mica schist and porphyritic biotite-granite) with some smaller amount of basalt. Major rock outcroppings are highly weathered, decomposing material that is unstable, highly transportable and easily eroded. Soils are primarily coarse textured. Predominant soil types within the valley are Archbal, a deep well-drained strongly acid loam formed in alluvium or glacial outwash occurring in 12 % of the watershed, 30 % of the agricultural land; Donnel, a deep well-drained medium acid sandy-loam soil formed in granitic alluvium and occurring in 5 % of the watershed, 20 % of the agricultural land; and Roseberry, a deep poorly-drained medium acid sandy-loam formed in alluvium or glacial outwash of granitic origin occurring in 7 % of the watershed, 20 % of the agricultural land (Rasmussen, 1981). Soil depths within the watershed are highly variable, ranging from 30 to 40 inches for Donnel and Roseberry soils and from 5 to 8 feet for Archbal soil types over the valley.

There are two major erosional processes within the Cascade Reservoir Subwatershed: surface erosion and mass wasting. Surface erosion is the transport of soil particles from the soil surface. Common causes are meteorological and occur with overland flow caused by snow-melt, rain impact and runoff; and wind or freeze/thaw forces on steep slopes (USFS, 1998). Mass wasting includes all forms of erosion in which large masses of soil are displaced. Typical mass-wasting events may include landslides, earthflows or slumps where unstable soil is the cause of movement, or debris torrents where the rapid movement of water displaces sediment and organic material down stream channels. Both types of erosion can be naturally induced, for example, the soil displaced by an avalanche; or management induced, as in the transport of material from an unstabilized cut-slope on a roadway. A U.S. Forest Service (USFS) study of the Cascade Reservoir Watershed (USFS, 1998) has identified approximately 40 mass-wasting events within the last 30 years. Most of which occurred along West Mountain where steep slopes combine with unstable lithology. Of these slides, roughly 84% were the result of natural processes including avalanche and rainstorm events. Management activities, mainly roads, accounted for the remaining 16% of the mass-wasting events. A similar study by Boise Cascade Corporation (BCC) in the Gold Fork subwatershed identified 173 landslides in the Gold Fork Basin, two of which (1.2%) were management induced (BCC, 1996).

The watershed is transitional ecologically with the western half of the valley found within the Blue Mountains ecoregion (Omernik and Gallant, 1986), which is characterized by mountain ranges separated by fault valleys and synclinal basins. The eastern and northern sections of the watershed are found within the Northern Rockies ecoregion with geology and soils typical of the northern portion of the Rocky Mountains.

Vegetation, Animals and Fisheries

Vegetative communities present within the Cascade Reservoir Watershed are *forestland*, containing a variety of spruce and fir species; *grassland-riparian*, containing shrub, grass and sedge species (both natural and introduced); and *nonriparian*, containing mixed conifers of various types. Species lists given (plant or animal) are not exhaustive or all-inclusive. Non-listed species may be present.

Predominant vegetation on the valley floor is introduced species for animal forage, cultivated for both hay and grazing. These species include bromes, timothy, fescue, clover and alfalfa. Native species in non-irrigated areas of the valley floor include bluebunch wheatgrass, Idaho fescue, lupine, elk sedge, arrowleaf balsamroot and mountain big sagebrush. Riparian vegetation includes sedges, rushes and willows. Mountainous areas are predominantly forested, with major species including Ponderosa pine, Douglas fir and Grand fir. Understory species include pine reedgrass, western thimbleberry, beargrass, elk sedge, Woods rose and snowberry (USFS, 1998; Rasmussen, 1981).

The Cascade Reservoir Watershed supports many natural and stocked fisheries. Fish species present include yellow perch; rainbow, brown, brook and bull trout; coho and kokanee salmon; mountain whitefish; brown bullhead, westslope cutthroat, large-scale sucker, sculpin, dace and northern squawfish. The Idaho Department of Fish and Game (IDFG) stocks the reservoir regularly with coho and kokanee salmon, rainbow and brown trout, small-mouth bass, splake, channel catfish, and tiger muskie. Wildlife populations within the watershed include elk, deer, fox, bear, beaver, cougar, otter, mink, badger, skunk, racoon, porcupine, weasel, coyote and moose. The watershed also supports both migrating and year-round water- and wild-fowl and a diverse population of raptors. Avian species include heron, geese, grebes, eagles, loons, pelicans, swans, forest grouse, ducks, osprey, owls, quail, cranes and a variety of shore and songbirds. Grebe and heron rookeries exist along the western edge and northern arms of the reservoir. A brown bat nursery has been identified near the inflow of the NFPR.

Special Designations. Special Status Plants are plants that are managed under the USFS Regional Sensitive Species Program. Only one Special Status Plant (Tall Swamp Onion) is documented as present within the watershed (Skein Lake). This plant requires marshes, mud flats, or standing water for survival and propagation. These plants tend to favor mid-range to high elevations and are heavily impacted by grazing and recreational activities (USFS, 1998).

The Cascade Reservoir Watershed is potentially home to three species currently listed under the Endangered Species Act: the grey wolf, the peregrine falcon and the bald eagle. Of the three, the bald eagle is the only regularly documented species present. The grey wolf occurs only occasionally in the watershed area, and the peregrine falcon, while historically documented within the watershed, has not been present for over 15 years.

Nine active nesting sites for bald eagles are within the watershed boundaries. Most nesting sites are on the edge of the reservoir, usually within 1.5 km of shore, and occupy USFS, BOR and private land. The eagles use snags, trees with exposed limbs and lateral branches, for perching and nesting. Forage is predominantly fish and small birds. Lack of adequate perch trees, recreational and urban encroachment on nesting and forage territories and poor water quality represent major impacts to bald eagle habitat within the watershed.

2.1.2 Cultural Characteristics

Land Use and Ownership

The watershed is predominantly forested (~67%), both public and private. The largest land owners are the USFS with 41% of the land area within the Boise and Payette National Forests, Boise Cascade Corporation with 14% and the State of Idaho with nearly 9%. Small-acreage, privately owned land accounts for approximately 33% of the drainage area (See Tables 2.1 and 2.2). Much of the private land is used for agricultural purposes (~24%), predominantly cattle ranching. Only a small amount of private land is used for crops. Both pasture/rangeland and cropland are divided into irrigated and non-irrigated categories. Urban and residential areas make up roughly 9% of the total land area (Figure 2.3). Historically, land use in the watershed was primarily forestry/timber and agricultural, with a very small amount of residential property. Land-use trends have recently shown a decrease in agricultural land use and an increase in land designated as subdivisions and rural ranchettes.

Table 2.1 Land ownership within the Cascade Reservoir Watershed.

Ownership	Acres	% of Total Land Area
State of Idaho	23,768	8.6
Bureau of Reclamation	6,013	2.2
Forest Service	113,714	41.1
Bureau of Land Management	2,265	0.8
Boise Cascade Corporation	38,945	14.1
Other Private	91,676	33.2
TOTAL	276,381	100%

Geographic information system (GIS) coverages, satellite imagery, aerial photographs and other cartographic resources were employed in the preparation of this document to determine accurate land-use values for the Cascade Reservoir Watershed on a subwatershed basis (Figure 2.3). Valley County tax assessment records, BCC GIS coverages, Idaho Department of Water Resources (IDWR) land-use coverages and local experience were combined to produce the current information (Table 2.1 and 2.2). It should be noted that there are some differences in land-use designations and acreages between Phase I and Phase II due to differences in the GIS coverage scales used by each document.

Phase I was prepared using existing designations and 1:100,000 scale coverages. Phase II was prepared using updated land-use designations and GIS coverages at a 1:24,000 scale. Slight subwatershed boundary changes were made because of greater accuracy at the finer scale. As explained previously, the drainage areas for Boulder and Willow creek, designated as separate subwatersheds in Phase I, were combined to form a single subwatershed for Phase II due to the connectivity of irrigation diversions. Given the updated coverages available and the finer GIS scale employed, the Phase II values are assumed to represent higher accuracy than Phase I designations.

Table 2.2 Land-use acreage within the Cascade Reservoir Watershed.

Drainage Area	Acres	% of Land Use Area	% of Watershed Area
Forest	**184,092**		**66.6**
Public Forest	139,747	75.9	50.5
Privately Owned Forested Land	44,345	24.1	16.1
Agriculture	**66,344**		**24.0**
Irrigated Crop and Pasture	39,711	59.9	14.4
Non-Irrigated Pasture	812	1.2	0.3
Rangeland	11,268	17.0	4.1
Other	14,553	22.0	5.3
Urban/Suburban	**25,945**		**9.4**
Urban/City Area	3,509	13.5	1.3
Subdivisions	11,741	45.3	4.2
Impact Area	10,695	41.2	3.9
TOTAL DRAINAGE AREA	**276,381**		**100%**

Population

Population centers within the watershed boundaries--McCall, Lake Fork, Donnelly, Roseberry and Cascade, are located in Valley County, primarily along State Highway 55 (Figure 2.4). In addition to the local resident population, tourism and recreational opportunities have created a significant transient (non-county resident) population and vacation home development in many areas. Total population figures for Valley County average approximately 8000 individuals, the majority of which reside in McCall (population ~2600) and Cascade (population ~1120), and in the adjacent unincorporated areas.

History and Economics

Historically, the economy of the watershed was based almost solely on timber harvest and agriculture. Recently however, the balance has shifted toward the service industry, as tourism and recreation in

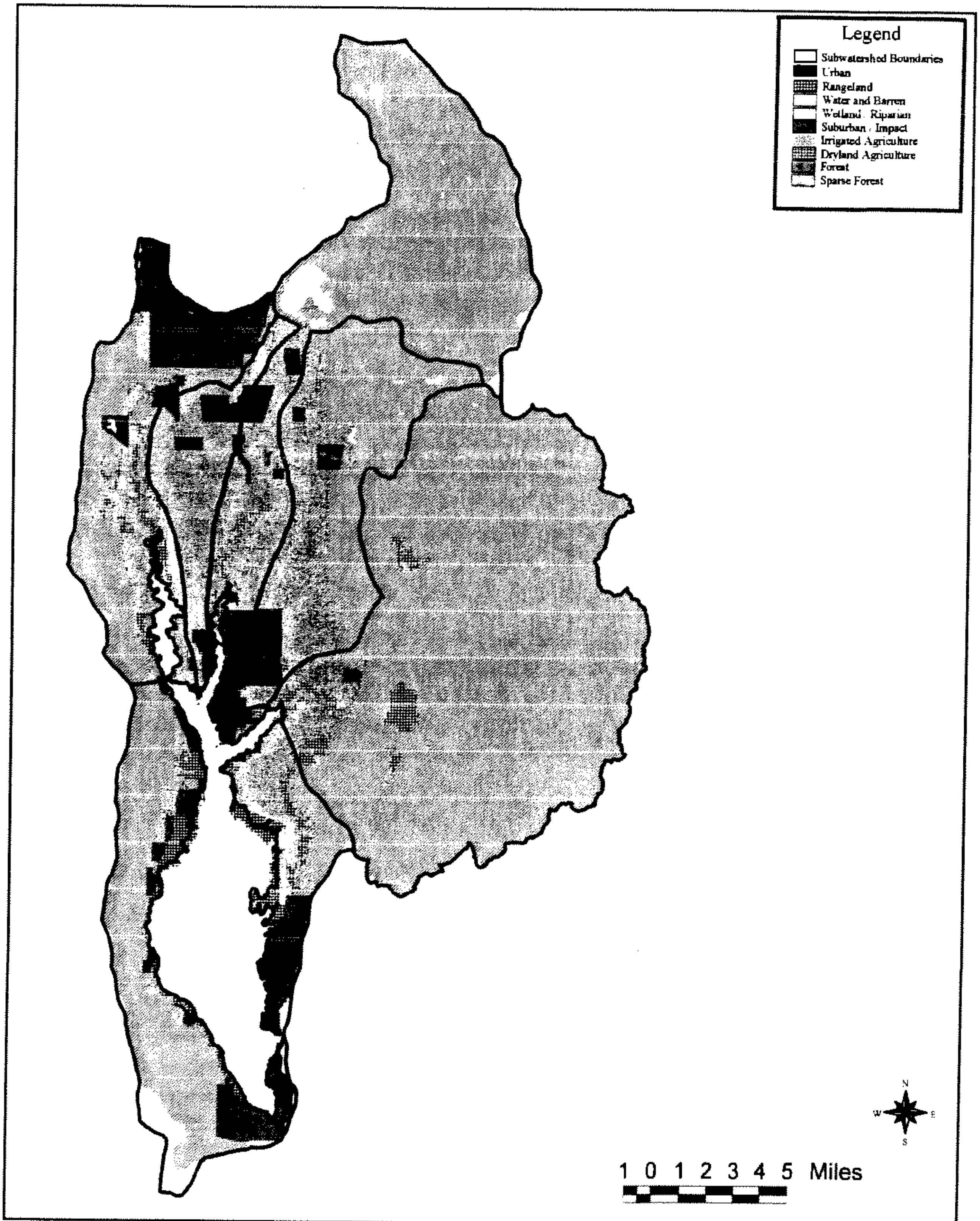


Figure 2.3 Land-use distribution within the Cascade Reservoir Watershed.

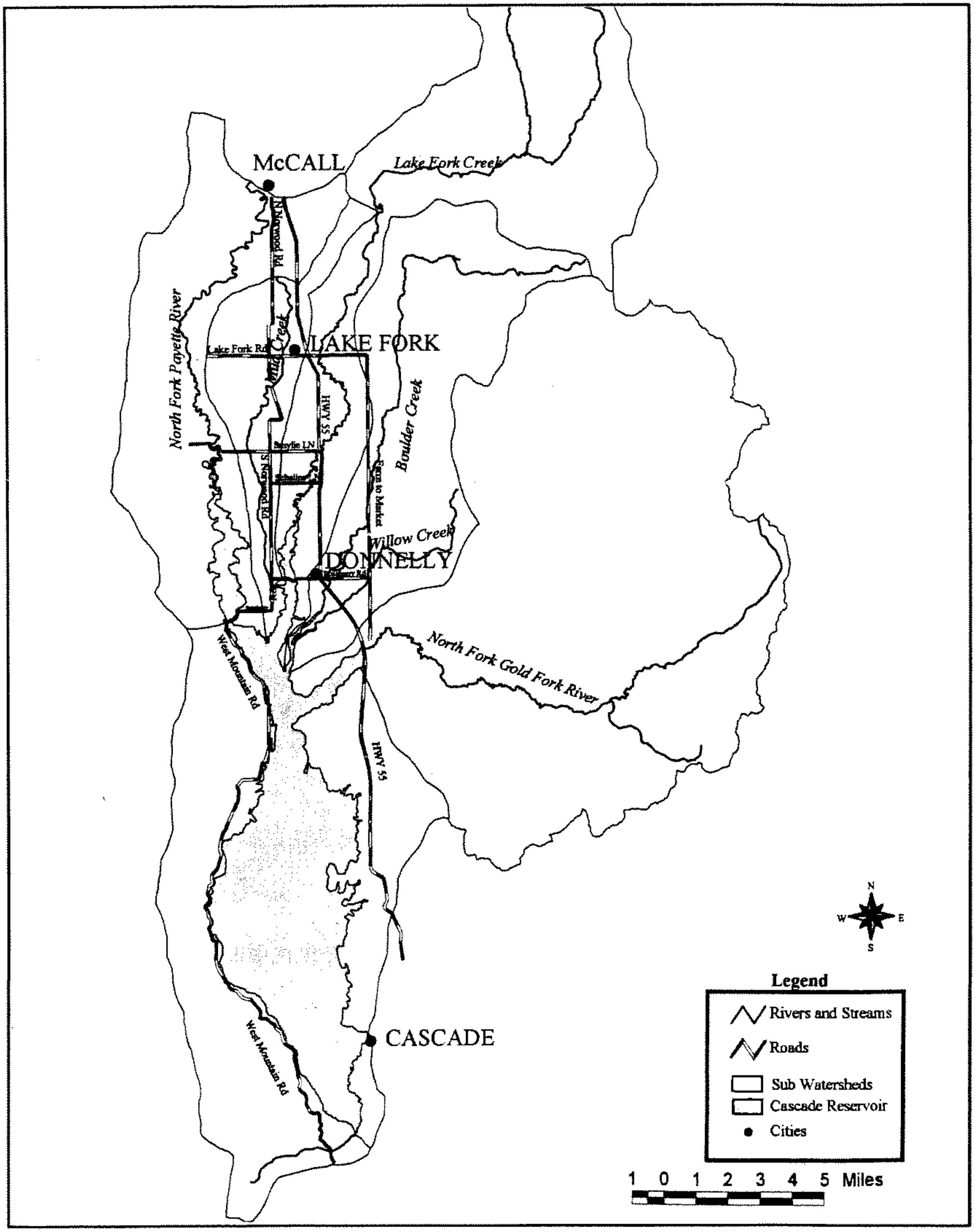


Figure 2.4 Major features of the Cascade Reservoir Watershed.

the area have increased. The current economy of the region, while still dependent on the timber and agriculture industries, is increasingly dependent on tourism, especially in the cities of McCall and Cascade. Smaller communities within the watershed remain heavily dependent on the timber-harvest industry, agriculture and livestock.

Valley County is one of the fastest growing counties in the state of Idaho. The current growth rate of the county is 4.7%, as compared to the state average of 2.9% (ISDC, 1998). The population of Valley County is expected to increase by over 50% by the year 2000. The proximity of Cascade Reservoir to State Highway 55 has contributed to its reputation as a major destination site. Many popular hiking, cycling, cross-country skiing and snowmobiling trails are available to residents and tourists, as are numerous opportunities for fishing, hunting, camping, boating and waterskiing. Popularity as a vacation destination is dependent upon water quality and (perhaps more importantly) perceived water quality within Cascade Reservoir and the surrounding watershed. Historically, Cascade Reservoir ranked first among the fisheries within the state. With the water-quality problems of the past few years however, it has fallen to number eight. While fish habitat within the reservoir rebounded somewhat in 1996 and 1997, estimated reservoir angler-hours for these years show a decrease of greater than 50% from the pre-1993 value. This decrease may be due more to the perceived water quality within the reservoir than to the actual quality of the fishery. This decline, and the accompanying decline in other recreational uses, has had a significant and noticeable impact on the local economy.

Public Involvement

Throughout the phased TMDL process, local experience and participation have been invaluable in the identification of water-quality issues and reduction strategies appropriate on a local scale. Because of the impact of the TMDL process on the local community and the dependence of any implementation plan on local participation, public involvement is viewed as critical for the entire TMDL process. During the compilation of Phase I, a structured citizen involvement program was established that included a watershed advisory group (WAG), a technical advisory committee (TAC) and subwatershed work groups. This program was established so the community could provide direction and leadership in developing and implementing this plan (Figure 2.5). The organizations established have persisted throughout the phased TMDL process and are currently composed as outlined below. A list of committee members is included in Appendix A.

The Cascade Reservoir Coordinating Council (CRCC) functions as the WAG for this TMDL process. Its membership includes nine local representatives appointed by the Boise Regional Office of DEQ from all major sectors of the local community as follows:

- Agricultural interests
- Cascade Reservoir Association
- Citizens at large
- City of McCall
- City of Cascade or Donnelly
- Environmental concerns

- ☐ Sporting or recreational interests
- ☐ Timber interests
- ☐ Valley County Commission

CRCC members work directly with their respective interest groups to provide direction to DEQ in developing and implementing a watershed management plan. They also help identify funding needs

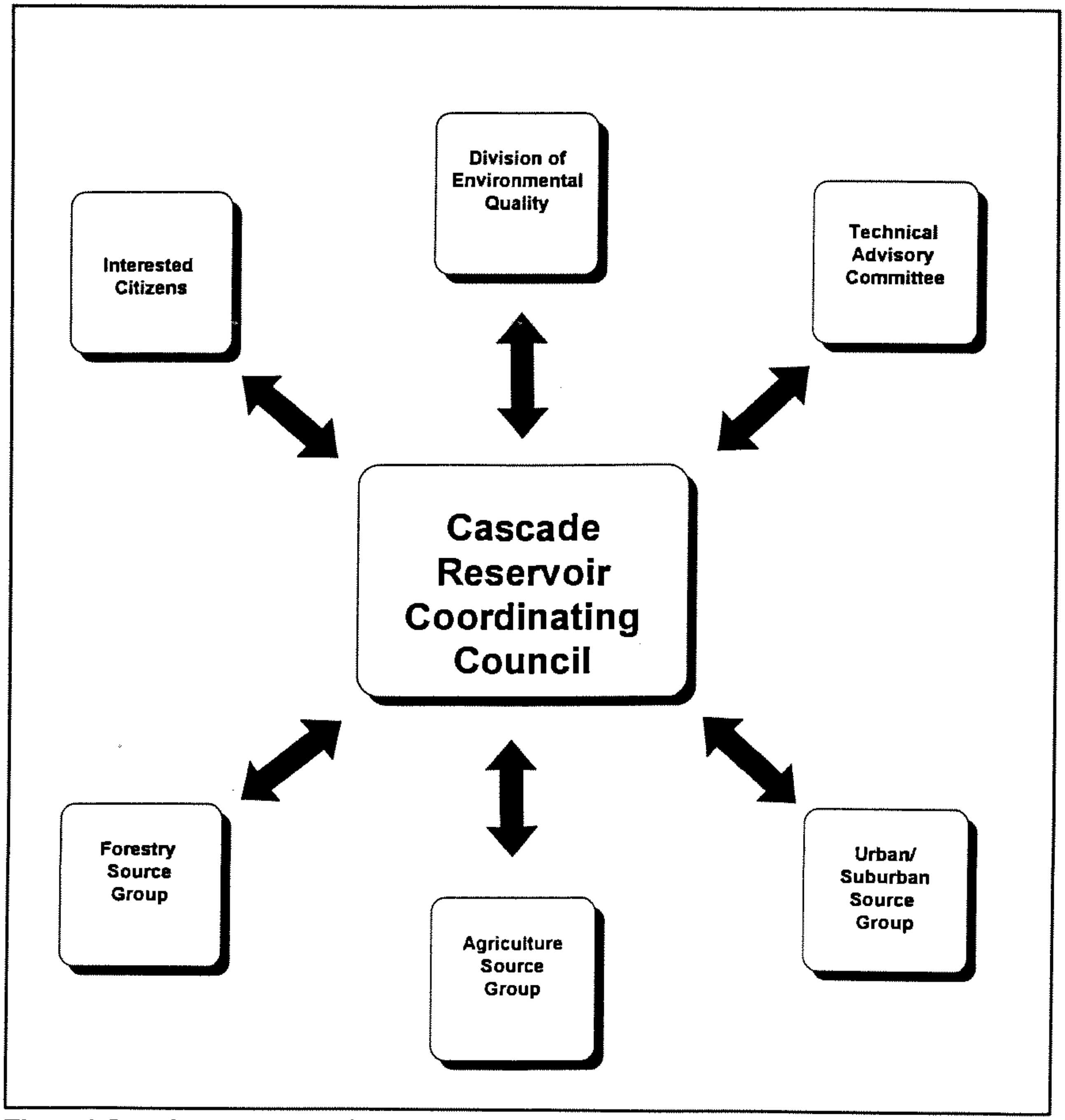


Figure 2.5 Cascade Reservoir Coordinating Council (CRCC) feedback loop.

and sources of support for specific projects that may be implemented. The CRCC assists with management plan implementation by setting priorities for expenditure of restoration funds. The CRCC will periodically review progress toward phosphorus reduction goals.

The TAC is responsible for reviewing proposed projects to ensure they are consistent with phosphorus reduction goals, are scientifically sound and that monitoring follows scientifically accepted procedures. The membership of the TAC includes scientific and engineering representatives from local, state and federal agencies, industry and municipal staff as follows:

- ☐ Boise Cascade Corporation
- ☐ Central District Health Department
- ☐ Idaho Soil Conservation Commission
- ☐ Idaho Department of Lands
- ☐ Idaho Division of Environmental Quality
- ☐ Idaho Power Company
- ☐ Idaho Department of Agriculture
- ☐ Idaho Department Fish and Game
- ☐ Idaho Department of Water Resources
- ☐ Payette Lakes Water and Sewer District
- ☐ USDI Fish and Wildlife Service
- ☐ USDA Natural Resources Conservation Service
- ☐ US Environmental Protection Agency
- ☐ USDI Bureau of Reclamation
- ☐ USDA Forest Service, Boise National Forest
- ☐ USDA Forest Service, Payette National Forest
- ☐ Valley Soil and Water Conservation District

Work groups were formed for each of the designated nonpoint source categories to identify and help assess nonpoint source phosphorus loading. These groups represent a variety of interests common to the source-plan specific land-use activities. The source plan work groups represent a significant resource for the phased TMDL process. It is expected that they will play an active role in the implementation phase of the management plan as well. Separate source plans prepared include:

- ☐ Agriculture Source Plan
- ☐ Forestry Source Plan
- ☐ Urban/Suburban Source Plan

The source plans generated were used as data sources for the Phase II document. (They are available from the Boise Regional Office of DEQ as a separate appendix volume.)

Several organizations within the watershed pre-date the citizens groups established by the TMDL process. These have been actively involved in monitoring and enhancement of water quality within the reservoir. The Cascade Reservoir Association (CRA), established in 1978, has been and continues to be a significant resource for man-power and implementation projects throughout the watershed. Much of the historical water-quality data available is due to the volunteer efforts of this organization. An interagency task force chaired by the Valley Soil and Water Conservation District (VSWCD) predated the current TAC and helped to lay the groundwork for the management process.

2.2 Water-Quality Concerns and Status

2.2.1 Water-Quality Limited Water Bodies

Cascade Reservoir has been identified as water-quality limited because it is not in compliance with Idaho water-quality standards. Designated beneficial uses for the reservoir including fishing, swimming, boating and agricultural water supply are impaired because of nuisance algal growth caused by excessive nutrient loading. The water quality of the reservoir has been identified as impaired under section 303(d) (1998) of the CWA, due to violations of water-quality standards for dissolved oxygen, nutrients and pH. The reservoir was listed as a high priority for TMDL development. A number of additional water bodies in the watershed were added to the water-quality limited list. Specifically, the water bodies and pollutants listed in Table 2.3 are found on the current (1998 draft) 303(d) list.

2.2.2 Applicable Water-Quality Standards

Beneficial Use Classifications for Surface Waters

As stated previously, the CWA requires that each state protect their surface waters from pollution. The State of Idaho has developed and enforced water-quality standards for the protection of state waters. A water-quality standard defines the water-quality goals of a particular water body by designating the use or uses to be made of the water and establishment of numerical and narrative criteria (ambient conditions) necessary to protect the "existing" uses (water-quality standards = designated use + criteria to protect the use). Existing use means those surface-water uses actually attained on or after November 28, 1975, whether or not they are designated uses. The state recognizes uses such as public, agricultural and industrial water supplies, protection and propagation of fish, shellfish and wildlife, and recreation in and on the water when establishing designated uses for water bodies. Idaho has adopted water-quality standards, which are found under the Idaho Department of Health and Welfare (IDHW) Rules, IDAPA 16.01.02, Water Quality Standards and Wastewater Treatment Requirements. Further details on these designations and standards are found in Appendix B.

All waters are protected through general surface water-quality criteria. Narrative criteria prohibit ambient concentrations of certain pollutants which impair designated uses. In Idaho, these criteria include: hazardous materials, toxic substances, deleterious materials, radioactive materials, floating, suspended or submerged matter, excess nutrients, oxygen demanding materials and sediment (IDAPA 16.01.02.200).

Once designated, beneficial uses are protected from impacts that may impair the use through application of numerical and narrative water-quality criteria. Prior to designation, undesignated waters shall be protected for beneficial uses, which include all recreational use in and on the water and the protection and propagation of fish, shellfish and wildlife, wherever attainable.

Table 2.3 Water-quality limited segments (WQLSEG) for the Cascade Reservoir Watershed.

Water Body	WQLSEG	Boundaries	Pollutants	Potential Criteria
Cascade Reservoir	2884	Inflow of NFPR to dam	DO, Nutrients, pH, Pathogens◆	General - nutrients Numerical - DO, Phosphorus
Gold Fork River	2893	Flat Creek to Cascade Reservoir	Nutrients, Sediment	General-nutrients, sediment Numeric- turbidity, intergravel DO
Boulder Creek	2895	Headwaters to Cascade Reservoir	DO, Flow Alteration, Nutrients, Sediment, Temperature	General- nutrients, sediment Numerical- DO, temperature, turbidity, intergravel DO
Mud Creek	2898	Headwaters to Cascade Reservoir	Bacteria, DO, Ammonia, Nutrients, Sediment	General-nutrients, sediment Numerical- DO, ammonia, turbidity, intergravel DO
Campbell Creek ⊠	5035	Headwaters to Cascade Reservoir	Sediment	General- sediment Numeric- turbidity, intergravel DO
French Creek ⊠	5079	Headwaters to Cascade Reservoir	Sediment	General- sediment Numeric- turbidity, intergravel DO
Hazard Creek ⊠	5092	Headwaters to Cascade Reservoir	Sediment	General- sediment Numeric- turbidity, intergravel DO
Lake Fork ●	5628	Headwaters to Cascade Reservoir	Unknown	Unknown
Willow Creek ●	5629	Headwaters to Cascade Reservoir	Unknown	Unknown
Duck Creek ●	5631	Headwaters to Cascade Reservoir	Unknown	Unknown
VanWyck Creek ●	5632	Headwaters to Cascade Reservoir	Unknown	Unknown
Brown's Pond	6897	on Lake Fork	Habitat alteration	Unknown

◆ It has been proposed in the 1998 303(d) list that Cascade Reservoir be delisted for pathogens.

● Designates a new 303(d) listed segment (1998 draft 303(d) list).

⊠ Designates 303(d) listed segments that have been proposed for delisting (1998 draft 303(d) list).

Existing uses of waters that are not designated are also protected. Both federal and state rules protect existing uses through the antidegradation policy (See Idaho Code § 39-3603). Impacts to existing uses are best prevented through steps employed in the water-quality standards to protect designated uses.

Applicable Water-Quality Standards and Criteria

Numerical standards for pH (6.5 to 9.5 standard units) and temperature (Cold Water Biota: 22 °C daily maximum, 19 °C maximum daily average; Salmonid Spawning: 13 °C daily maximum, 9 °C maximum daily average, during time periods designated for salmonid spawning and incubation) have been established by the State of Idaho (IDAPA 16.01.02). The State of Idaho has established the following standards for minimum concentrations of dissolved oxygen in lakes and reservoirs. These parameters represent regulatory standards for Cascade Reservoir. "Dissolved oxygen concentrations exceeding 6 mg/L at all times. In lakes and reservoirs this standard does not apply to: (1) The bottom 20% of water depth in lakes and reservoirs where depths are thirty-five (35) meters or less, (2) Those waters of the hypolimnion in stratified lakes and reservoirs."

Narrative criteria have been established by the State of Idaho which indicate that surface waters of the state shall be free from excess nutrients that can cause visible slime growths or other nuisance aquatic growths impairing designated beneficial uses (IDAPA 16.01.02.200.06). Coliform bacteria standards have also been established that are dependent on level of exposure (primary or secondary contact) and applicable for a limited time period only (IDAPA 16.01.01.250). These are discussed in greater detail in Appendix B.

Designated Beneficial Uses for Cascade Reservoir Subwatersheds

Idaho has designated the following beneficial uses for specified water bodies within the Cascade Reservoir Watershed:

NORTH FORK PAYETTE RIVER - source to McCall.

Domestic water supply, agricultural water supply, cold water biota, salmonid spawning, primary and secondary contact recreation and special resource water.

NORTH FORK PAYETTE RIVER - McCall to Cascade Dam (includes the reservoir).

Domestic water supply, agricultural water supply, cold water biota, salmonid spawning and primary and secondary contact recreation.

LAKE FORK OF THE NORTH FORK PAYETTE RIVER - source to mouth.

Domestic water supply, agricultural water supply, cold water biota, salmonid spawning, primary and secondary contact recreation and special resource water.

GOLD FORK OF THE NORTH FORK PAYETTE RIVER - source to mouth.

Domestic water supply, agricultural water supply, cold water biota, salmonid spawning, primary and secondary contact recreation and special resource water.

NORTH FORK PAYETTE RIVER - Cascade Dam to mouth (Banks).

Domestic water supply, agricultural water supply, cold water biota, salmonid spawning, primary and secondary contact recreation and special resource water.

All other water bodies within the watershed are unclassified, thus, they are protected for beneficial uses, which includes all recreational use in and on the water and the protection and propagation of fish, shellfish and wildlife, wherever attainable. As noted, state water-quality standards require that all existing uses are fully protected.

2.2.3 Summary and Analysis of Existing Water-Quality Data

Historical data

Table 2.4 lists data sources significant to the evaluation of water quality within Cascade Reservoir. Initial monitoring consisted of the evaluation of fish-habitat indicators by IDFG in 1968 and water-quality parameters by the BOR in 1975. Historical monitoring was augmented by further studies conducted by the CRA, Central District Health Department (CDHD), BOR, DEQ and others. Historical monitoring of water quality in Cascade Reservoir (Clark and Wroten, 1975; Klahr, 1988; Klahr, 1989; Entranco, 1991; Ingham, 1992; Worth 1993 and 1994) has indicated significant impairment resulting from excess nutrients entering the reservoir through tributary and diversion inflow, and overland runoff. While there is an extensive list of historical monitoring available, a concerted, routine monitoring effort was not undertaken until the early 90's. Historical data, while valuable in establishing baseline conditions and directional trends, does not provide consistent information on water quality on a watershed scale. BOR inlake sites have been consistently monitored since the early 70's. Routine, in-depth monitoring was started by DEQ and other agencies for specific inlake sites in 1992, and in 1993 for all major tributaries (Figure 2.6), and covers a diverse suite of physical and analytical parameters.

In 1993, pollutant loads and an unusual runoff pattern combined to produce dense mats of blue-green algae on the reservoir. In September, 23 cattle died as a result of ingesting toxins produced by the blue-green algae (Long Valley Advocate, 1993). As a result, health advisories were issued by DEQ discouraging contact with the reservoir water. Unfortunately, 1994 was a low water year. The high pollutant loads in 1993, combined with the reduced reservoir volume and lows flows of 1994, resulted in high overall total phosphorus concentrations within the water column. Dissolved oxygen levels decreased due to algal growth and decay and warmer water temperatures produced by low water levels. This in turn led to anaerobic conditions at the water-sediment interface, increasing sediment phosphorus release. This series of events resulted in a substantial fish kill affecting nearly all species of fish in the reservoir, and impacted beneficial uses for both 1993 and 1994. These events served to focus and enlarge existing efforts for water-quality improvement within the reservoir.

Causes of Impairment. Cascade Reservoir has been identified as water-quality limited due to violations of water-quality standards for dissolved oxygen, nutrients and pH. Dissolved oxygen concentration is a fundamental measure of the ability of a waterbody to support aquatic life. Ambient

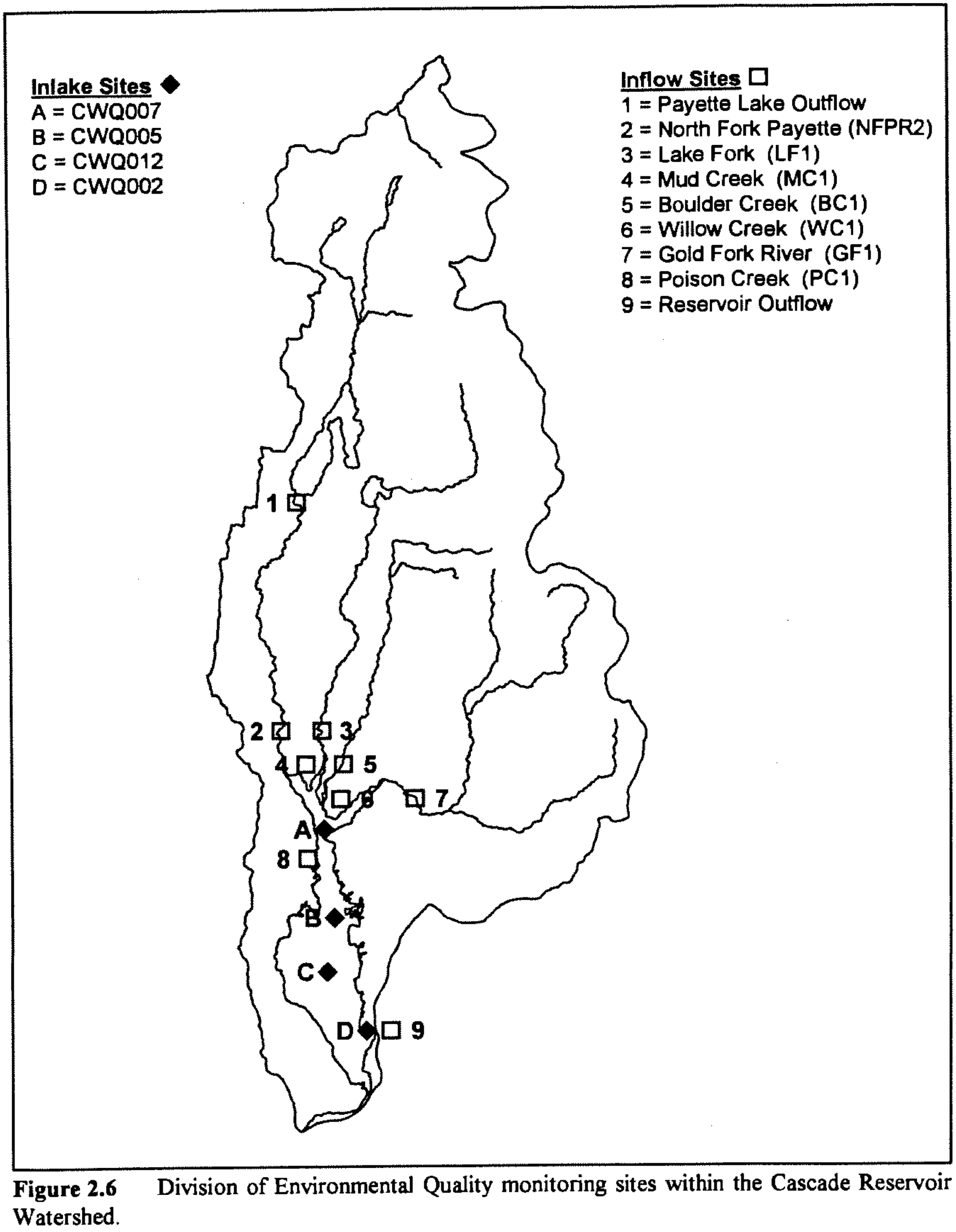


Figure 2.6 Division of Environmental Quality monitoring sites within the Cascade Reservoir Watershed.

Table 2.4 Data resources for the Cascade Reservoir Phase II Watershed Management Plan.

Subject	Year	Reference
Water quality and sediment transport - Gold Fork Subwatershed	1996	Boise Cascade Corp.; 1996 (December); *Gold Fork River Watershed Analysis*; Boise Cascade Corporation, Boise, Idaho; ~250 p + appendix.
Water Quality - Payette River & Cascade Reservoir	1975	Bureau of Reclamation; *Water Quality Studies, Payette River Basin and Cascade*; 1975; 74 p.
Water Quality - Cascade Reservoir	1975	Clark, William H.; Wroten, Jon, W.; *Water Quality Status Report: Cascade Reservoir, Valley County, Idaho; Water Quality Series No. 20;* 1975; Idaho Dept. Of Health & Welfare, Division of Environment, Boise, Idaho; 46 p.
Sedimentation within Cascade Reservoir	1996 (revised May 1998)	Ferrari, Ronald, L.; *Cascade Reservoir 1995 Sedimentation Survey;* 1998; USDI, Bureau of Reclamation, Sedimentation and River Hydraulics Group, Water Resources Services, Technical Service Center, Denver, Colorado; 29 p.
Phosphorus Transport, Soil Phosphorus Chemistry - Gold Fork River	1997	Fischer, J.G.; Amacher, M.C.; Clayton, J.L.; *Dissolved and Sediment-bound Phosphorus Transport During Spring Snowmelt - Gold Fork River;* NPS Workshop Presentation; 1997; Boise State University, Boise, Idaho.
Fisheries (WQ & Habitat Study) - Cascade Reservoir	1980 September	Horner, N; *Cascade Reservoir Fisheries and Limnological Investigations, Interim Report*; 1980; Idaho Dept. of Fish & Game, Boise, Idaho; 12 p.
Fisheries (WQ & Habitat Study) - Cascade Reservoir	1981	Horner, N.; Rieman, B.; *Cascade Reservoir Fisheries Investigations*; 1981; Project F-73-R-3, Idaho Dept. of Fish & Game, Boise, Idaho; 85 p.
Water Quality - Cascade Reservoir	1992	Ingham, Michael; *Cascade Reservoir, Valley County, Idaho 1988-1991; Water Quality Status Report No. 103;* 1992; Idaho Dept. Of Health & Welfare, Division of Environmental Quality, Southwest Idaho Regional Office, Boise, Idaho; 17 p.
Water Quality - Cascade Reservoir Tributaries	1988	Klahr, Patricia C.; *Lake Irrigation District Survey and Cascade Reservoir Tributary Assessment, Valley County, Idaho, 1986; Water Quality Status Report No. 70;* 1988; Idaho Dept. Of Health & Welfare, Division of Environmental Quality, Water Quality Bureau, Boise, Idaho; 46 p.
Water Quality - Cascade Reservoir	1989	Klahr, Patricia, C.; *Cascade Reservoir, Valley County, Idaho, 1988; Water Quality Status Report No. 85;* 1989; Idaho Dept. Of Health & Welfare, Division of Environmental Quality, Water Quality Bureau, Boise, Idaho; 12 p.
Water Quality - Gold Fork River	1985	Klahr, Patricia, C.; *Water Quality Assessment of Gold Fork River, Valley County, Idaho*; 1985; Idaho Dept. Of Health & Welfare, Division of Environmental Quality, Boise, Idaho; 19 p.

Subject	Year	Reference
Water Quality Impact of Recreation & Grazing - Cascade Reservoir	1986 December	Lappin, J.L.; Clark, W.H.; ***An Assessment of Water Quality Impacts of Recreational Housing and Livestock Grazing in the Cascade Reservoir Watershed;*** 1986; Journal of the Idaho Academy of Science; Volume 22, No. 2; p 45-62.
Phosphorus Sorption Capacity of Cascade Reservoir Watershed	1996 December	McGeehan, Steven, L.; ***Phosphorus Retention in Seasonally Saturated Soils Near McCall Idaho (Final Report);*** 1996; University of Idaho, Division of Soil Science, Moscow, Idaho; 54 p + appendix.
Sediment Transport-Gold Fork River	1997 July	Whiting, Peter, J.; Matisoff, Gerald; Bonniwell, Everett, C.; ***Phosphorus Radionuclide Tracing of Fine Sediment in Forested Watersheds;*** 1997; Case Western Reserve University, Dept. Of Geological Sciences, Cleveland, Ohio; 39 p + appendices.
Nutrient & Bacterial Loading - Cascade Reservoir	1983 August	Zimmer, David, W.; ***Phosphorus Loading and Bacterial Contamination of Cascade Reservoir, Boise Project, Idaho***; 1983; Boise Project Power and Modification Study, USDI, Bureau of Reclamation, Pacific Northwest Region, Boise, Idaho; 143 p.

water-quality monitoring indicates that Cascade Reservoir experiences periodic low dissolved oxygen levels during the summer months. Decomposition of algal mass and water temperatures influence dissolved oxygen levels. Tributary temperature increases may be minimized through increased cover vegetation and related improvements in riparian areas. Such improvements may additionally provide temporary "thermal refuge" areas during peak summer months for fish requiring cooler water temperatures for survival. However, solar inputs to the reservoir are certainly beyond the control of any management activities. A change from the current cold-water biota standard to the proposed cool-water biota standard may be merited.

Water-quality studies have shown that phosphorus is the pollutant of concern within the watershed. When present in excess, it stimulates the growth of noxious aquatic weeds and algae blooms. Extensive algae blooms are key indicators of high nutrient loading within the reservoir and lead to depressed dissolved oxygen levels. In 1975, Clark and Wroten reported that water quality within the reservoir was good yet slightly eutrophic, noting that ortho-phosphate was conducive to algae growth. Later reports demonstrated that phosphorus was entering the reservoir from nonpoint sources (primarily spring runoff and irrigation returns) and from point sources. Continued inputs of phosphorus and fluctuations in water level within the reservoir have led to eutrophic conditions. Water-quality data collected by DEQ from 1993 to 1997 reveal that a significant phosphorus load is carried in the increased flows present during spring runoff. Poor conditions within the watershed, especially within the riparian areas, may be contributing to this situation. As spring flows increase, degraded riparian areas contribute to increased phosphorus loads with accelerated runoff due to inadequate sediment and groundwater holding capacities.

In addition to the excessive phosphorus loading, several physical limitations exist for Cascade Reservoir that should be considered. The reservoir is shallow, with a mean depth of 26.5 feet at full pool. As such, it is highly susceptible to eutrophication due to nutrient loading and elevated summer water temperatures from solar input. Dominant weather patterns in the region move laterally (west to east) across the reservoir. Wind currents created by thunderstorms cause wave action that can result in resuspension of sediment within the water column.

Reservoir drawdown is also a necessary consideration in water-quality management. While the BOR has administratively established a conservation pool of 300,000 acre-feet as adequate to provide a zone of oxygenated water sufficient for winter fish survival, there is some concern that this volume may not be adequate to protect fish populations during the summer months, as shallow depths and summer temperatures were not considered in establishing the pool. BOR, DEQ and IDFG will continue to study pool elevations in relation to dissolved oxygen concentrations in the future.

Internal recycling of sediment-bound phosphorus within the reservoir is also a concern. This source was estimated in Phase I to contribute about 19% of the annual total phosphorus load to the reservoir. Reduction of this source by dredging or chemical sealing of the sediments was evaluated through reservoir models, but has not been shown to demonstrate substantial beneficial effect. In a reservoir the size of Cascade, both options would be very costly and may cause significant water-quality problems through disturbance of the sediments and changes in water-column pH.

Although phosphorus is often the nutrient which limits the growth of algae in lakes and reservoirs, nitrogen is also an important nutrient. The relative balance of nitrogen and phosphorus can influence the type of algae species that grow and dominate a lake or reservoir. While water-quality data from Cascade Reservoir suggests that phosphorus supply is largely responsible for the prevalence of algae, the quantity and concentrations of nitrogen entering the reservoir may also contribute to the growth of algae blooms.

The outlet to Cascade dam is located on the eastern shore of the reservoir (Figure 2.4), "upstream" of approximately one-fifth of the total reservoir area. Water stored in the southern end of the reservoir therefore has substantially lower flow and greater residence time than the area north of the outlet. The southern tip of the reservoir is more susceptible to algae blooms and increased temperatures because of the shallow depth and sluggish water and represents a sensitive area within the reservoir.

Key Indicators. There are several major indicators of water-quality impairment for Cascade Reservoir. Algae blooms represent the most obvious visual indication of poor water quality. In mid to late summer, dense algae blooms are noticeable on the water surface. Blooms generally start at the north end of the reservoir and move south with inflowing water, increasing in size and density as they move toward the outflow and the south end of the reservoir. These blooms often result in substantial color change; blue water early in the summer appears gray-green as the summer progresses. As a visual indicator, algae blooms are occurrences of concern to the local population and to the tourist population utilizing the reservoir. Additional key indicators of water-quality impairment within the reservoir are increased nutrient concentrations and dissolved oxygen sags. Both of these analytical indicators are directly related to the algal growth. Nutrients (most notably phosphorus) represent a primary food source and dissolved oxygen is depleted as algae die, sink below the surface and decompose. Chemical and microbial decomposition require oxygen, which is removed from the surrounding water. During the summer months, substantial oxygen depletion occurs in the lower depths of the reservoir as the algae settle within the water column.

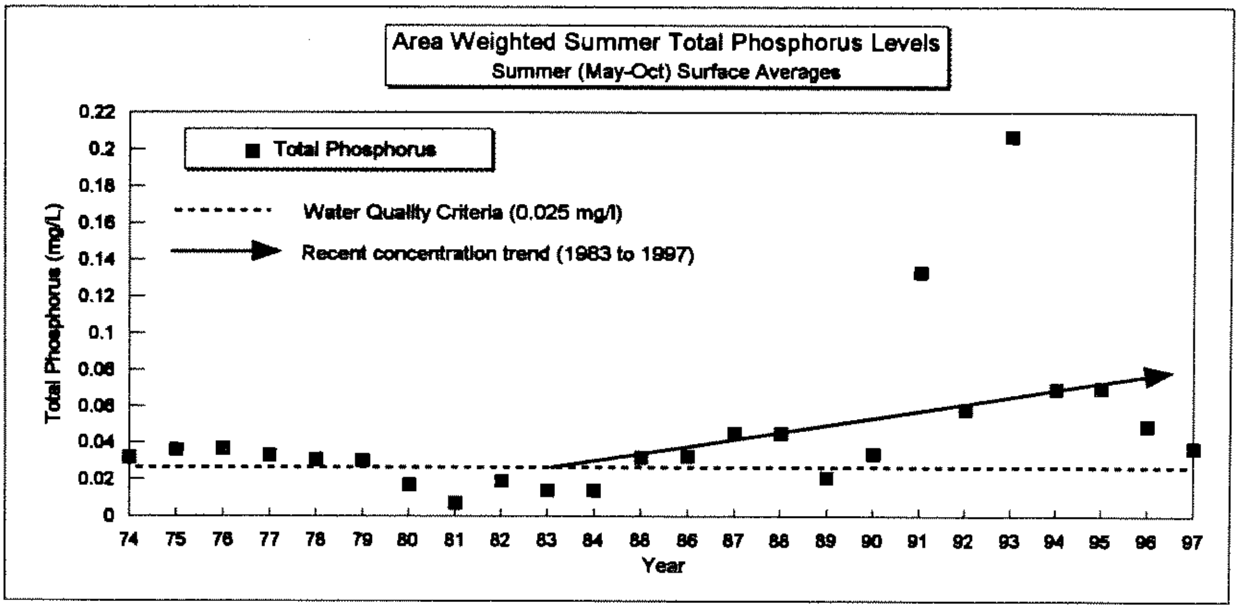
Data collected in 1993, a normal runoff year, indicate poor water quality within the reservoir due to increased inputs of phosphorus which encouraged the growth of excess algae as measured by chlorophyll a concentrations and citizen complaints. Even though total phosphorus loads decreased in 1994, (Figure 2.7) the reservoir continued to experience poor water quality due to low flows, decreased dissolved oxygen, warm water temperatures and internal recycling of nutrients. These conditions placed tremendous stress on the reservoir's fish population. A substantial fish kill occurred and a fish salvage effort was initiated. For these two water years all beneficial uses were impacted.

Data collected for water years 1995 and 1996 (both slightly above average precipitation) indicate increased flow volume and subsequent increases in water quality, although the listed standards and criteria were not achieved. Dissolved oxygen levels increased overall (although late summer monitoring identified significant dissolved oxygen sags below the thermocline) and chlorophyll a counts showed a decreasing trend, a positive development given the sharply upward trend defined by previous years (Figure 2.7). Fisheries within the reservoir rebounded to some extent, but have not regained their pre-1993 status.

Because of the direct relationship between high total phosphorus concentrations and excess algae growth within the water column, and the direct effect of the algal life cycle on dissolved oxygen and pH within the reservoir, the reduction of total phosphorus input to the reservoir is being specifically targeted as a mechanism for overall water-quality improvement. It is expected that phosphorus management will result in improvement in all listed water-quality parameters: nutrients (phosphorus), dissolved oxygen and pH.

Historical monitoring data for total phosphorus measurements represent the most complete and reproducible data set available for the watershed. For this reason, total phosphorus measurements were targeted for both load estimation and reduction allocations. Ortho- and bioavailable phosphorus represent the portion of phosphorus readily available for uptake by aquatic organisms. Total phosphorus is a measurement of all phosphorus that may *ever* be available for biological uptake, thus offering an estimation of long-term availability within the watershed. Available data and continuing monitoring for both ortho- and bioavailable phosphorus concentration will be used to augment the existing data set and to further understanding of the overall trend of phosphorus concentration within the watershed. It should be noted that because of the complex hydrology within the watershed and the lack of available data on bedload sediment and delivery, only suspended loads were evaluated for the purpose of this document. Interpretation of the values presented and the conclusions drawn should be made with these considerations in mind.

Data collected show that identification and reduction strategies based on phosphorus form and transport pathways are critical to the improvement of water quality within the reservoir. Direct correlation of total phosphorus concentration and time-stepped chlorophyll a concentration is possible



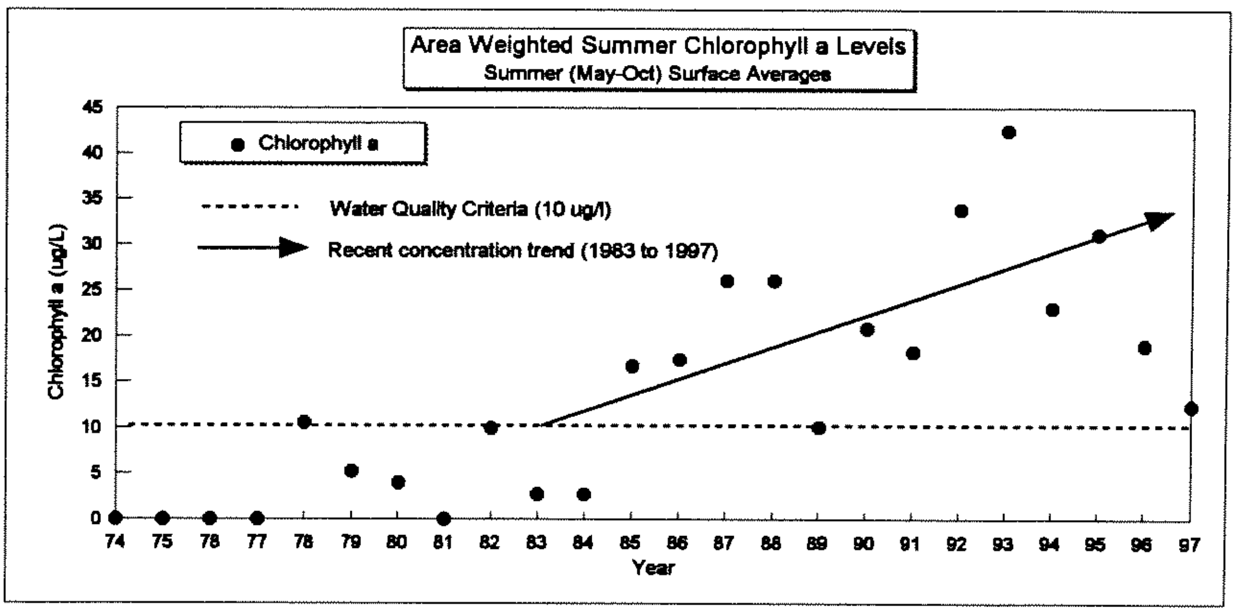


Figure 2.7 Area-weighted summer total phosphorus and chlorophyll a levels for Cascade Reservoir.

within the water column. Heavy total phosphorus loads from spring runoff correlate well with the initial summer algae bloom and concurrent elevated chlorophyll a levels. Sustained higher total phosphorus inputs from the tributaries during the summer months can be correlated with the incidence of late summer algal blooms and subsequent increases in chlorophyll a. Obviously temperature also plays a significant role in the growth of algae within the reservoir, but cannot be designated as the primary cause for the dense summer and fall blooms. Given the conclusions drawn, the input of phosphorus during spring runoff and summer irrigation represents a critical time-step in the reversal of beneficial use impairment. Both represent increased sediment-bound total phosphorus and dissolved ortho-phosphate delivery and result in both long-term and immediately available phosphorus sources (respectively) within the reservoir water column.

The reservoir listing for pathogens has been evaluated extensively. Data gathered from October 1994 to October 1997 have shown that pathogen counts have not exceeded statewater-quality standards within the reservoir. Based on these data, a recommendation was made to delist Cascade Reservoir for pathogens on the 1998 303(d) list. However, monitoring of bacteria levels (may include fecal coliform, total coliform, and E. Coli) will continue to be an integral part of the water-quality monitoring for Cascade Reservoir.

2.2.4 Plan Goals and Objectives

To improve the water-quality status of Cascade Reservoir and its tributaries, the current contribution of phosphorus from external sources must be reduced by 37%. This goal, which includes a 7% margin of safety, was established through the use of modeling efforts undertaken by DEQ. A 37% reduction in phosphorus loading was selected because it is anticipated to result in water-quality improvements that reach the desired water-quality objectives of 10 µg/L chlorophyll a and 0.025 mg/L total phosphorus in the reservoir. Reduction in the quantity of nutrients entering the reservoir will, in time, modify chemical and biological processes and result in improved water quality. Model simulations conducted for 20 consecutive average water-years have shown that a 37% reduction in phosphorus load should result in substantially diminished algae blooms within five years of attainment of the total 37% reduction and continued water-quality improvements over time.

The goal of this plan is to achieve state water-quality criteria and restore beneficial uses in Cascade Reservoir in as immediate a time frame as possible. The reduction goal will be accomplished by focusing efforts on reducing the source and transport of nutrients throughout the watershed. Key components of this plan include the establishment of measurable objectives (load reductions) for improvement of water quality, monitoring assessment of the success of load reduction goals, and meaningful public involvement in implementation of this and any subsequent implementation plan.

It is recognized that a significant number of implementation measures have been accomplished and others are currently in progress to accomplish this reduction goal. This concurrent implementation strategy, combined with the phased TMDL process and pending formal implementation plan are expected to result in rapid progress toward the specified reduction goal.

2.3 Pollutant Source Inventory - Major Types and Sources of Pollutants of Concern

As part of the plan to improve the quality of water in Cascade Reservoir, total contributions and applicable reduction allocations have been evaluated. Point and nonpoint sources have been defined. Nonpoint sources have been evaluated on both a subwatershed and land-use basis.

2.3.1 Point Source Pollution

There are two point sources of pollution to Cascade Reservoir, the McCall wastewater treatment plant (WWTP) and the IDFG fish hatchery in McCall (Figure 2.8). Both sources discharge nutrients and other pollutants directly to the NFPR upstream of Cascade Reservoir under NPDES permits. The WWTP processes approximately 1.8 million gallons per day (MGD) at full capacity. The average load is roughly 0.7 MGD. Peak flows of 2.3 MGD have been reported however, due to infiltration of ground water and snow-melt. Infiltration is estimated to contribute as much as 1.6 MGD to the base flow. Peak inflow occurs during spring runoff and snow-melt periods and declines during the remainder of the year. For the purposes of this document, the major pollutants of concern associated with the WWTP discharge are nutrients, predominantly phosphorus. Effluent concentrations vary seasonally and typically exceed ambient concentrations in the NFPR. In sewage effluent, the majority of the entrained phosphorus is present as dissolved ortho-phosphate, a readily bioavailable form of phosphorus. Proportionately, greater than 85% of the total phosphorus in sewage effluent is in the form of dissolved ortho-phosphate, as compared to <1% in sediment associated phosphorus. Dissolved ortho-phosphate concentrations in treated effluent range from 1.0 to 6.0 mg/L. Annual total phosphorus loading attributable to the treated effluent rose markedly from the early 1970's to 1988 due to increased population and recreational use. Since 1988, annual total phosphorus loading has remained relatively stable, ranging from 3815 kg to 4751 kg annually. The WWTP for the City of Cascade lies outside of the watershed for Cascade Reservoir. The City of Donnelly uses land application to dispose of treated effluent.

The IDFG Fish Hatchery requires flowing water for maintenance and growth of Chinook Salmon stock and discharges 12.9 MGD (20 cubic feet per second (cfs)) to the NFPR. The major pollutants of concern associated with the hatchery discharge are nutrients, again, predominantly phosphorus. In 1994 the fish food being used (1.7% phosphorus by weight) was replaced by a food type with lower phosphorus content (0.7% phosphorus by weight). This substitution was further augmented by changes in feeding practices. The combination of these changes has resulted in a substantially reduced phosphorus load since 1994. Pre-1994 total phosphorus loads were evaluated at 726 kg/yr (average). Post-1994 loads have been evaluated at 218 kg (average) total phosphorus annually.

2.3.2 Nonpoint Source Pollution

There are many, varied, nonpoint sources of pollution in the Cascade Reservoir Watershed. Major sources include forestry, agricultural and urban/suburban management practices; and internal recycling of nutrients within the reservoir. Due to the complexity inherent in the evaluation of nonpoint sources, each of these major categories was evaluated separately. Table 2.5 shows a distribution of land-use acreage by subwatershed.

Forestry Management Sources

A total of 184,092 acres are included in the forestry land-use designation of the watershed (Figure 2.9). Principal ownership is with the USFS, who holds 113,714 acres of land between the Boise and Payette National Forests, nearly 62% of all forested land. Other major forested-land owners are

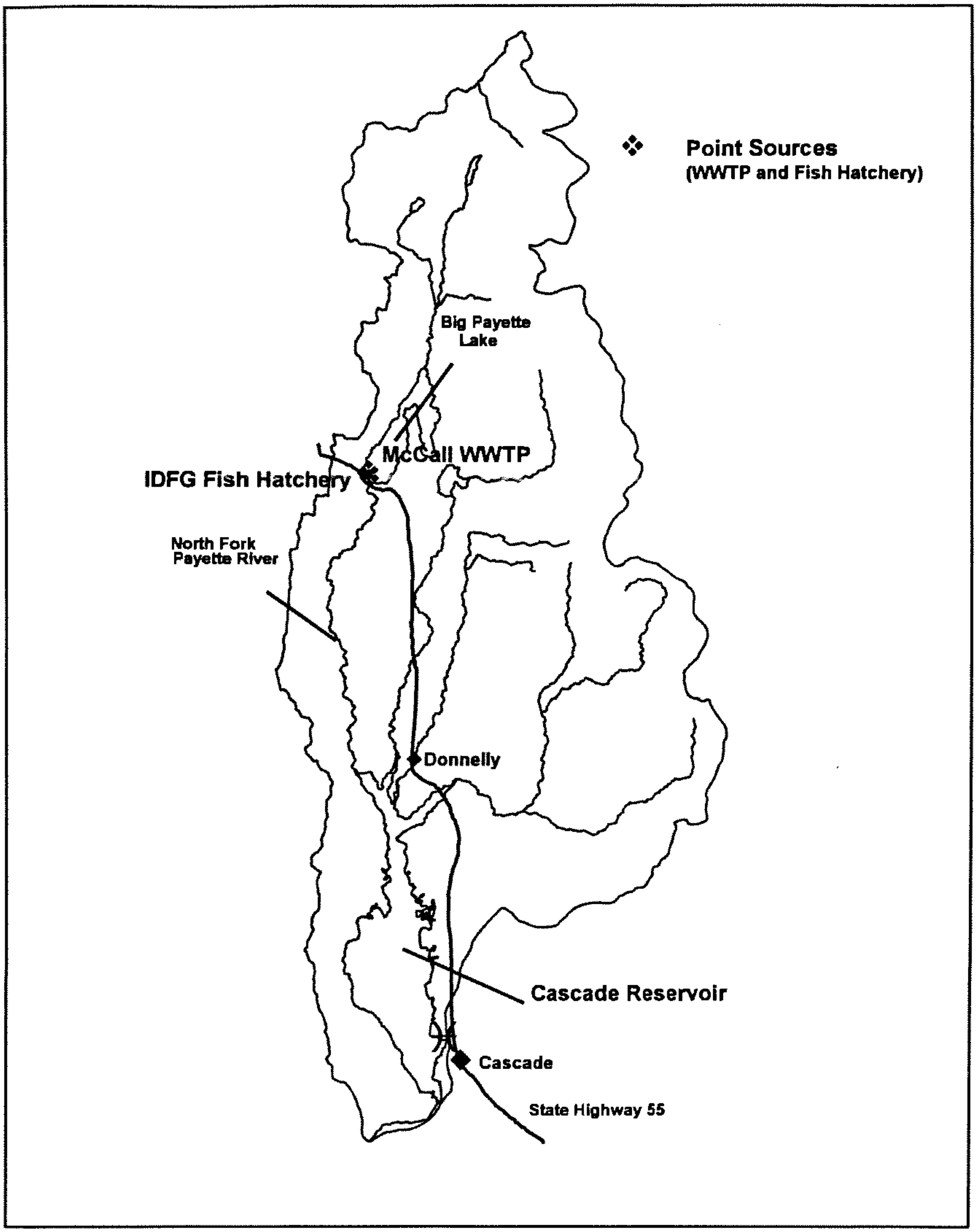


Figure 2.8 Point sources located within the Cascade Reservoir Watershed.

Table 2.5 Subwatershed acreage by land use within the Cascade Reservoir Watershed.

Land Use	Bldr/Wlw	Cascade	Gold Fork	Lake Fork	Mud	NFPR	West Mtn.	Totals	% of Total
Total Forested Land	**18,301**	**2,443**	**93,741**	**38,656**	**177**	**11,525**	**19,249**	**184,092**	**66.6**
Public Forest	11,275	2,343	67,350	37,793	0	5,197	18,032	139,747	50.5
Privately Owned Forested Land	7,026	100	26,391	863	177	6,328	1,217	44,345	16.1
Total Agricultural Land	**11,596**	**8,118**	**7,470**	**10,400**	**10,843**	**11,392**	**6,525**	**66,344**	**24.0**
Rangeland	558	2,343	1,621	762	102	1,608	4,274	11,268	4.1
Wetland/Riparian	16	0	6	144	90	420	0	676	0.2
Barren	10	3	2	2	0	0	2	19	0.0
Irrigated AG & Pasture	9,138	4,202	3,306	6,917	10,186	5,830	135	39,714	14.4
Dryland AG	0	0	812	0	0	0	0	812	0.3
Sparse Forest	1,874	1,570	1,723	2,575	465	3,534	2,114	13,855	5.0
Total Urban/Suburban Land	**3,875**	**4,392**	**786**	**2,779**	**2,077**	**8,347**	**3,689**	**25,945**	**9.4**
City	682	380	0	289	0	2,158	0	3,509	1.3
Impact	1,964	1,187	0	621	10	5,160	1,753	10,695	3.9
Subdivision	1,229	2,825	786	1,869	2,067	1,029	1,936	11,741	4.2
GRAND TOTAL	33,772	14,953	101,997	51,835	13,097	31,264	29,463	276,381	100.0

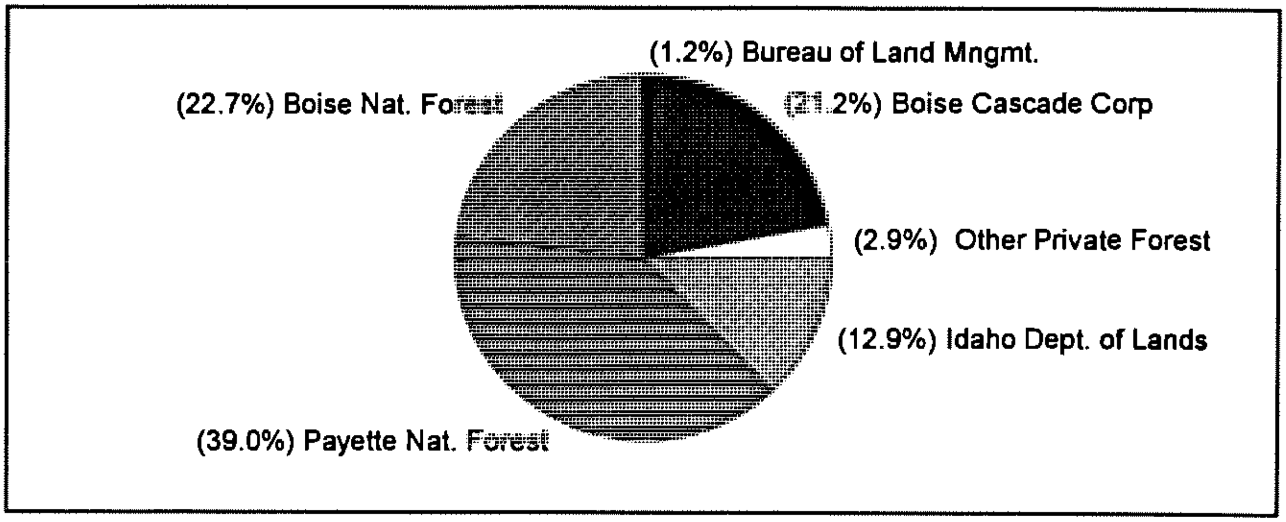


Figure 2.9 Proportional acreage of forestry land by ownership within the Cascade Reservoir Watershed.

Boise Cascade Corporation with 21% of forested land and the State of Idaho with 13%. Other privately owned forested land accounts for less than 3% of the total forested area.

Forestry management practices include timber harvest and related activities such as road construction and use, timber removal, replanting and livestock grazing on forested allotments. Potential impacts from forestry management practices are listed in Table 2.6. Road construction and use, landslides

Table 2.6 Potential pollutant loading from forestry management practices.

Management Practices	Resulting Status of Sediment Loads	Resulting Status of Nutrient Loads	Resulting Status of Other Pollutants
Road Building & Use	Increased sediment load	Increased nutrient load from sediment-bound phosphorus	
Grazing	Increased sediment load Increased erosion Vegetation reduction/removal Higher stream temps	Increased nutrient load from animal waste deposition and transport Greater dissolution of nutrients at elevated temps	Increased bacterial levels
Harvest	Destabilization of slopes Increased sediment transport in storm events and runoff	Increased nutrient load from sediment-bound phosphorus	
Landslides	Increased sediment loads	Increased nutrient load from sediment-bound phosphorus	
Stream Flow Alterations	Increased velocity resulting in increased erosion and sediment transport	Increased nutrient load from sediment-bound phosphorus	

and soil creep, and livestock grazing on forested allotments were determined to contribute the vast majority of the dissolved and sediment-bound phosphorus associated with forestry management, and were directly evaluated in the estimation of the total pollutant load contribution from forested land.

Timber Harvest. The major pollutant associated with forestry management practices is sediment which may contain phosphates and carry adsorbed nutrients. The geology of forested lands within the Cascade Reservoir Watershed is conducive to erosion and sediment production. Predominant lithology is granite and related basaltic rocks that are decomposing to unstable, easily transportable sediments. Local lithology also contributes to landslides. Most slides are due to natural causes but some are management induced (i.e. from a destabilized road cut and fill). Traditional timber harvest activities can result in increased sediment loads within the watershed due to construction of roads, erosion of road surfaces, landslides on destabilized slopes and erosion of harvest areas. Nearly all forested areas within the watershed have an extensive network of roads which increases sediment yields. The construction and use of roadways represent the major source of sediment from timber harvest activities, with erosion from streambanks and landslides caused by management activities representing more minor sources. The recommended practices outlined by the Forest Practices Act (FPA) minimize non-road related sediment transport. The FPA also prohibits removal of timber within riparian areas near the stream channel. When these practices are adhered to impacts associated with removal of overhanging vegetation (i.e. increased water temperatures in the tributaries resulting in greater dissolution of adsorbed phosphorus and other nutrients from sediment-bound forms) should not occur.

Grazing. Impacts from grazing practices include increased sediment and nutrient loading due to erosion of stream bank areas destabilized by animal impacts and waste deposition (Table 2.7). (The impacts of grazing practices are discussed in greater detail in the *Agricultural Management Sources* section below.) As grazing animals tend to frequent streambank areas due to easy access to water, wastes are often deposited directly in the stream channel. Grazing within these areas results in decreased stubble height and damage to riparian areas due to removal of vegetation and hoof action on stream bank sediments.

Pollutants from timber harvest (sediment), grazing activities (sediment and animal waste) and natural processes (sediment) deposited in streams during low flow can be rapidly resuspended and transported to the reservoir during high flow events (Megahan, 1972 and 1979; Mahoney and Erman, 1984; Whiting, 1997).

Forested land, as identified by the land-use designations discussed earlier, is present in all subwatersheds within the Cascade Reservoir Watershed. While forested land represents the major land use in all but Cascade, Mud Creek and the NFPR subwatersheds; only Gold Fork and West Mountain subwatersheds represent areas where forested land is the major contributor to total phosphorus load. These two subwatersheds, along with the NFPR subwatershed also contain the vast majority of the grazed acres of forested land and have a large proportion of steeply-sloped, forested land which grades rapidly toward the valley floor. Because of this, transport of both dissolved and sediment-bound phosphorus is highly efficient in these areas.

Agricultural Management Sources

A total of 66,344 acres were identified under agricultural land-use within the watershed. Irrigated crop and pasture land account for the majority of the agricultural land-use acres (60%). Non-irrigated rangeland makes up 17% of agricultural acres. Total cropland comprises about 8% of the agricultural land. Non-irrigated crop land within the watershed accounts for less than 2% of the total agricultural acres (Figure 2.10). Primary sources of pollutants associated with agriculture are sediment and nutrients present in both dissolved and sediment-bound forms (Table 2.7). Related impacts are alteration of stream flows and temperatures. The generation and transport of pollutants from agricultural nonpoint sources are influenced by the health of riparian areas through which water is transported to the reservoir, overland flow from runoff and snow-melt, irrigation practices, pasture and grazing management and fertilizer application (Agriculture Source Plan, 1998).

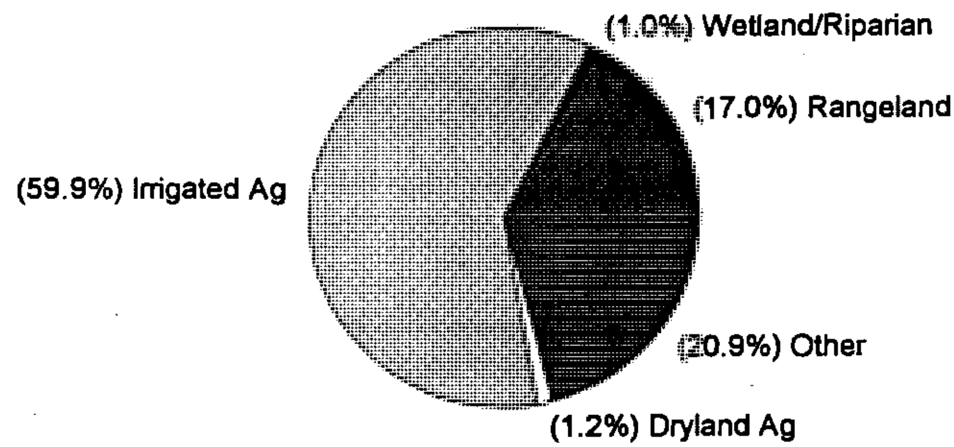


Figure 2.10 Proportional acreage of agricultural land use within the Cascade Reservoir Watershed.

The main agricultural products of the area are cattle, pasture rentals, potatoes, wheat, barley, oats, grass/clover seed and hay (USFS, 1998), with cattle and related grazing the predominant practice. Cattle grazing accounts for 82 % of the farm income in Valley County and while absolute numbers of stock are difficult to obtain and verify, roughly 30,000 head are estimated to utilize the watershed in an average year (ISDA, 1998). Ranges in reported/estimated numbers of livestock vary from 10,000 to 60,000 annually for the watershed. The 30,000 head value employed within this document represents an approximate median value for the counts/estimates available. Because of the lack of consistent, verifiable information, this value was used as a general comparison of proportional densities between separate subwatersheds and identified grazing allotments only and is not meant to be interpreted as a "hard" quantitative value for the watershed as a whole.

Historical trends in grazing have shown a gradual decrease in total stock counts for the watershed, but livestock densities near the reservoir and major tributaries have shown an increasing trend over

Table 2.7 Potential pollutant loading from agricultural management practices.

Management Practices	Resulting Status of Sediment Loads	Resulting Status of Nutrient Loads	Resulting Status of Other Pollutants
Riparian Grazing and Watering	Increased sediment load Increased erosion Vegetation reduction/removal Higher stream temps	Increased nutrients from animal waste deposition and transport within the channel Greater dissolution of nutrients at elevated temps	Increased bacterial levels
Over Utilization of Pasture	Increased erosion-sheet and rill Increased transport of sediment Decreased stubble height Soil compaction leading to reduced water infiltration	Increased nutrient load from animal waste deposition Increased nutrient transport from overland flow caused by soil compaction and decreased stubble height	Increased bacterial levels
Flood Irrigation	Removal of soil fines from surface and subsurface Increased bank erosion from subsurface drainage and recharge Subsurface saturation, decreased permeability and increased erosion from surface runoff	Prolonged saturation leads to anaerobic soil conditions and decreased capacity for phosphorus sorption Removal of soil fines decrease surface area of soils and decreases available capacity for phosphorus sorption	
Ranchettes	Increased sediment transport from high road and livestock density	Increased nutrient loads from increased animal waste deposition and transport	Increased bacterial levels Increased storm-water pollutants

the last 50 years. Thus, although the total number of cattle within the watershed has dropped, the relative number of cattle immediately adjacent to the reservoir and major tributaries has increased.

Grazing. Impacts from grazing practices include direct and indirect effects related to sediment and pollutant loading. Potential impacts from grazing management practices are listed in Table 2.7. Local streams represent the major source of water for livestock and a secondary source of forage. Access to streams is generally unrestricted. Cattle grazing along the stream banks and within the channel exacerbate erosion in two major ways. The shearing action of hooves on stream banks destabilizes the soil and increases the potential for significant erosion as loose sediments are rapidly removed by flowing water. Grazing cattle also remove or substantially reduce riparian vegetation (Platts and Nelson, 1995). Bank erosion is accelerated where riparian vegetation has been removed or heavily grazed. Streambank vegetation serves to stabilize bank sediments and reduce the erosional force of flowing water. It also serves as a depositional area for sediment already in the stream. Water entering vegetated reaches slows down because of the resistance plant stems create within the flow path. As flow velocity decreases, larger sediment particles settle out within the riparian areas. Reduction or removal of riparian vegetation decreases bank stability through the loss of root mass within the soil profile and decreases settling and sedimentation at the edges of the stream channel. As a result, stream banks have become unstable in many stream reaches.

In addition to increased erosion and sediment transport effects, grazing practices also contribute to nutrient loading through the deposition and transport of animal wastes. While a small portion of the available phosphorus in plant material is used in growing and maintaining bones and teeth, grazing animals partition nearly all phosphorus intake into manure. Manure has a slower physical decomposition rate than plant material on the surface. This results in increased accumulation of soluble phosphorus in a physically unstable form within the pasture. Such deposition is especially noticeable when correlated with the spatial distribution of animals in grazing and bedding routines. Cattle within a grazed pasture rarely spread out and cover the entire acreage evenly. Rather, they tend to congregate around areas where water is readily available (riparian areas and stream channels) and forage is plentiful. Because greater numbers of livestock are concentrated in these areas, a greater proportion of the manure produced is consequently deposited in or nearby stream channels and riparian areas. Manure concentration per unit of land is relatively small but the total grazed-land area is very large and correlates well with major water bodies, resulting in a greater potential for direct transport. The phosphorus contained within manure is in a highly soluble, readily bioavailable form. Because of the high solubility, phosphorus loading and transport from a manured field can exceed those from a non-manured field by as much as 67 times (Khaleel *et al.* 1980; Olness *et al.* 1975; Omernik *et al.* 1981; Reddell *et al.*, 1971; Hedley *et al.*, 1995; Sharpley *et al.* 1992). Erosional processes occurring within an ungrazed or forested watershed would require a significantly greater amount of time and transport to produce the same effect on bioavailable phosphorus loading as a direct deposition of phosphorus-rich animal wastes into the channel or flood plain of a stream.

Related impacts include increased water temperatures in the tributaries due to removal of stream side vegetation, allowing greater dissolution of adsorbed phosphorus and other nutrients from sediment-bound forms. Also, monitoring performed above and below grazed land shows higher levels of bacterial loading in waters below the grazed area than in those above (Lappin and Clark, 1986; Zimmer, 1983). This is most probably due to deposition of manure in and around the streams and overland transport of manure through storm events.

Sheet and rill erosion from storm events, combined with reduced vegetation from improper grazing management also result in increased sediment transport to streams and channels. In a related fashion, over utilization of pasture land can result in subsurface compaction of soils as hoof action combined with animal weight create a pressure wave that compresses the soil profile, resulting in the formation of a dense layer of low permeability twelve to fifteen inches below the soil horizon. The VSWCD reports that many grazing pastures within Valley County have highly compacted soils. In storm events and spring melt, water cannot penetrate this compacted layer, and the volume and velocity of overland flow are increased, as is the total suspended sediment and nutrient load. Vegetation in over-utilized pasture areas is commonly insufficient to retain sediment within overland flow and deposited manure is easily transported directly into or down stream within existing stream and irrigation channels (NRCE, 1996).

Irrigation. Sub-flood irrigation, commonly used to irrigate pasture land, also impacts sediment and nutrient loading. Water diverted from natural streams is applied in excess to pasture land through a series of canals and ditches. These canals are filled and water is allowed to saturate the surrounding soil, creating an artificially high water table. Practices like sub-flood irrigation that substantially alter the water table can lead to changes in the mobility of phosphorus within the shallow subsurface. Phosphorus has been observed to move more easily through soils that are consistently water-logged because the majority of the iron present in these soils is no longer in the Fe^{+3} form and sorption potential is decreased (Sharpley *et al.*, 1995). Such irrigation practices create a substantially increased subsurface flow which facilitates transport. Increases in water table levels also lead to decreased crop yield, especially palatable plants (extent depends on crop type). In some cases natural vegetation may be replaced with species that require more water, propagating the need for increased subsurface irrigation. In addition, movement of water in subsurface layers results in the preferential loss and transport of fine, light-weight soil fractions which represent the primary phosphorus sorption sites in the soil. These particles carry a significant amount of sorbed phosphorus with them when they are removed and leave the remaining soil deficient in sorption sites. Therefore, not only is the subsurface water enriched directly through the sorbed phosphorus on the particulate, but further runoff from the original soils will be enriched due to the decrease in phosphorus sorption capacity (Hedley *et al.*, 1995). In addition, phosphorus sorption-desorption characteristics, buffer capacity and the sorption index of the transported sediments are altered, and the equilibrium phosphorus content is usually enriched (Shapely *et al.*, 1995).

The fine, light-weight soil fractions preferentially removed from the subsurface through sub-flood irrigation practices are deposited within the flow channel after subsurface flows discharge to streams and tributaries. Material deposited in this fashion can function as a nutrient source to the overlying water column. Natural processes act to maintain equilibrium between nutrient concentrations in the bed-sediment and the flowing water. Thus, if nutrient concentrations in overlying water are less than nutrient concentrations occurring within the deposited sediments, sorbed nutrients will be more readily dissolved by the flowing water. This process acts to enrich tributary inflow concentrations to the reservoir, and to extend the peak nutrient input period to the reservoir beyond the traditional irrigation season (Sonzongi, 1982).

Irrigation recharge and surface runoff created by sub-flood irrigation practices are diverted to local streams or returns as shallow ground water. These waters generally contain high concentrations of phosphorus and nitrogen compared to ambient concentrations of local streams (Klahr, 1988; Omernik *et al.* 1981; Shewmaker, 1997). These same irrigation systems funnel and accelerate delivery of runoff from snow-melt during spring thaw. In addition, inefficient irrigation water management practices can reduce stream flows unnecessarily, resulting in increased water temperatures.

Cropping. Impacts from cropping within the watershed are relatively minor due to the small acreages dedicated to crop production. These impacts include those detailed for sub-flood irrigation in the section above and the impacts of fertilizers applied in the production of grains and to establish growth in newly seeded pastures. Fertilizer is reportedly not applied to pastures routinely once growth is established.

Ranchettes. Certain aspects of rural ranchettes have been included in the agricultural land-use designation because the methods used to address reduction strategies most closely approximate those of agricultural practices. These properties are a potential source of high nutrient loading and bacteria from hobby livestock such as horses, mules, llamas and other domestics. Because BMPs are not regularly implemented in many cases, animal densities (particularly of horses and mules) are often greater than the available land can support, causing over utilization of existing vegetation and problems with waste management, leading to increased erosion and nutrient transport. However, in addition to contributing common agricultural pollutants, these properties represent a significant source of urban pollutants as well. Increased road density is observed with such development. This aspect of loading and the management practices recommended will be addressed through both the agricultural and urban/suburban land-use designations, as poor drainage within these developments and runoff from snow-melt can wash urban stormwater pollutants and animal waste materials into local streams.

Agricultural land, as identified by the land-use designations discussed earlier, is present in all subwatersheds within the Cascade Reservoir Watershed. Agriculture is the major land use in the Cascade and Mud Creek subwatersheds, and represents the major contributor to total phosphorus load in the Lake Fork, Mud Creek and Boulder/Willow subwatersheds. Cascade subwatershed shows a nearly even split of the load between agricultural and urban/suburban phosphorus load. With the exception of Gold Fork, all subwatersheds contain a significant amount of agricultural land, a large proportion of which is in close proximity to the reservoir or tributaries discharging directly into the reservoir. Because of this, transport of both dissolved and sediment-bound phosphorus to the reservoir is rapid and highly efficient.

Urban/Suburban Sources

Urban/suburban land-use totals 25,945 acres within the watershed. The largest portion of this acreage (45%) is within subdivisions, city impact areas account for 41% and the actual urban/city areas make up the remaining ~14% of acreage (Figure 2.11).

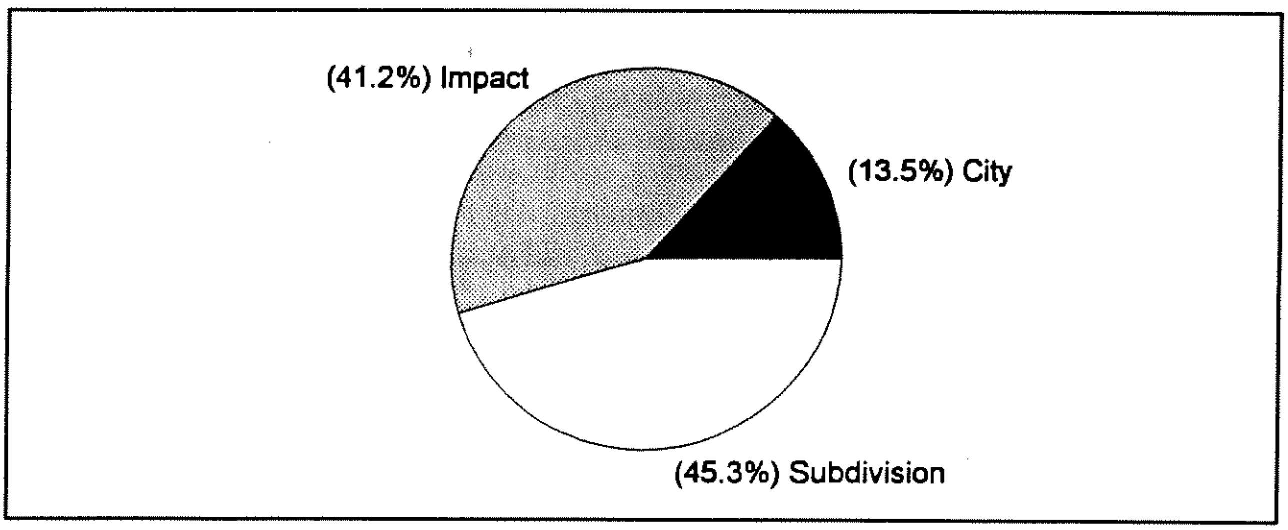


Figure 2.11 Proportional acreage of urban/suburban land use within the Cascade Reservoir Watershed.

There are three primary components to the urban/suburban nonpoint-source pollutants: municipalities, rural residential subdivisions and their respective roads and highways and the transient (non-resident) tourist/recreation population. Rural ranchettes with hobby livestock and other domestic livestock, including their respective drives/driveways are included in with agriculture management sources. General roads associated with these developments and their related stormwater runoff are accounted for in the urban/suburban load evaluation. Roads for timber activities in forested lands are accounted for in the forestry management sources outlined above. Public and private roads and highways not related to timber activities are addressed as urban/suburban nonpoint sources. Urban lands in the Cascade Reservoir watershed encompass approximately 9.4% of the total watershed area between municipalities, their respective city impact areas and rural residential subdivisions.

The transient population of the region has increased over the years and inevitably, increased the potential impact to urban runoff. Most of the impact is difficult to track and related to increased seasonal usage during the summer. Thus, calculated urban/suburban nonpoint source pollutant loading should be considered a conservative estimate. One additional component from the Phase I, phosphorus contributions from septic tank effluent, was re-examined further based on known developed lots for Phase II.

Stormwater Runoff. The three urban/suburban centers in the Cascade Reservoir watershed are the incorporated cities and city impact areas of Cascade, Donnelly and McCall (Figure 2.3). Most of the City of Cascade is located outside the hydrologic drainage of the Cascade Reservoir. However, the city impact area of Cascade resides within and adjacent to the south-end shores of Cascade Reservoir. Runoff from Donnelly discharges into Boulder Creek and Willow Creek through a network of road swales and drainage ditches. Approximately half of the City of McCall is within the drainage of the North Fork of the Payette River, entering through storm sewers, road swales and drainage ditches. The city impact area of McCall located within the Cascade Reservoir drainage includes the McCall Airport, which serves a small commercial fleet and private planes.

Quantity and quality of runoff from these sources is unknown, but has been evaluated extensively using validated models developed for quantifying urban runoff and stormwater pollutant loads. Pollutant sources of concern associated with urban runoff include nutrients, sediment from erosion of conveyance systems, oils, pesticides and bacteria. Potential impacts from urban/suburban management practices are listed in Table 2.8.

Septic Systems. Two areas adjacent to the reservoir with developed subdivision parcels were identified as potential nutrient source locations due to inadequate retention time and treatment of septic tank effluent. Subdivisions are aggregated around the north end of the reservoir, in the vicinity of the three tributary arms of Boulder Creek, Gold Fork River and Lake Fork, and in the west and southwest reach of the reservoir. It was previously recognized that these locations were dominated by high ground-water tables, evidence of ground-water contamination, high septic tank density and poor soil types (DEQ, 1996; Urban/Suburban Source Plan, 1998).

Phosphorus contribution from septic tank effluent was first estimated during Phase I. A more complete inventory of developed subdivision parcels throughout the watershed was used to calculate septic tank effluent, both for a revised Phase I estimate and Phase II. All subdivisions with developed parcels within at least 600 feet of a waterbody were considered to have the potential to act as pollutant sources. Quantitative potential for initial and subsequent estimates are based on the number of installed systems, usage and application of a phosphorus retention factor after Reckhow and Simpson (1980) (DEQ, 1996). The soil retention coefficient is an estimate of how well the soil matrix functions in binding and reducing the transport of phosphorus through shallow groundwater. The most important mechanisms responsible for immobilizing phosphorus are the formation of insoluble iron and aluminum phosphate compounds and the adsorption of phosphate ions onto clay particles (Tilstra, 1972). It was determined during Phase I that surface soils in the vicinity of Cascade Reservoir have good binding capacity, but with depth phosphorus sorption declines (McGeehan, 1996). In addition, it was concluded that seasonal high ground-water tables may increase the mobilization of phosphorus, ultimately transporting all phosphorus from septic tank effluent to the reservoir.

Table 2.8 Potential pollutant loading from urban/suburban management practices.

Management Practices	Resulting Status of Sediment Loads	Resulting Status of Nutrient Loads	Resulting Status of Other Pollutants
Urban Runoff	Increased sediment from roads and construction practices	Increased sediment-bound nutrients from runoff and construction	Petroleum products and road/home/ lawn care chemicals
Septic	Nominal: construction induced increases only	Increased nutrient load in highly bioavailable form	Increased bacterial levels
Sewage Effluent	Nominal: construction induced increases only	Increased nutrient load in highly available form	Increased bacterial levels
Recreational Users	Increased sediment from off-road and irresponsible camping vehicle use	Increased nutrient load from improperly disposed wastes	Increased bacterial levels from improperly disposed human, fishing, and hunting wastes Increased petroleum products in water column from motorized boats and/or personal watercraft use and maintenance and/or fueling practices

Recreational Sources. A variety of recreational opportunities are available on Cascade Reservoir and within the surrounding watershed. The USFS, BOR and the City of Cascade operate and maintain public access to the reservoir for a variety of uses (boating and fishing are the most popular). Facilities include 17 boat ramps, 105 picnic areas and 406 camping sites. Cascade Reservoir is one of the most popular fishing areas in the state as measured by angler hours and fish landed by anglers. Economic value as a sports fishery has been estimated at over two million dollars annually. Due to its proximity to populated urban areas of the state, the reservoir is a major destination site. Water-based recreational activities peak in the season between Memorial Day weekend and Labor Day

Weekend, when the reservoir is utilized by boaters, swimmers, campers and fishermen. The physical carrying capacity of the reservoir for recreational boating has been established at 1,300 boats/day (BOR, 1991). Peak use during a weekend has been estimated at 150 to 200 boats.

Potential impacts from recreational uses are varied, ranging from increased erosion potential caused by irresponsible forest road and off-road vehicle use, to direct contamination of surface water by personal water craft or accidental fuel spills. Pollutants of concern generated by recreational use of the watershed include (but are not limited to) hydrocarbons from outboard motors, organic material from fish cleaning, potential bacterial contamination from human waste (improper sanitary disposal) and addition of nutrients, grease and oils from parking lot runoff at camp grounds and boat ramps. Sediments are also contributed by erosion of banks around popular beach areas and camping sites, and heavy use of forested roads, particularly during the wet season.

Internal Recycling and Reservoir Water Levels
Phosphorus contained in reservoir bed sediments represents a significant loading source to the water column. The deposition, release and dissolution of this phosphorus is dependent on both physical and chemical processes within the watershed and reservoir. Physical processes dominate in the transport of phosphorus contained within or adsorbed to sediment and particulate. Chemical processes dominate in the transport of dissolved phosphorus and in the transformation of phosphorus from one form or state (i.e. free or adsorbed) to another, within both the transport pathway to the reservoir and the water column.

Phosphorus within the water column can be divided into two major sources: suspended sediment-bound phosphorus and dissolved phosphorus. Suspended matter can be colloidal in nature (under 0.45 μm in diameter) and resist settling forces because the surface area to mass ratio is high enough that internal buoyancy counteracts gravitational forces. Sediment and organic matter that has settled to the reservoir bed may also become resuspended and act as a source of dissolved phosphorus as the chemical environment within the water column changes with proximity to the surface. Dissolved phosphorus may be present in tributary inflow, or phosphorus released from bed-sediments. Significant phosphorus release from bed sediments has been observed under anaerobic conditions. Phosphorus sorption sites are related to the charge state and concentration of iron and aluminum within sediment particles. Under anaerobic conditions, the charge state of these metals is changed, resulting in the release of bound phosphorus to the overlying water column as sorption potential is decreased (Shapely *et al.*, 1995). Low dissolved oxygen levels lead to sediment release of bound phosphorus in this manner.

Availability of sediment-bound phosphorus and potential leaching into surface water can also be affected by operational conditions controlling the water depth over the reservoir sediments. Fluctuating water levels that periodically expose lake sediments or alter the aerobic/anaerobic conditions at the sediment/water interface affect the sink/source characteristics of these sediments. Under annual drawdown conditions, sediment phosphorus availability may be increased, further contributing to the enrichment of the water column and increased algal productivity. Improved understanding of the sediment interactions has facilitated the current program of split summer/winter releases from Cascade Reservoir to augment the salmon-flush flow requirements. Operational guidelines to reduce recycling of nutrients and improve water quality will be developed as additional information becomes available.

2.3.3 Data gaps

Several data gaps were identified in the Phase I management plan, as outlined in Table 2.9. These have been filled, to the extent possible, by work conducted after the completion of the Phase I document. Substantial information is now available on these subjects with the exception of the minimum pool concerns which are still the object of considerable study. Project status for data gaps outlined in Phase I is displayed in Table 2.9, followed by a general discussion of findings for completed projects.

A study of winter dissolved oxygen levels was initiated by DEQ and IDFG in 1997 to determine ice-in conditions. Current monitoring programs include an evaluation of depth-integrated phosphorus and nitrogen levels within the reservoir. This information has allowed the validation of predicted sediment-phosphorus release under anaerobic conditions. Depth-integrated phosphorus and nitrogen monitoring, together with further phytoplankton information will be continued in an effort to further quantify related effects.

Watershed soil phosphorus content was evaluated by both USFS and DEQ monitoring personnel (Fischer *et al.*, 1997). Soil-type to soil-type phosphorus content was not found to be statistically different, as the sample to sample variability was high. The only significant differences identifiable for soil phosphorus content within the watershed was between the A and C horizons sampled. The A horizon soils showed significantly higher concentrations of both bioavailable and total phosphorus (4.9 and 617 mg/kg of soil, respectively), than the C horizon soils (2.5 and 417 mg/kg of soil, respectively). Stream bottom sediments showed phosphorus levels that were 50% (average) lower than the C horizon soils, indicating that fine particles with high levels of adsorbed phosphorus are preferentially transported in stream flow once sediment enters the channel. Stream bottom sediments from the western side of the reservoir showed significantly higher levels of both bioavailable and total phosphorus than those collected on the eastern side of the watershed (Gold Fork River). It can be observed from these studies that total phosphorus levels are commonly orders of magnitude higher than the related bioavailable phosphorus levels, with bioavailable phosphorus accounting for between 1.0 and 0.1% of the total phosphorus associated with the sediment. This and other available information was used to determine natural phosphorus contributions from soils within the watershed, a discussion of which follows in Section 3.3 of this document.

To determine levels and distribution (both spatial and depth) of phosphorus within reservoir bed-sediments, sediment samples were collected from over 40 sites within the reservoir. Samples were collected in 10 cm depth-increments that ranged from surface (0-10 cm) to 40-50 cm (total sediment depth). Available data show that phosphorus concentrations decrease with increasing depth. The greatest total phosphorus concentrations are distributed within the top 10 cm of the reservoir bed sediments. Both the total phosphorus and the bioavailable phosphorus data echo this trend, indicating

Table 2.9 Status of data gaps identified in the Cascade Reservoir Phase I Watershed Management Plan.

Data Gap	Description	Progress Status
Winter DO	Determine winter levels of DO in Reservoir	Initiated
Vertical Nutrient Stratification	Determine how phosphorus and nitrogen concentrations change with depth in reservoir	Initiated
Watershed Soil Phosphorus	Determine phosphorus distribution in watershed soils	Completed
Background Phosphorus	Determine background phosphorus in soils and other natural resources	Completed
Internal Recycling	Improve understanding of how internal recycling affects the reservoir	Completed
Sedimentation Rates	Investigate the rate at which the reservoir fills with sediment	Completed
Phosphorus in Reservoir Sediments	Determine quantity and type of phosphorus stored in reservoir sediments	Completed
Sediment Sources and Transport	Determine sources of sediment and evaluate travel time to the reservoir for Gold Fork subwatershed	Completed
Phytoplankton Composition	Determine differences in phytoplankton species over time and their relationship to trophic states	In-Progress
Beneficial Use Status of Tributary Streams	Complete analysis of beneficial use reconnaissance data to determine use status of streams	Initial Eval. Completed - Continued Monitoring
Reservoir Hydrology	Determine influence of hydrology on phosphorus loading rate	Completed
Re-evaluation of Load, In-Lake Chlorophyll a, Total Phosphorus	Model will be run based on more than one year of data	Completed
Beneficial Use Attainability	To determine if reservoir is capable of supporting beneficial uses	Addressed by Modeling
Adequacy of Minimum Conservation Pool	The minimum conservation pool was established based on a 1984 IDFG recommendation for winter fish survival. IDFG and DEQ will jointly re-evaluate the minimum conservation pool for summer fish survival and improved water quality.	In-Progress

that deeply buried sediments do not represent a significant source of total or bioavailable phosphorus for the overlying water column. The most logical explanation for this trend is that the available or loosely-bound ortho-phosphate within the older (deeper) sediments has already leached to the water column, leaving the lower sediment layers somewhat depleted of available ortho-phosphate relative to sediments that were deposited more recently. Sediment phosphorus distribution was relatively static across the reservoir.

To increase understanding of the impact of delivered sediment to the reservoir, the BOR conducted a bathymetric survey (Ferrari, 1998) in September of 1995 to establish the extent of sedimentation within Cascade Reservoir. The study was conducted using sonic depth recording instrumentation interfaced with a differential global positioning system capable of recording both depth and horizontal coordinates of the survey craft. Water surface elevations for conversion of sonic depth information to lake bottom elevations were obtained from a BOR gauge during time of bathymetric data collection. The purpose of the survey was to determine reservoir topography, compute area-capacity relationships, resolve conflicts about storage capacity and to estimate the loss of capacity due to sedimentation since dam closure in 1947. Total accumulated sediment volume was measured at 10,330 acre-feet, representing a 1.47% total capacity loss, average annual loss of 216.1 acre-feet. While the initial bathymetric survey, completed in 1995, was not able to access the upper (northern) arms of the reservoir, the data presented above is from a 1997 revision of this study which includes some information from these regions where the most significant amount of sedimentation would be expected to occur.

Sediment transport rate and distance were evaluated in a study conducted in the Gold Fork Subwatershed (Whiting, 1997). Findings showed that in the upper watershed, transport of fine suspended particles occurred rapidly and involved predominantly "new" sediment. Hypotheses drawn and supported showed that as distance to the reservoir decreases, the relative amount of new sediment and the transport rate will decrease in a correlated fashion, while residence time increases. Longer residence times allow chemical and microbial breakdown of pollutants (often resulting in pollutant forms which are less toxic). Transport distances were found to be significant (15-60 kilometers) and increased with increasing discharge. Therefore, at highest discharges, most of the "new" material was delivered to the reservoir in the initial (undegraded) form. At low discharge, sediment delivered was predominantly from areas closer to the reservoir inlet.

In an effort to improve understanding of the affect management practices have on future water quality, internal recycling issues, impact on water quality of reservoir hydrology and beneficial use attainability in Cascade Reservoir, a modeling effort was undertaken. Two models, the 2-D BETTER model and the 1-D Cascade model, were used to evaluate both immediate and long-term responses to reservoir management practices and watershed phosphorus reductions. The output data obtained from these models have been used to augment existing data and determine if the proposed phosphorus load reductions could be reasonably expected to have the desired beneficial effects. The models used differed in predictive capacity and have unique characteristics and capabilities. A more defined framework of applicability for each model and the respective outputs obtained is available in Appendix C.

For both models, the reservoir geometry evaluated included the main water body, the five major tributary arms (the NFPR, Mud Creek, Lake Fork, Boulder/Willow Creek and Gold Fork River), and the outflow at the dam. In-reservoir geometry was obtained from the 1995 bathymetric sediment study (Ferrari, 1998).

Output from the Box, Exchange, Transport, Temperature and Ecology of a Reservoir (BETTER) model, (Bender, 1997) was designed to calculate flow exchange, heat budget and dissolved oxygen within a water body and was adapted to account for site specific parameters unique to Cascade

Reservoir. The BETTER model was calibrated using existing monitoring data (both in-reservoir and inflow) for the 1989, 1993 and 1994 water-years, which included dissolved oxygen, inflow nutrient loading, temperature (reservoir, release and inflow), and algae levels (derived from chlorophyll a and Secchi depth measurements). The model was verified using monitoring data from water-year 1995. The BETTER model is based on a longitudinal segment-specific orientation for the reservoir and includes dissolved oxygen, algae levels, anaerobic sediment releases and temperature on a depth specific basis. Operation of the model is limited to a single, ~180 day season (ice-out to ice-in) and therefore cannot be used in an iterative fashion. The simulation capabilities of the BETTER model were directed primarily toward evaluation of the short-term effects of reservoir management options. Modeled inflow loading reductions were not shown to have a significant affect on water quality within the reservoir over a single season. Chemical sealing of bed sediments was shown to have a beneficial effect on water quality but was not simulated in a sufficiently specific fashion to allow action to be taken based on modeled information alone. Dredging of the trashrack inlet channel and increased spillway discharge were both shown to have negative effects on water quality and fish habitat within the reservoir. Aeration of the reservoir water was shown to have some beneficial effect on a localized scale but carries a secondary risk of bed-sediment re-suspension. Operational changes in reservoir water levels were interpreted as having a potentially negative effect on water quality at both higher and lower pool volumes, although there is not general agreement on this interpretation at the present time.

Output from the Cascade Reservoir 1-D Model (Worth, 1997; Chapra, 1990) is available for an entire year (365 days) and so can be run iteratively to simulate long-term effects. Output parameters include inflow nutrient loading, dissolved oxygen, sediment oxygen demand, particulate organic carbon, dissolved organic carbon, methane, chlorophyl a, zoo-plankton, phytoplankton population estimates (biased to blue-green algae), Secchi depth, flow and temperature. The simulations completed focussed on evaluation of the 37% reduction in total phosphorus loading called for in Phase I. Modeling showed this reduction level to be adequate to attain the required water-quality goals within the simulation period. Marked water-quality improvements were predicted over a five year period of sustained 37% reduction, with a more gradual improvement beyond this time frame assuming the 37% reduction level was consistently maintained.

Beneficial-use Reconnaissance Program (BURP) data are available for several streams within the watershed, including Campbell Creek, Deer Creek, Duck Creek, French Creek (upper and lower), Poison Creek (upper and lower), Silver Creek (upper and lower) and VanWyck Creek (upper and lower). Of these tributaries, all except Duck Creek show a full support site status.

Data gaps identified in Phase II. An existing data gap for the evaluation of total phosphorus loading to Cascade Reservoir has been identified within the NFPR subwatershed. Land-use acreages are almost equally divided between forested land, agricultural land and urban/suburban land use, but load allocations based on instream monitoring show a significant amount of the total phosphorus mass attributed to agricultural practices within the subwatershed. Loads assigned to forested land (739 kg/yr) and urban/suburban land (1342 kg/yr), represent 8.1% and 14.8% of the load respectively. The agricultural load calculated (6994 kg/yr) represents 77.1% of the total load attributable to the subwatershed. (An in-depth discussion of load allocation for the NFPR and all other subwatersheds is presented in the following sections of this document.) While similar percentage proportions exist within other subwatersheds -- Mud Creek, Lake Fork and Boulder/Willow subwatersheds for example, there is some concern that a considerable portion of the load allocated to agricultural land uses may be due to streambank erosion induced sediment loads rather than direct agricultural practices. The NFPR channel is very large and complex, with multiple areas identified where stream bank erosion is extensive. Several areas within the channel have also been tentatively identified where sub-flood irrigation recharge is exiting the subsurface directly into the river channel. Monitoring is currently scheduled to identify the nutrient concentration in this recharge in an effort to quantify the source it represents. Efforts currently underway to reduce irrigation water recharge in this subwatershed by converting from sub-flood to sprinkler irrigation may also succeed in reducing the volume of recharge draining into the river. This reduction should reduce erosion rates in the areas where irrigation water is exiting the subsurface midway up existing destabilized slopes. Lack of data on specific phosphorus sources within the NFPR subwatershed is not expected to present a major problem in the allocation of existing load reductions. It is expected that the implementation plan will more accurately address specific sites for best management practice implementation as geographic evaluation and in-depth monitoring projects specific to the NFPR are currently in progress.

An additional data gap identified is the lack of instream monitoring data for the Cascade subwatershed. There are currently no consistently maintained monitoring sites within this subwatershed. Load and reduction allocations have been estimated using available information on land-use practices and comparing specific land-use acreages and flow volumes to other, similar subwatersheds for which comprehensive monitoring is available.

2.4 Summary of Past and Present Pollution Control Efforts

Within the Cascade Reservoir Watershed, implementation has proceeded concurrently with the TMDL process, thus a considerable number of pollution control measures have been implemented, others are currently in progress. A more in-depth discussion of in-place, pending, and proposed implementation will be compiled in a formal implementation plan to be completed for Cascade Reservoir within 18 months of the finalization of the Phase II document. This correlated implementation strategy is expected to result in progress toward the specified phosphorus reduction goal. Pollution control measures have been incorporated by all categories of land use.

2.4.1 Point Source Efforts

A unique combination of agricultural and urban/suburban efforts has been undertaken by ranchers and farmers in the Mud Creek subwatershed and the City of McCall. This project, named after the J-Ditch irrigation canal it replaces, will allow treated effluent from the City of McCall to be mixed with "clean" water and applied at agronomic rates to pasture and crop land in the Mud Creek drainage during the summer irrigation season. The J-Ditch project represents a major step in the eventual, 100% removal of the WWTP effluent from the NFPR called for in the Phase I document. Additional effluent collected during non-irrigation season months will be retained in storage lagoons constructed by the City of McCall. Stored effluent will be land-applied the following irrigation season. Farmers and ranchers participating in this project were originally using sub-flood irrigation practices. To date, all participants have installed on-farm sprinkler systems to be able to utilize the mixed effluent. Currently, the system as designed will be able to remove all treated effluent from the NFPR during the irrigation season. Work on the winter storage lagoons is on-going. Total (100%) removal of treated effluent from the NFPR will be possible with the completion of winter storage lagoons by the City of McCall. As the mixed effluent will be applied at agronomic rates, no adverse inputs or additional phosphorus loading within the Mud Creek subwatershed is expected to occur.

As noted previously, the McCall Fish Hatchery has made significant reductions in phosphorus inputs to Cascade Reservoir by implementing changes in operation and maintenance and in replacing the fish food previously used with a type containing significantly less phosphorus. Current contributions account for less than 1% of the total phosphorus load. A maintenance and operation plan is required for this facility as part of formal NPDES permit renewals.

2.4.2 Nonpoint Source Efforts

A variety of nonpoint source reduction efforts have been completed within the watershed. Many others are pending.

Forestry Management
Forest Practices Act. The FPA (Title 38, Chapter 13, IDAPA 20.15, IDL 1992) outlines rules and regulations pertaining to forest management activities. These rules include the establishment of stream protection zones along stream channels within which operation of skidding equipment is prohibited, reforestation procedures, guidance on the use of chemicals and slashing management. Annual audits of the FPA are performed by Idaho Department of lands to determine if appropriate management practices are being implemented on federal, state and private lands.

Road Upgrades. The forestry industry (private, state, federal and commercial), has made a concerted effort to limit erosion and sediment transport from logging roads within the watershed. Many roads have been upgraded by hard-surfacing, culvert replacement and drainage improvement measures. Other roads have been obliterated and re-seeded to establish natural vegetation. Local city and county agencies, along with the BOR have made efforts to improve existing roadways that show significant sediment loads in snow-melt or storm events.

Agricultural Management
Irrigation Management Changes. As discussed with the J-Ditch project above, some ranchers and farmers in the watershed have converted from sub-flood irrigation practices to sprinkler systems. This is expected to reduce phosphorus load to the reservoir in several ways. Irrigation water from flooded fields often discharges directly into the reservoir and tributaries. This recharge has been shown to be highly enriched in nutrients. Exit areas from unstable streambanks are also a source of erosion. In addition, conversion from sub-flood irrigation to sprinkler systems is expected to result

in lowered water tables, allowing greater oxygenation of the soils and increased phosphorus sorption capacities. Sub-flood to sprinkle irrigation changes, along with improved irrigation water management practices may also result in increased instream flows and reduced instream water temperatures. While current participation in sub-flood to sprinkle irrigation changes is minor (most probably limited by the substantial initial costs incurred), it is hoped that participation will increase during the implementation phase of the TMDL process.

Livestock and Grazing Changes. In some areas of the watershed, management practices on private pasture and rangeland, BOR, BCC, IDL and USFS forested grazing allotments have been improved to reduce livestock densities, limit access to stream banks and riparian areas, provide off-site watering and incorporate rotational grazing. The BOR has fenced off a large portion of their land holdings directly adjacent to the reservoir and significant revegetation has occurred. Many farmers and ranchers have made an effort to restrict the use and accessibility of riparian areas around streams and rivers within their properties. Riparian fencing and the creation of hard-crossings and off-site watering sources have resulted in substantial improvements in the riparian areas where projects were sited.

Urban/Suburban Management

Stormwater Runoff. Stormwater runoff improvements have been completed in most of the population centers within the watershed with more scheduled. BOR campground facilities have been improved to incorporate stormwater runoff and filtering facilities on several of the major camp grounds around the reservoir.

Septic to Sewer Upgrades. The North Lake Recreational Sewer and Water District is currently providing sewer service to over 500 subdivision residences aggregated around the north end of the reservoir. By mid-1998, additional residences are expected to be connected to sewer and disconnected from their septic tanks (NLRSWD, 1998).

Urban/Suburban Development. A handbook of stormwater BMPs has been developed for new and existing construction. This handbook has been adopted as a technical reference by resolution by Valley County, and has also been adopted by ordinance by the City of McCall. Valley County Resolution #21-98 (Resolution to Implement TMDL) specifically resolves that all new development applications within Valley County will be evaluated not only for economic and land-use impacts but for water quality/TMDL impacts as well, and will be formally assessed on these issues in the permitting process.

Created Wetlands

Many existing wetland areas have been augmented and others created by the BOR in cost-share agreements with various agencies and land owners. Eight major wetlands (Figure 2.12) currently exist along the perimeter of the reservoir, with expansions and several new constructions planned. Created wetlands act to filter sediment from incoming flows, reduce water temperatures and (often) increase dissolved oxygen levels. Many plant species within the wetlands uptake phosphorus from

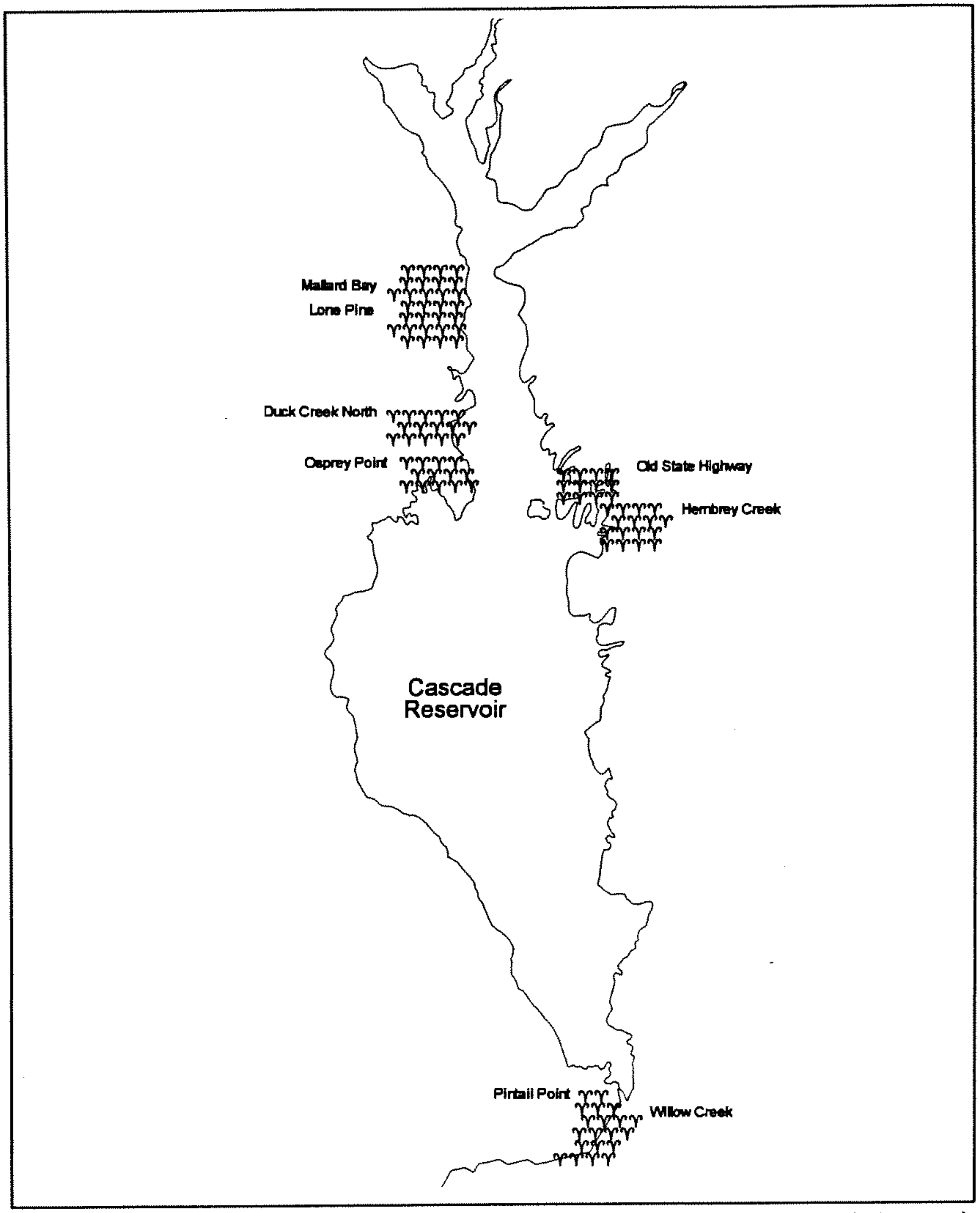


Figure 2.12 Approximate location of major created wetlands within the Cascade Reservoir Watershed.

the water and complex it metabolically into an organic form. These organic compounds are much less bioavailable, even when the plant dies and decomposes, than the original dissolved or sediment-bound form entering the wetland (Reddy *et al.*, 1978; Sharpley *et al.*, 1995; Sharpley *et al.*, 1984; Tiessen, 1995; Salminen and Beschta, 1991).

Riparian Enhancement

Several areas of the watershed have been targeted for revegetation and development of riparian areas. The majority of this work has been associated with agricultural activities, primarily grazing management changes. When implemented in areas of tributary inflow to the reservoir, increased streamside vegetation provides not only sediment reduction, but also increases fish and wildlife habitat. In addition, improved streamside vegetation increases cover over the stream channel and helps to maintain lower temperatures within the water column. During summer months when solar inputs influence reservoir temperatures, such improvements, combined with augmented streamflows, may provide a temporary thermal refuge for fish seeking cooler, oxygenated waters.

All current and ongoing pollution reduction activities within the watershed are expected to result in improvements in water quality. However, existing projects alone will not attain water-quality goals. Additional participation in pollution reduction measures will be required to regain acceptable water quality within the reservoir.

3.0 TMDL - Loading Analysis and Allocation

Cascade Reservoir is listed on Idaho's 1998 303(d) list for nutrients, dissolved oxygen and pH. Phosphorus has been identified as the pollutant of concern within the reservoir. Phosphorus loading affects both dissolved oxygen and pH levels within the reservoir. High phosphorus concentrations result in excessive algae growth which impairs beneficial uses including fishing, swimming and boating. The decomposition of dead algae depletes dissolved oxygen within the water column, with the most severe effect occurring within the lower level of the water column as algae drift downward and accumulate on the bed sediments. Reduced dissolved oxygen levels result in a change in reduction-oxidation potential within the reservoir environment which in turn can lead to pH changes and further release of sorbed phosphorus from deposited bed sediments. Reduced dissolved oxygen levels, combined with warmer water temperatures in the summer months result in reduced fish habitat within the reservoir.

Because of the cause-and-effect relationship of phosphorus within the reservoir, phosphorus is being targeted specifically by this watershed management plan. Phosphorus loading modifications are addressed through the load allocations and reductions discussed below. Dissolved oxygen and pH modifications will be addressed through activities implemented for phosphorus load modification resulting in reduced algal growth.

3.1 Water-Quality Targets

Inlake water-quality targets are based on numerical standards for phosphorus (0.025 mg/L inlake total phosphorus concentration), chlorophyll a (10 µg/L inlake chlorophyll a concentration) and dissolved oxygen (concentrations exceeding 6 mg/L at all times, with the exceptions listed previously for the bottom 20% of water depth in lakes and reservoirs where depths are thirty-five (35) meters or less and those waters of the hypolimnion in stratified lakes and reservoirs). These objectives, based on water-quality modeling efforts for Cascade Reservoir, were set to achieve full support of designated beneficial uses (specifically fishing, swimming, boating and agricultural water supply). Pollutant loads are allocated as kg/year total phosphorus. Reductions required are based on assessment of the maximum inlake load that can be sustained without beneficial use impairment. Reductions were assessed at the level required to achieve the inlake water-quality objectives for phosphorus concentration. Load capacity was divided among load allocations, waste-load allocations and a margin of safety.

When water-quality monitoring shows that water-quality standards have been met and beneficial uses are being fully supported, the watershed management plan will be successful. Total and ortho-phosphate concentrations have been monitored consistently at the lower ends of each major tributary since 1993, and at a minimum of 4 inlake sites since 1992 (Figure 2.6). Inlake sites are monitored during summer months by both the BOR and DEQ. A gross annual estimate of cumulative inflows to Cascade Reservoir is calculated by the BOR using the change in storage method. Stream flow and water quality within the tributaries have been measured at least monthly or biweekly during spring snow-melt (Zimmer, 1983, Entranco, 1991; DEQ, 1994; 1995; 1996; 1998). Total phosphorus has been and will continue to be monitored within the reservoir and at the inflows of major tributaries. Additional monitoring sites or constituents may be added as deemed necessary.

3.2 Load Capacity

An annual phosphorus load allocation was established for Cascade Reservoir using measured total phosphorus loads for water years 1993 to 1996. Monitoring data was available for both tributary inflows and point sources (from NPDES monitoring). Some uncertainty was introduced by estimates made to interpolate missing flow data when direct stream measurements were not available for monitoring data. Such uncertainty should be minor as flow estimates and resulting cumulative flows were checked against total inflow and outflow data available through the BOR. External contributions of total phosphorus (measured in kg/yr) from point and nonpoint sources were evaluated to determine current loading and establish a quantitative value from which appropriate reduction levels could be assessed.

To evaluate load capacity for the reservoir, the above data was used to calibrate and validate two computer models specific to Cascade Reservoir. The revised Cascade Reservoir 1-D Model (Worth, 1997; Chapra, 1990) and the BETTER Model (Bender, 1997) were used to simulate changes in reservoir total phosphorus and chlorophyll a concentrations in response to changes in total phosphorus contributed by the subwatersheds. The revised Cascade Reservoir 1-D Model included modifications to better simulate internal phosphorus recycling and improve sensitivity to changes in the phosphorus contributed by the subwatersheds. There are a number of assumptions that must be used to apply a model in any given reservoir. These include use of limited data to run the model for key factors such as runoff volumes, measured concentrations of nutrients, and weather conditions; and assumptions about biological and chemical mechanisms that govern use of nutrients in the production of algae.

The results of the computer modeling were observed to agree well with the results of an alternative evaluation mechanism based on scientific data using the direct relationship between the amount of total phosphorus entering the reservoir (external loading) and the concentration of total phosphorus measured in the reservoir water column to determine the level of phosphorus loading resulting in acceptable water-quality concentrations. Using two models, and the identified relationship allowed independent validation of the results of each method of analysis. The maximum acceptable total phosphorus loading value generated by both mechanisms is about 70% of the averaged total phosphorus loading measured by instream tributary monitoring. Model simulations using a 30% reduction value were shown to result in substantially reduced algae growth which in turn resulted in improved dissolved oxygen and pH levels. Modeling showed this reduction level to be adequate to attain the required water-quality goals within the simulation period. To further assure attainment of water-quality standards inlake, a 7% margin of safety was established. With the inclusion of the margin of safety, the total required reduction is 37%.

Seasonal variability of flow and delivered phosphorus load is high. Concurrent evaluation of time/delivery plots for total phosphorus loading show that between 70% and 80% of the total phosphorus load is delivered to the reservoir during spring snow-melt and related precipitation events (Figure 3.1). The input of phosphorus during spring runoff and summer irrigation represents a critical time-step in the reversal of beneficial use impairment. Both represent increased sediment-bound total phosphorus and ortho-phosphate delivery and result in both long-term and immediately available phosphorus sources (respectively) within the reservoir water column. This time period should be heavily targeted in any implementation strategy.

3.3 Estimates of Existing Pollutant Loads

As discussed above, an annual phosphorus load allocation was established for Cascade Reservoir using measured total phosphorus loads for water years 1993 to 1996 for both tributary inflows and point sources (from NPDES monitoring). The water years evaluated represent both above average and below average precipitation levels (Figure 3.2). Historical monitoring values for these years are available in Appendix D. The assumption was made that by averaging data from water years with a range of precipitation levels, the resulting load allocations would represent the best possible data fit for future water years and would provide a level of confidence sufficient to account for natural variability. Some uncertainty was introduced by estimates made to interpolate missing flow data when direct stream measurements were not available for monitoring data. Again, such uncertainty

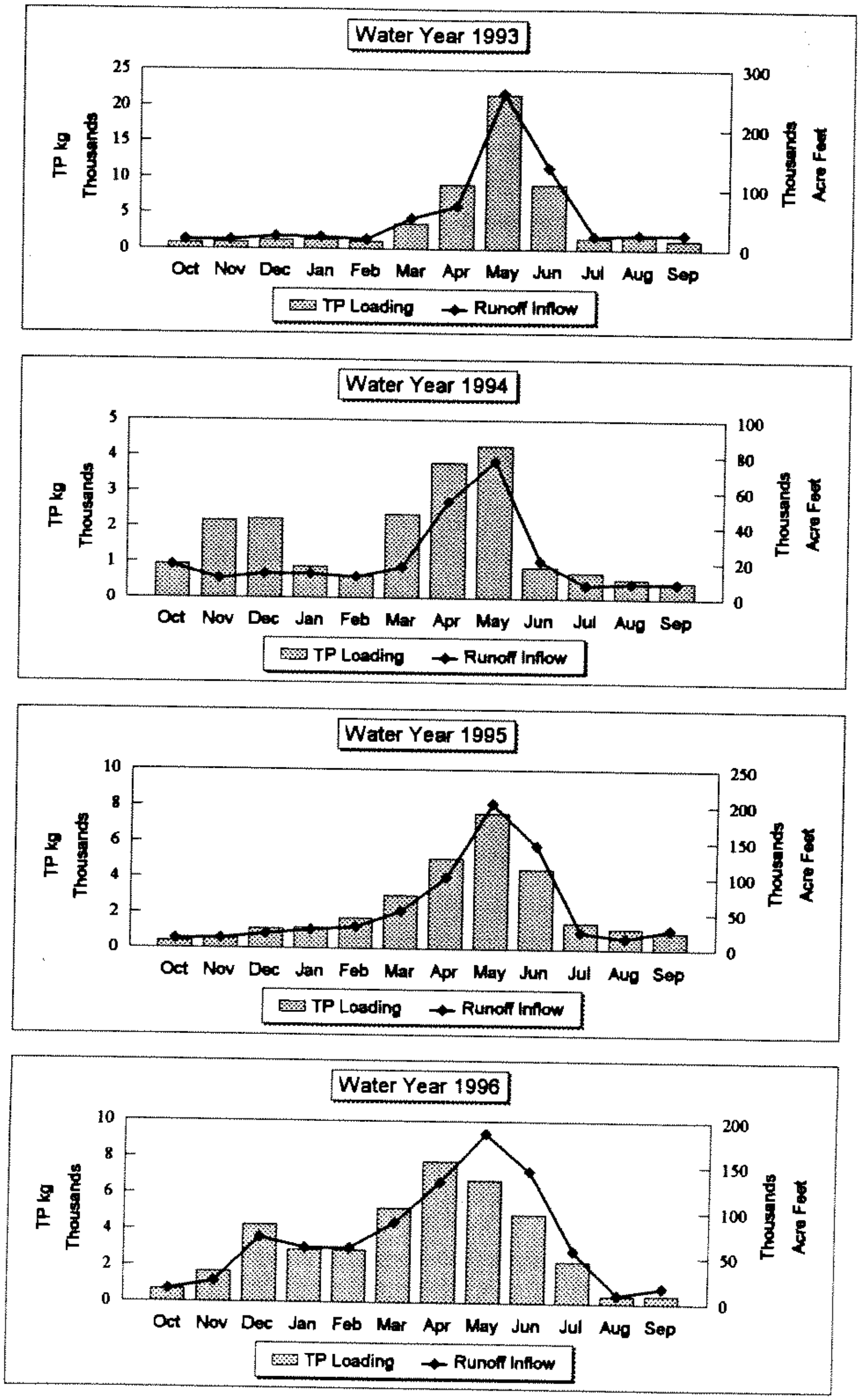


Figure 3.1 Seasonal total phosphorus loading and runoff inflow to Cascade Reservoir.

should be minor as flow estimates and resulting cumulative flows were checked against total inflow and outflow data available through the BOR. Subwatershed load allocations were evaluated through a review of previous studies and other available data on the amount and sources of nutrients from point and nonpoint sources within the watershed (EPA, 1977; Zimmer, 1983; Entranco, 1991). Each of these studies offered monitoring information collected from the same general points of inflow to the reservoir as the current monitoring effort. External contributions of total phosphorus (measured in kg/yr) from point and nonpoint sources were evaluated.

In Phase I, nonpoint source land-use specific loads were assigned on a land-use area proportional basis. Further refinement of this allocation process was possible for the Phase II document as more complete monitoring and modeling information was available. Existing monitoring data was combined with modeling results to allow reasonably accurate estimates of the subwatershed loads generated by each of the major land-use categories (forestry, agriculture and urban/suburban). Specific information on the models and validation procedures used is available in the source plans (1998). The loads estimated by this modeling process were then summed to provide a total estimated load contribution specific to each subwatershed. The relative percentage of the total estimated

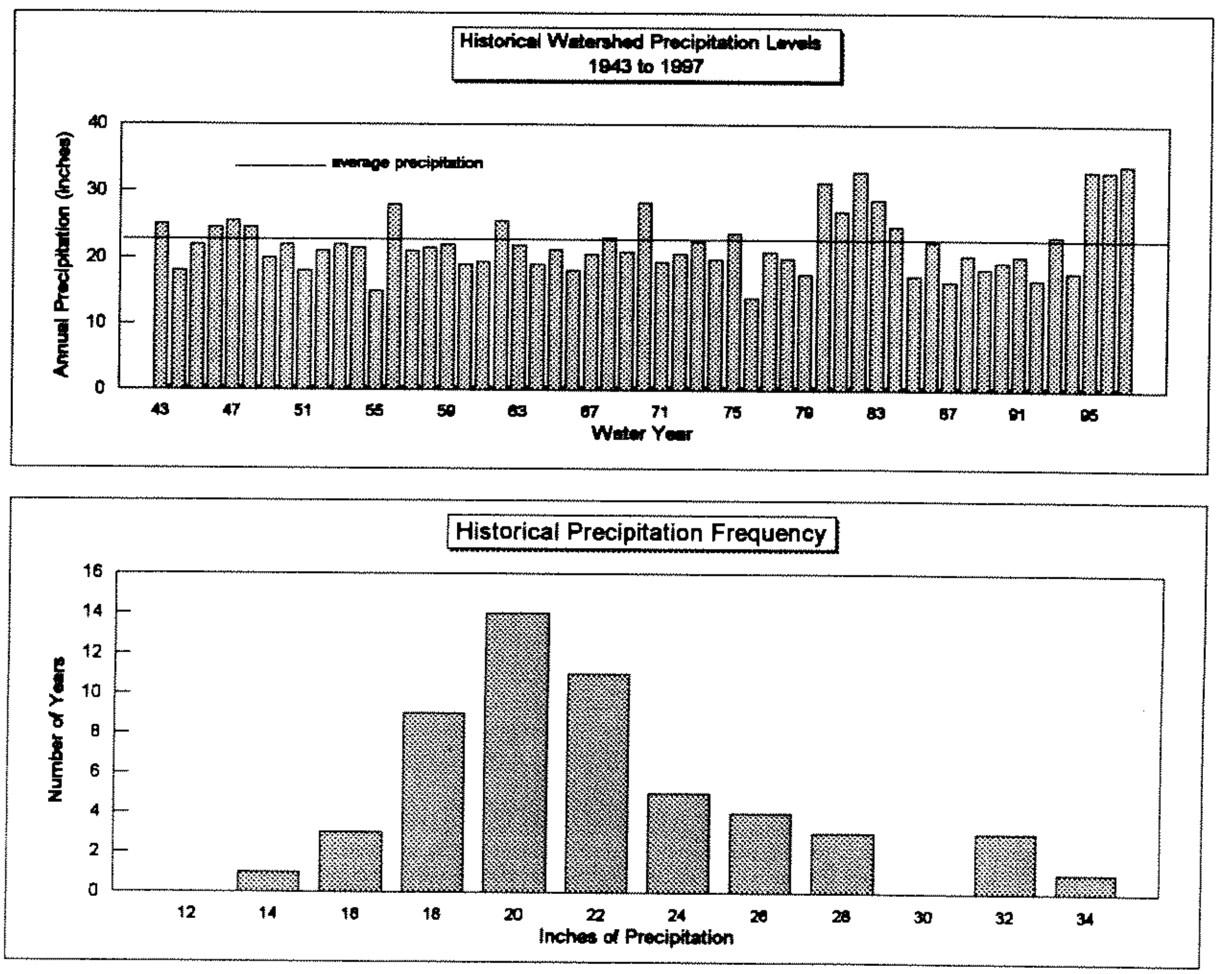


Figure 3.2 Historical precipitation levels and frequency for the Cascade Reservoir Watershed.

management load was determined for each land use within the watershed. This percentage (combined with the appropriate percentage of the natural load identified for that subwatershed) was applied to the total measured load for that subwatershed. In this manner, it was possible to account for differences in load contribution specific to land use within a subwatershed. For example, the natural contribution of forested lands within the Gold Fork subwatershed is significantly higher than that identified for acreage within the agricultural land use. The forestry management contribution per acre however is lower overall than that assessed per acre for agriculture within this same subwatershed. This contribution may be due to land-use practices that differ from region to region within the watershed and to proximity of a specific land use to major tributaries or the reservoir. The mechanism developed to assess total load was able to account for such differences.

The method for determining the wasteload allocation is based on scientific data that indicates there is a direct relationship between the amount of total phosphorus entering the reservoir (external loading) and the concentration of total phosphorus measured in the reservoir water column.

In an attempt to maintain consistency, grazing allocation contributions within forested lands were evaluated using subwatershed specific coefficients developed within the Agriculture Source Plan for assessment of agricultural grazing loads. An in-depth discussion of grazing and agricultural loading is available within the Agriculture Source Plan (1998). Livestock densities were determined for forested grazing allotments and compared to agricultural grazing densities within the watershed. The ratio obtained was used as an additional factor to determine relative contribution by forested grazing allotments.

Annual estimates of phosphorus loading from nonpoint sources were observed to vary greatly from year to year. These differences may be related to differences in runoff conditions and errors in estimates of individual stream flow, concentration of nutrients and frequency of measurement. Sample locations, methods of measurement and frequency are most consistent among surveys conducted in water years 1993, 1994, 1995 and 1996. Highest rates of phosphorus loading were observed in 1993 an above average year for precipitation which followed several consecutive years of below normal rainfall (Figure 3.2). Phosphorus loading is closely tied to precipitation amounts and frequencies, as is evidenced by the decline of more than 50% in the following water year in response to a decline in total rainfall.

Estimates of the point and nonpoint sources of phosphorus entering Cascade Reservoir through runoff are presented in Table 3.1 and Figure 3.3. These estimates represent the average annual total phosphorus loading by subwatershed as calculated from monitoring data for water years 1993 through 1996. Annual estimates for water years 1993 to 1996 are in Appendix D.

Nonpoint source runoff accounts for the majority of phosphorus input to the reservoir, averaging 83% in an assessment of current and historical monitoring data. The largest portion (~37% average) of nonpoint source phosphorus is contributed by the NFPR, due to its high flow volume (49% average of total inflow). Point source loading for 1993 to 1996 averages 10.3% (Figure 3.4).

Table 3.1 Annual total phosphorus load (kg/yr) to Cascade Reservoir averaged from 1993-1996 instream monitoring data.

Nonpoint Sources		**Annual kg Phosphorus Allocated from Measured Load**				
		Natural Load	Forestry	Agriculture	Urban	TOTAL
Subwatershed	Cascade*	209	2	222	229	662
	Gold Fork	4704	3164	742	63	8673
	Lake Fork	600	126	2401	792	3919
	Mud Creek	167	8	612	245	1032
	North Fork*	3445	739	6994	1342	12520
	West Mtn.	984	924	391	83	2382
	Boulder/Willow	922	866	2232	303	4323
Septic						2205
Non Point Source Totals		11031	5829	13594	3057	35716
Point Sources		**Annual kg Phosphorus Allocated from Measured Load**				
						TOTAL
McCall Water Treatment Plant						3947
McCall IDFG Fish Hatchery						218
Point Source Totals						4165
GRAND TOTALS		**11031**	**5829**	**13594**	**3057**	**39881**

* Please see *Identified Data Gaps* discussion in Section 2.3.3.

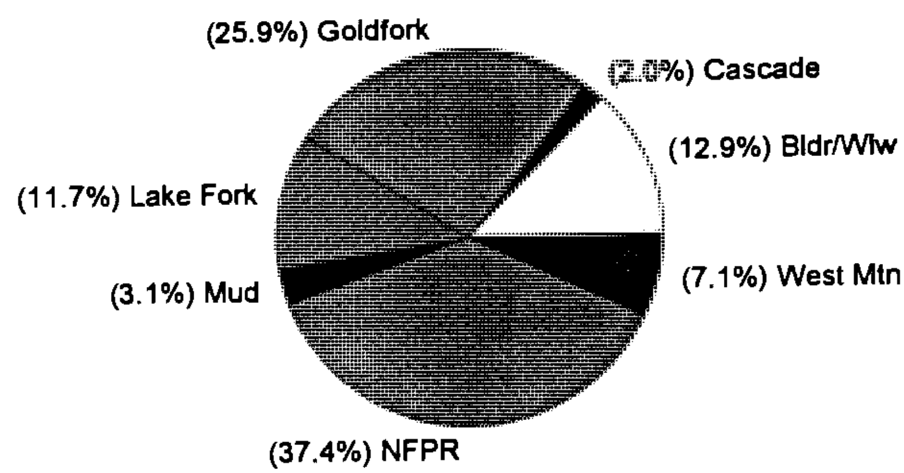


Figure 3.3 Proportional annual total phosphorus loading by subwatershed within the Cascade Reservoir Watershed.

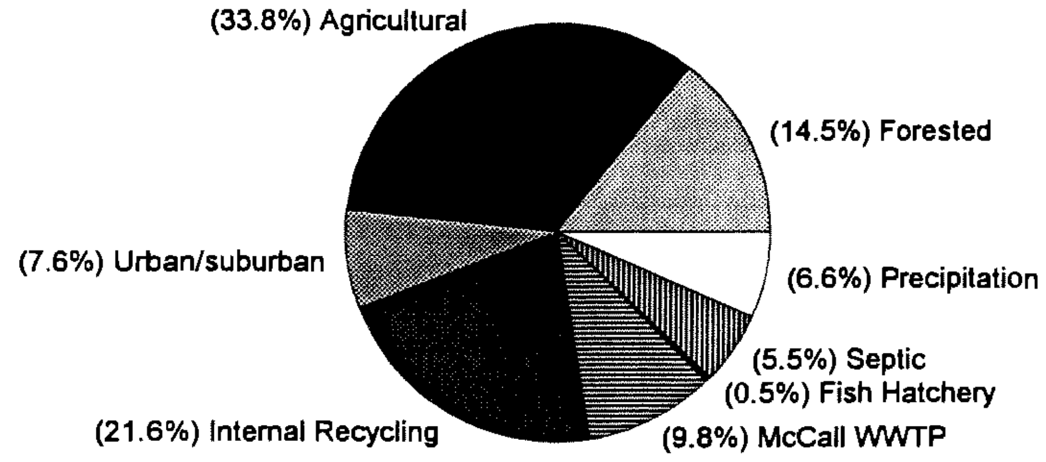


Figure 3.4 Proportional annual total phosphorus loading by source within the Cascade Reservoir Watershed.

Phosphorus contribution from septic tank effluent was first estimated during Phase I. The cumulative effects of septic tank effluent was estimated at 1,917 kg/yr total phosphorus or 5% of the total load. A more complete inventory of developed subdivision parcels throughout the watershed was used to calculate septic tank effluent for the Phase II. All subdivisions with developed parcels within at least 600 feet of a waterbody were included. Initial and subsequent estimates are based on the number of installed systems, usage and application of a phosphorus retention factor after Reckhow and Simpson (1980) (DEQ, 1996). The current estimate for septic tank effluent is 2,205 kg/yr total phosphorus based on 1795 septic tanks (Table 3.2).

Contributions of phosphorus from direct rainfall were based on precipitation data, applying a phosphorus content of rainfall (assumed equal to 0.05 mg/L) and multiplying by the volume of direct rainfall/snowfall in the water budget. Actual measurements of phosphorus content in rainfall have not been obtained and could be underestimated in the loading budget.

Internal recycling, identified in Phase I as representing roughly 8,700 kg phosphorus was evaluated using the revised Cascade Reservoir 1-D Model. No significant discrepancies were identified for this value. However, it should be noted that seasonal and annual variance associated with internal recycling are likely to be significant, and actual contributions are expected to vary considerably under differing limnological conditions.

Other potential contributions of phosphorus are associated with erosion of shorelines within the reservoir. The amount of the annual phosphorus loading attributed to this source was evaluated by the BOR using aerial photographs dating from 1988 to 1995. Phosphorus loading from shoreline erosion was not observed to be a significant contributor to the overall annual load.

Table 3.2 Annual total phosphorus contribution from septic systems adjacent to Cascade Reservoir.

Area	Name	# Septic Tanks	Summer Use Days	Average Use Days							Soil Retention Factor*	Estimated Load Based on Total P Output @ Coef. Value ++		
				Person Use	Pre-1996 # of Tanks	Seasonal Capita/yr	Winter Use Days	Person Use	Occupied # Units	Permanent Capita/yr		1.8 kg/yr High	0.8 kg/yr Med	0.3 kg/yr Low
1	NF Payette	90	150	4	54	89	215	3	27	48	0.1	221	111	37
2	Mud Creek	154	150	4	92	152	215	3	46	82	0.1	378	189	63
3	Lake Fork	191	150	4	115	188	215	3	57	101	0.1	469	235	78
4	Boulder	53	150	4	32	52	215	3	16	28	0.1	130	65	22
5	Willow	158	150	4	95	156	215	3	47	84	0.1	388	194	65
6	Gold Fork	151	150	4	91	149	215	3	45	80	0.1	371	185	62
7	Cascade	388	150	4	233	383	215	3	116	206	0.1	953	477	159
8	West Mtn.	610	150	4	366	602	215	3	183	323	0.1	1499	749	250
	TOTALS	1795			1078	1771			637	952		4410	2205	735

* Soil Retention Factor estimates the adsorption capacity of soils to trap P. Groundwater tables, age of septic systems and soil types affect the retention capacity. Retention values range from 0-1.0; 0=no retention and 1.0=100% retention of P.

++ Typical literature values for P inputs from septic tanks with no phosphate detergent restrictions (Uttomark et al., 1974).

kg/yr TP/single DU/person	@ Effluent Concentrations		
	20 mg/L	15 mg/L	8 mg/L
Septic Output Coefficients	1.0441	0.7831	0.4176

TOTALS		1.8 kg/yr High	0.8 kg/yr Med	0.3 kg/yr Low
	Winter	1542	771	257
	Summer	2868	1434	478
	%1994 TP	16.4	8.9	3.2
	%1993 TP	6.8	3.5	1.2
	%1989 TP	10.5	5.5	1.9

Soil type, average age of septic system and soil retention factor were considered in the above assessment.

3.3.1 Natural and Background Load Contributions

Natural sources of phosphorus are present within the watershed and contribute to the total phosphorus load measured within the reservoir and the tributaries. An evaluation of the magnitude of the natural phosphorus contribution was considered to be an important element of the overall watershed management plan, as it represents a phosphorus source that cannot be easily addressed by best management practices. Because the impact of settlement and management practices within the watershed do not represent a "natural" environment; a pristine, pre-management condition was assumed for all natural contribution calculations.

The calculation of natural contribution was made specific to slope and vegetative cover throughout the subwatersheds (Table 3.3). Shallow-sloped land (<12%) within the Cascade Reservoir Watershed occurs mainly near the reservoir (on the valley floor) and is occupied predominantly by agricultural and urban/suburban land uses. Steeply-sloped land (>12%) occurs primarily within the forested areas of the watershed. Although agricultural uses such as grazing may currently exist within these areas, natural contributions were assessed only on the basis of sediment load generated by pristine grassland, the assessed pre-management condition. Both literature and monitoring sources were used to determine the levels of phosphorus attributable to natural contribution within the watershed (Lindsay, 1979; McGeehan, 1996; Rasmussen, 1981; Reddy *et al.*, 1978; Sweeten and Reddell, 1978; Tiessen, 1995; Whiting *et al.*, 1997; USDA, 1992; Gilley *et al.*, 1992; Van Sickle, 1981; Swanson *et al*; Hoyt *et al.*,1978; Menzel *et al.*,1975; Omernik *et al.*, 1981).

Table 3.3 Annual natural total phosphorus contribution allocations by subwatershed (kg/yr) for the Cascade Reservoir Watershed.

Subwatershed	Acres	<12% Slope Contribution	≥12% Slope Contribution	Ground-Water Contribution	Total Contribution
Cascade	14,953	65	94	51	209
Gold Fork River	101,997	69	4,201	434	4,704
Lake Fork *	51,835	101	255	243	600
Mud Creek	13,097	99	0	68	167
NF Payette	31,264	106	493	1,129	**3,445
West Mountain	29,463	54	832	98	984
Boulder/Willow	33,772	123	720	79	922
TOTAL	**276,381**	**617**	**6,595**	**2,102**	**11,031**

* Drainage area above Little Payette Lake was evaluated separately from the rest of the subwatershed as the lake acts as a sediment sink.

**Background sediment and phosphorus concentrations from Big Payette Lake were accounted for in addition to the natural contribution from the subwatershed.

The natural contribution from shallow-sloped acreages (<12%) was assessed as the sum of sheet and rill erosion (calculated using the USLE and RUSLE equations for pristine grassland conditions, USDA, 1992; Toy and Osterkamp, 1995) and snow-melt based erosion. As available modeling programs did not demonstrate adequate representation of snow-melt based erosion, existing monitoring data from water years 1992-97 were used to account for erosion based on a relative percentage of total load attributable to snow-melt/runoff events. Irrigation, grazing and agricultural tilling practices were defined as non-existent in a pristine pre-management condition. Therefore, all total phosphorus contributions resulting from these practices were therefore not accounted for as part of the natural contribution load.

The natural contribution of total phosphorus from steeply-sloped acreages (≥12%) was calculated using a combination of monitoring data available in subwatersheds with little or no recent management activities, aerial photos and landslide inventories from both the USFS and BCC, an extensive study on erosion in the Gold Fork subwatershed (BCC, 1996) and the BOISED model developed by the USFS for estimation of erosion based sediment loads. This model has been shown to work well in areas such as the Cascade Reservoir Watershed, where the predominant lithology is weathered granite. Both soil creep and mass-wasting events (e.g. landslides) were accounted for in the natural contribution calculations for steeply-sloped acreages. Because the incidence of mass wasting is slightly different from the eastern side of the watershed to the western side (possibly a result of steeper slopes and predominance of highly-weathered exposed surfaces), an attempt was made to compare and compensate for the frequency of mass-wasting events on a subwatershed basis. The West Mountain, Gold Fork and NFPR subwatersheds were consequently given slightly higher mass-wasting contribution coefficients in the initial calculations than the other subwatersheds. As in the shallow-sloped acreages, irrigation, grazing and timber harvest practices (including road construction and use) were defined as non-existent in a pristine pre-management condition. Total phosphorus contribution resulting from these practices was not accounted for as part of the natural contribution load.

Natural contribution loads calculated for each subwatershed are shown in Table 3.3 and Figure 3.5. The natural contribution for Lake Fork subwatershed was calculated using a sediment transmittance factor of 15% (Ferrari, 1998; BCC, 1996; Salminen and Beschta, 1991; Beaty, 1994; Bjornn, *et al.*, 1977; Mahoney and Erman, 1984; Megahan, 1972, 1976 and 1979; Granger *et al.*,1996; Ketcheson, 1986) and available total phosphorus data for the outlet of Little Payette Lake. The 15% transmittance factor applied is a conservative estimate. Monitoring data available for Big Payette Lake and Cascade Reservoir show lower sediment transmittance values, as do the literature sources (5 to 12.9%). The 15% transmittance factor was applied to the load calculated for land lying within the drainage basin of Little Payette Lake. The majority of the land in the Lake Fork subwatershed north of Little Payette Lake is steeply sloped (≥12%) producing increased sediment loads as compared to shallow-sloped land on the valley floor. Little Payette Lake acts as a sediment "sink" for a significant portion of the Lake Fork subwatershed. Lake Fork subwatershed acreage located at the backwaters of Little Payette Lake and those acreages not within the Little Payette Lake drainage area were assessed a natural contribution load equivalent to similarly sloped land within the Cascade Reservoir Watershed using the methodology discussed above.

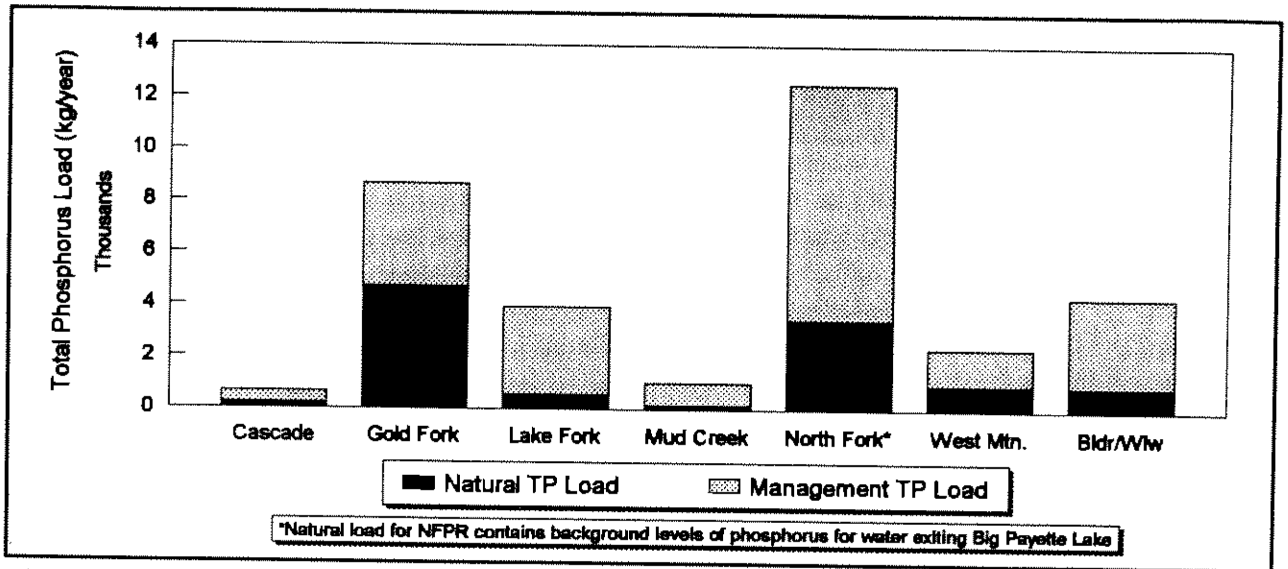


Figure 3.5 Relative annual total phosphorus contributions from natural and management sources by subwatershed for the Cascade Reservoir Watershed.

The natural contribution load attributed to the NFPR subwatershed contains both the calculated natural contribution and the existing total phosphorus background level contributed by Big Payette Lake. Monitoring data available at the outflow of Big Payette Lake was used to establish an accurate total phosphorus load attributable to Big Payette Lake. Because this portion of the total load is not contributed by natural or management sources located within the NFPR subwatershed and therefore would not be addressed by BMPs within this subwatershed, it has been included as background. Cascade subwatershed has no available in-stream monitoring data. Therefore, loads for this subwatershed were estimated from data available for similar land-use areas in nearby subwatersheds.

3.4 Load Allocations

The maximum acceptable total phosphorus load determined for Cascade Reservoir was about 70% of the averaged total phosphorus load measured by instream tributary monitoring. To attain this maximum load, a 30% overall total phosphorus load reduction is required. The 30% reduction was established during Phase I through the use of a model designed specifically for Cascade Reservoir (Chapra, 1990). Further, more recent modeling suggests that this reduction is appropriate to reduce and eliminate excessive algae growth in the reservoir (Appendix C) and that the 30% reduction in loading is anticipated to result in water-quality improvements that attain the desired water-quality objectives of 10 µg/L chlorophyll a and 0.025 mg/L total phosphorus in the reservoir. To account for natural variations in environmental conditions, to allow for confidence intervals on estimated values and assumptions made, to allow for the precision of monitored values, and further assure attainment of water-quality standards inlake, a 7% margin of safety has been established which makes the total required reduction 37%. A 30% reduction in total phosphorus load has been assigned to nonpoint sources within each subwatershed. The remaining 7% reduction will be supplied by the removal of the treated effluent from the City of McCall from the NFPR. This effluent represents a direct source of highly bioavailable phosphorus to Cascade Reservoir.

There are a number of assumptions that must be made to apply a model to any given reservoir. These include use of limited data to run the model for key factors such as runoff volumes, measured concentrations of nutrients, and weather conditions and assumptions about biological and chemical mechanisms that govern use of nutrients in the production of algae. Some uncertainty was also introduced by estimates made to interpolate missing flow data when direct stream measurements were not available for monitoring data. Such uncertainty should be minor as flow estimates and resulting cumulative flows were checked against total inflow and outflow data available through the BOR.

To accomplish the overall reduction, total and management phosphorus loads have been assessed for each subwatershed (Table 3.4). Point-source reductions totaling 7% of the total phosphorus load, and nonpoint-source reductions totaling 30% of the total phosphorus load (management load plus natural and/or background load) have been calculated on both a subwatershed and a subwatershed land-use basis (Table 3.4 and Figure 3.6). In the NFPR, the subwatershed load allocation reflects full (100%) removal of the City of McCall's WWTP, the changes in feeding management practices already in place for the IDFG fish hatchery, and a 30% reduction of all nonpoint sources. Current annual nonpoint source total phosphorus loads, and reduced total phosphorus loads for each subwatershed are shown in Figure 3.7. In all nonpoint-source reduction allocations, a 30% reduction of the total load (management load plus natural and/or background load) is possible from management sources alone.

Attainment of the 30% overall nonpoint-source reduction may be difficult in some subwatersheds (i.e. Gold Fork) where natural phosphorus loads represent the majority of the total load (Figure 3.6). It should be understood that an *overall* reduction of 30% of the nonpoint-source total phosphorus load (management load plus natural and/or background load) is required to reach water-quality standards.

It is recognized that efficient use of management efforts and available implementation monies should be of primary concern. Therefore, it is reasonable to expect that the 30% nonpoint source reduction goal may reached by implementation measures resulting in greater than 30% in some subwatersheds to offset less than 30% reductions in others. To this effect, it may be more cost-effective to eliminate or reduce certain significant pollutant sources, rather than reduce phosphorus from all sources equally. It is also possible that certain projects may present exceptional opportunities for achieving significant reductions, thus allowing other sources to seek less than a 30% reduction.

If a particular source is unable to achieve its phosphorus reduction goal, other sources may need to make larger reductions to make up the difference. DEQ, in cooperation with the community, may look beyond site-specific load reductions and explore more cost-effective options to reduce pollutant loading from other sources in the watershed. This is known as pollutant trading. The Cascade Reservoir Coordinating Council and other work groups will be instrumental in identifying high priority and cost-effective load reduction projects that can be used for pollutant trading.

Table 3.4 Average total phosphorus load and reduction goals by subwatershed (kg/yr).

Nonpoint Sources		Total Phos	Reduction Goal
Subwatershed	Cascade	662	199
	Gold Fork	8,673	2,602
	Lake Fork	3,919	1,176
	Mud Creek	1,032	310
	North Fork	12,520	3,756
	West Mtn.	2,382	715
	Boulder/Willow	4,323	1,297
Septic		2,205	840
Non Point Source Totals		35,716	10,895
Point Sources		**Total Phos**	**Reduction Goal**
McCall Water Treatment Plant		3,947	3,947
McCall IDFG Fish Hatchery		218	0
Point Source Totals		4,165	3,947
GRAND TOTALS		**39,881**	**14,842**

3.4.1 Point Source Reductions

As defined in Phase I, treated effluent from the McCall WWTP will be removed 100% from the NFPR using a combination of land application of treated effluent (J.U.B Engineers, Inc., 1995) and winter storage facilities. As stated previously, the on-farm system is essentially complete and will provide disposal of irrigation season effluent starting the summer of 1998. The construction of winter storage lagoons is pending. The proposed plan for removal of treated effluent from the NFPR is consistent with the management strategy of this phased Watershed Management Plan as it would result in an effective long-term reduction or elimination of a known significant source of phosphorus.

The McCall Fish Hatchery has implemented changes in the operation and maintenance of their facility to reduce phosphorus inputs to Cascade Reservoir. Current contributions account for less than 1% of the annual total phosphorus load. Operations staff will attempt to further improve maintenance and operation for additional phosphorus removal. A maintenance and operation plan will be submitted as part of a formal NPDES permit renewal.

3.4.2 Nonpoint Source Reductions

The process to control nonpoint source pollution is identified in the Idaho Water Quality Standards and Wastewater Treatment Requirements (Section 350). Nonpoint source activities are required to operate according to state approved BMPs, or, in the absence of approved BMPs, activities must be conducted using "knowledgeable and reasonable efforts to minimize water-quality impacts" (Subsection 350.02.a). Routine instream monitoring will continue to be used to evaluate overall water-quality trends within the watershed. Site-specific monitoring may be implemented in some cases. New or developing BMPs may incorporate on-site monitoring to evaluate reduction efficiencies. If instream monitoring indicates a violation of standards despite use of approved BMPs or knowledgeable and reasonable efforts, then BMPs for the nonpoint sources activity must be modified by the appropriate agency to ensure protection of beneficial uses (Subsection 350.02.b.ii). This process is known as the "feedback loop" in which BMPs or other efforts are periodically

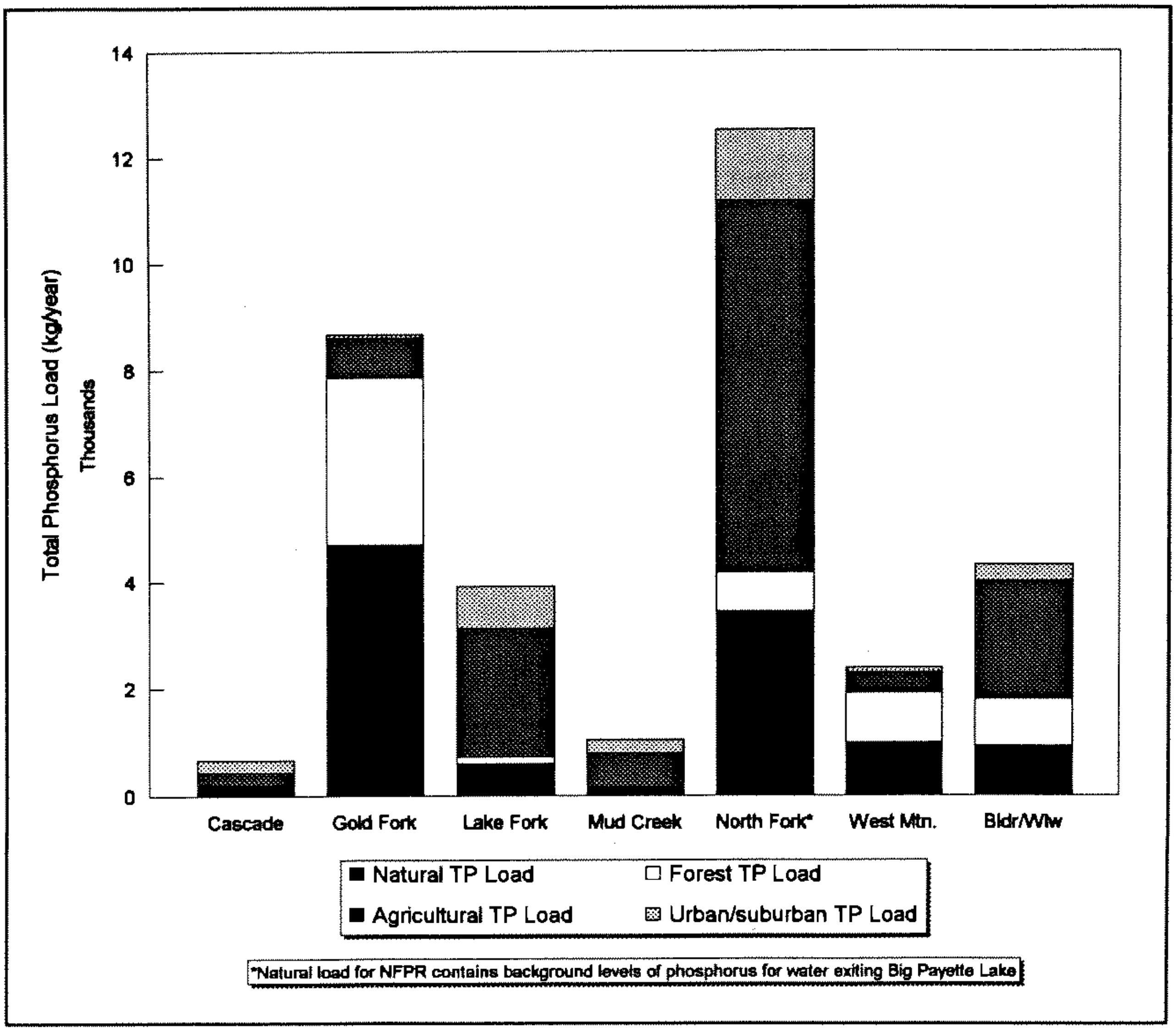


Figure 3.6 Annual total phosphorus loads allocated to nonpoint, land-use sources by subwatershed for the Cascade Reservoir Watershed.

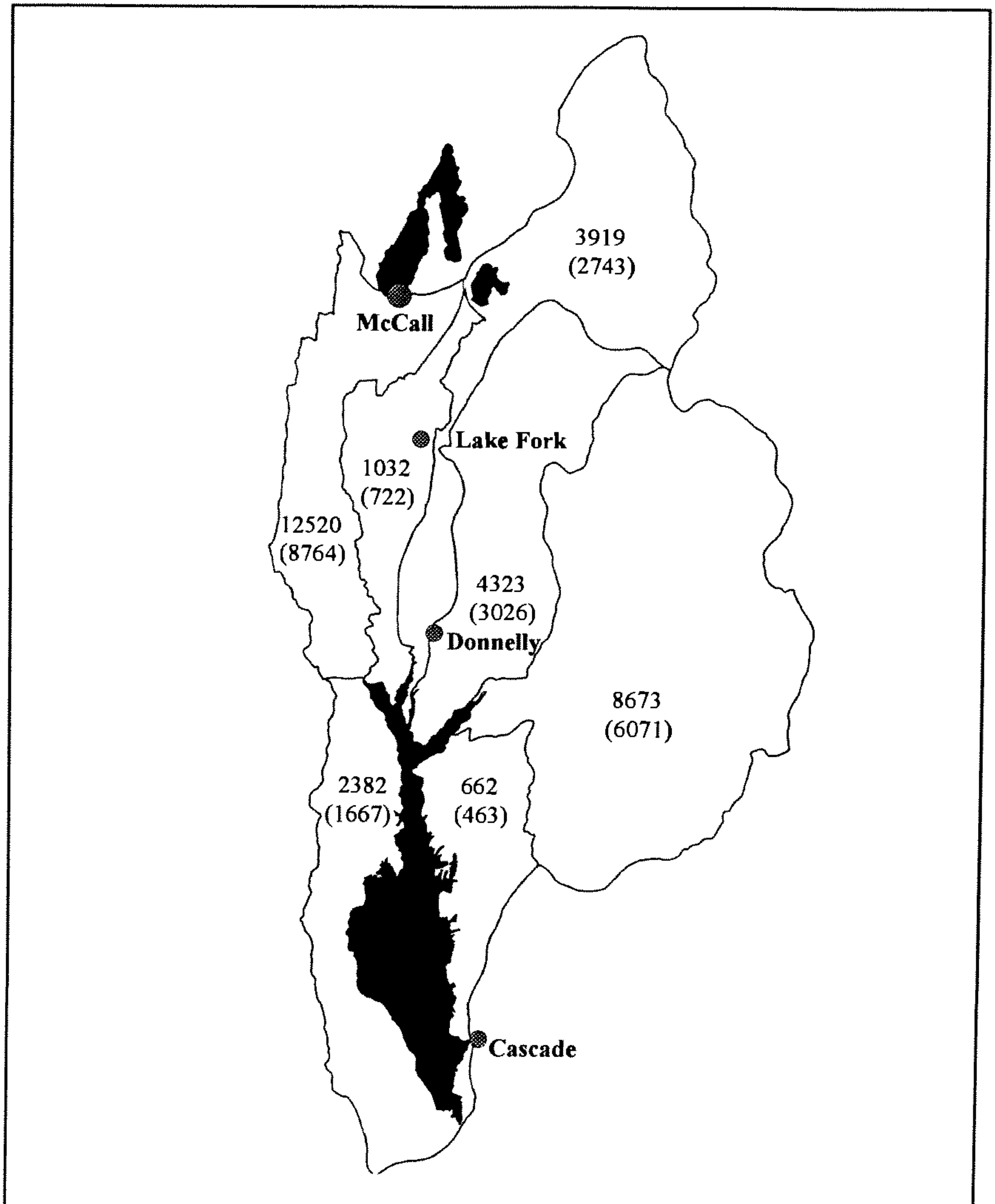


Figure 3.7 Annual nonpoint source total phosphorus load allocation and reduced load (in parentheses) by subwatershed for the Cascade Reservoir Watershed.

monitored and modified if necessary to ensure protection of beneficial uses (Figure 3.8).

With continued instream monitoring, the TMDL will initiate the feedback loop process and will evaluate the success of BMP implementation and its effectiveness in controlling nonpoint source pollution.

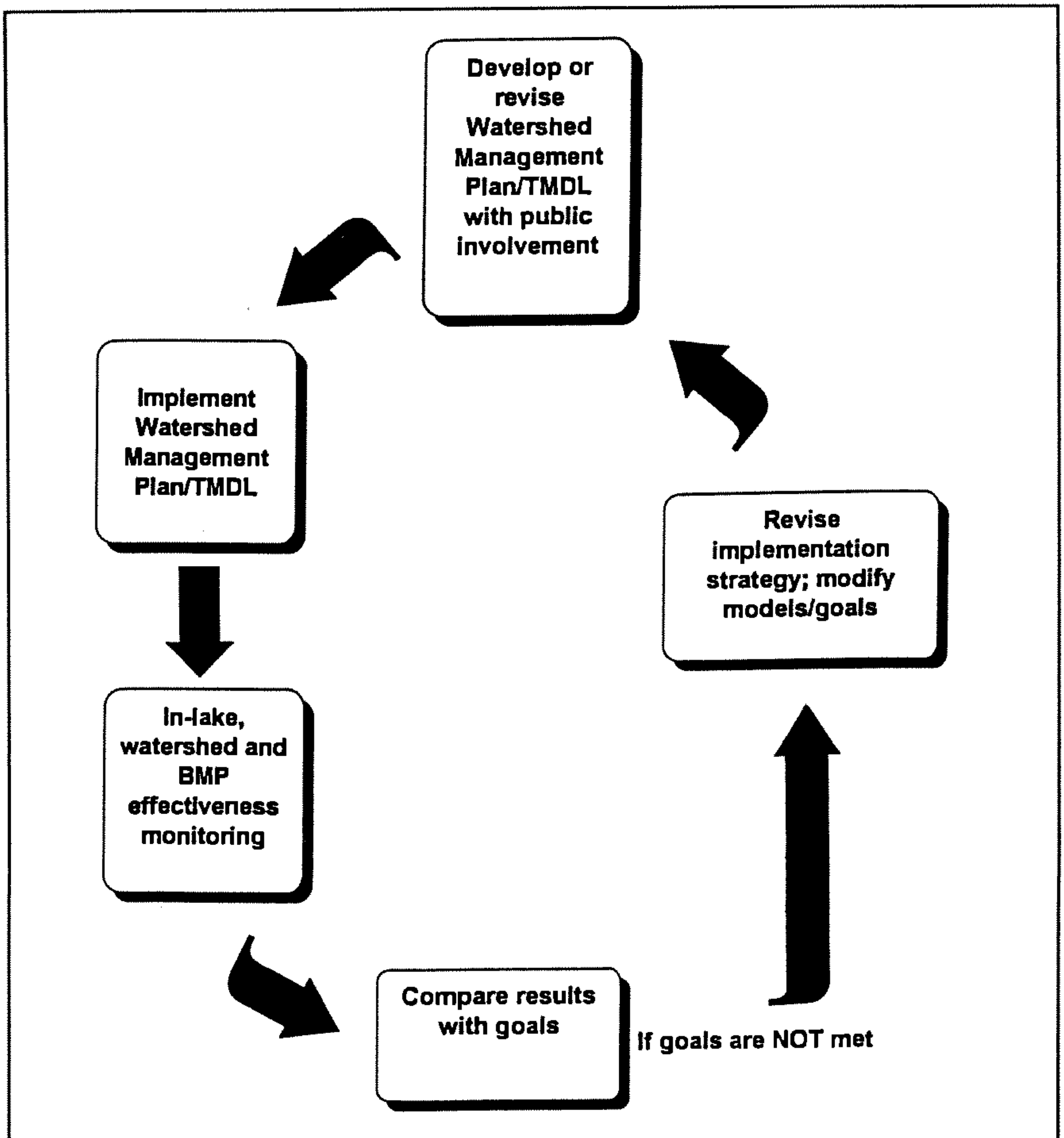


Figure 3.8 Feedback loop for the evaluation of best management practice (BMP) effectiveness.

Forestry Practices

The Idaho Forest Practices Act was passed in 1974 (revised 1992; Title 38, Chapter 13, Idaho Code). Rules that implement the Act establish required minimum BMPs for forestry practices to protect state water quality. In addition to logging, forestry practices include road construction, slash management and other activities associated with silviculture. The rules, which govern activities on Forest Service, private and state lands, primarily address sediment and erosion of streams impacted by logging activity. Reductions in the export of nutrients are not directly assessed, rather, they are addressed through reduction in sediment and sediment transport. Moreover, forestry BMPs do not address the export of nutrients and sediment caused by land disturbing activities that occurred prior to 1974. However, Boise and Payette National Forests, Idaho Department of Lands (IDL), in conjunction with BCC have jointly developed the Forestry Source Plan (1998) to achieve load reductions. The Forests have also identified a method to determine sediment and phosphorus yield from roads and landslides and have developed a list of forestry practice BMPs and treatments with an estimate of their effectiveness in reducing phosphorus (sediment).

Agricultural Practices

For agricultural activities there are no required BMPs. Consequently, agricultural activities must use knowledgeable and reasonable efforts to achieve water-quality standards. Generally, voluntary implementation of BMPs would be considered a knowledgeable and reasonable effort. A list of recommended BMP component practices, which when selected for a specific site become a BMP, has been published in the Idaho Agricultural Pollution Abatement Plan (1991). To facilitate use of these practices, a variety of state and federal funding sources are available to provide cost share incentives. Projects are directed at improving water quality through control of nonpoint source pollution at the subwatershed level using BMPs developed by the Natural Resources Conservation Service (NRCS). Cost share funds are dispersed to private landowners through local Soil Conservation Districts. Contracts with landowners require that BMPs be implemented for ten years, but changes in management practices should provide longer term benefits. Currently, BMPs are directed at changes in irrigation practice, fencing or other access-restriction of riparian areas, creation of wetland habitat, establishment of off-site watering facilities and related practices.

Urban/Suburban Practices

At present, a handbook of stormwater BMPs has been developed for new and existing construction. This handbook has been adopted as a technical reference by resolution by Valley County, and has also been adopted by ordinance by the City of McCall. A resolution dealing with new development has been passed by Valley County (Resolution #21-98 - Resolution to Implement TMDL) specifically resolves that all new development applications within Valley County will be evaluated not only for economic and land-use impacts but for water quality/TMDL impacts as well, and will be formally assessed on these issues in the permitting process.

Septic Tanks

The North Lake Recreational Sewer and Water District is currently providing sewer service to over 500 subdivision residences aggregated around the north end of the reservoir, identified as a significant source of concern in Phase I. By mid-1998, additional residences are expected to be connected to sewer and discontinue use of their septic tanks (NLRSWD, 1998). By deducting the known and expected connections in several subdivisions, septic tank total phosphorus contribution was calculated for Phase II. The Phase II estimate for septic tank effluent is 1,365 kg/yr total phosphorus based on 1,111 septic tanks. The North Lake Sewer District connections will contribute an estimated 38% *reduction* from the revised Phase I estimate. A second sewer district has been proposed for the southwest shore and is currently seeking sources of funding to establish service. The southwest location has a high ground-water table, evidence of ground-water contamination, a high density of septic tanks and poor soil types.

4.0 Compliance Strategy

Success in reducing the current annual load of total phosphorus will be measured by comparing individual subwatershed allocations with the measured contributions monitored at or near the mouth of major tributaries (Figure 2.6). A comprehensive monitoring plan is available in Appendix E.

DEQ will rely upon existing authorities and voluntary implementation of additional phosphorus reduction measures to achieve the goals and objectives of this plan. Attainment of water-quality standards for Cascade Reservoir, as demonstrated by this plan, will require a significant long-term coordinated effort from all pollutant sources throughout the watershed.

For point source discharges of pollutants subject to NPDES permits, DEQ will ensure achievement of water-quality goals established in this plan through water-quality certifications provided in Section 401 of the CWA.

For nonpoint sources, the feedback loop will be used to achieve water-quality goals, as described in Section 3.4.2. DEQ and other involved agencies will conduct instream and qualitative effectiveness monitoring throughout the watershed to evaluate the overall effectiveness of BMPs and other restoration projects in reducing phosphorous loading. If BMPs and other restoration projects prove ineffective, they will be modified to ensure effectiveness of existing and future projects. Any modifications to required BMPs will be subject to state rule-making requirements. DEQ will work closely with the CRCC, applicable resource agencies and affected parties to review the existing regulatory authorities and determine if there is a need for additional requirements for nonpoint sources activities to achieve the goals of the plan.

DEQ's regulatory and enforcement authorities are generally set forth in the Idaho Environmental Health and Protection Act of 1972, as amended. See Idaho Code Sections 39-101 *et. seq.*.

Phase III

Within 18 months of the approval of the Phase II Watershed Management Plan an implementation plan will be prepared identifying specific areas and measures to be taken to reach the 37% reductions outlined above. Following the approval of the implementation plan, a Phase III document will be prepared (December, 2003) using monitoring data to evaluate progress toward attainment of water-quality standards and support of designated beneficial uses. If goals are being reached, or if trend analysis indicates that improvements made are substantial enough to result in attainment of water-quality objectives within a reasonable time frame, the watershed management plan will be a success. If not, the plan will be revised and will outline new goals and a new implementation strategy.

4.1 Reasonable Assurance

For watersheds that have a combination of point and nonpoint sources where pollution reduction goals can only be achieved by including some nonpoint source reduction, a reasonable assurance that reductions will be met must be incorporated into the TMDL (EPA, 1991). The load reductions for the Cascade Reservoir Phase II Watershed Management Plan will rely on nonpoint source reductions to meet the load allocations (LAs) to achieve desired water quality and to restore designated beneficial uses.

To ensure that nonpoint source reduction mechanisms are operating effectively, and to give some quantitative indication of the reduction efficiency for in-place BMPs, monitoring will be conducted. The monitoring will not be carried out on a site specific basis but rather as a suite of indicator analyses monitored at the outflow of major tributaries within the watershed. For example, a decrease in total phosphorus over time as monitored at the outflow of Mud Creek would serve as an indicator that BMPs emplaced within this subwatershed were acting to reduce total phosphorus levels within the tributary water column. This data will be further utilized, in conjunction with flow measurements, to evaluate the overall decrease in total phosphorus mass being contributed to the reservoir by the subwatershed. Concurrent monitoring of reservoir water quality will be undertaken to determine the direct effects of the monitored subwatershed concentration trends on reservoir water quality. If instream monitoring indicates an increasing total phosphorus concentration trend (not directly attributable to environmental conditions) or a violation of standards despite use of approved BMPs or knowledgeable and reasonable efforts, then BMPs for the nonpoint sources activity must be modified by the appropriate agency to ensure protection of beneficial uses (Subsection 350.02.b.ii). This process is known as the "feedback loop" in which BMPs or other efforts are periodically monitored and modified if necessary to ensure protection of beneficial uses (Figure 3.8). With continued instream monitoring, the TMDL will initiate the feedback loop process and will evaluate the success of BMP implementation and its effectiveness in controlling nonpoint source pollution.

All identified point sources within the Cascade Reservoir Watershed are permitted facilities administered by the EPA. These facilities are located within the City of McCall (Figure 2.8). Wasteload (WLAs) reductions can be precipitated by modification of the NPDES permit. However, the load reductions (WLAs and LAs) needed to achieve desired water quality and restore beneficial uses in the reservoir will not be achieved in its entirety by upgrades of the point sources.

The state has responsibility under Section 401 of the CWA to provide water-quality certification. Under this authority, the state reviews the projects to determine applicability to local water-quality issues.

Under Section 319 of the CWA, each state is required to develop and submit a nonpoint source management plan. Idaho's Nonpoint Source Management Program (Bauer, 1989) was submitted and approved by the EPA. The nonpoint management program describes many of the voluntary and regulatory approaches the state will take to abate nonpoint pollution sources. Since the development of the Nonpoint Management Program in 1989, revisions of the water-quality standards have occurred. Many of these revisions have adopted provisions for public involvement, such as the formation of Basin Advisory Group (BAGs) and WAGs (IDAPA 16.01.02052), as discussed in section 2.1.2. The WAGs are to be established in high priority watersheds to assist DEQ and other state agencies in developing TMDLs and Watershed Management Plans (WMPs) for those segments.

The State of Idaho water-quality standards refer to other programs whose mission is to control nonpoint pollution sources. Some of these programs and responsible agencies are listed in Table 4.1.

Table 4.1 State of Idaho regulatory authority for nonpoint pollution sources.

Citation	IDAPA Citation	Responsible Agency
Rules governing Idaho forest practice	16.01.02350.03(a)	Idaho Department of Lands
Rules governing solid waste management	16.01.02350.03(b)	Idaho Department of Health and Welfare
Rules governing subsurface and individual sewage disposal systems	16.01.02350.03(c)	Idaho Department of Health
Rules and standards for stream channel alteration	16.01.02350.03(d)	Idaho Department of Water Resources
Rules governing exploration and surface mining operations in Idaho	16.01.02350.03(e)	Idaho Department of Lands
Rules governing placer and dredge mining in Idaho	16.01.02350.03(f)	Idaho Department of Lands
Rules governing dairy waste	16.01.02350.03(g) or IDAPA 02.04.14	Idaho Department of Agriculture

The State of Idaho uses a voluntary approach to control agricultural nonpoint sources. However, regulatory authority can be found in the state water-quality standards (IDAPA 16.01.02350.01 through 16.01.02350.03). IDAPA 16.01.02054.07 refers to the Idaho Agricultural Pollution Abatement Plan (IAPAP) (IDHW, SCC, EPA; 1993) which provides direction to the agricultural community for approved BMPs. As a portion of the IAPAP, it outlines responsible agencies or elected groups (SCDs) that will take the lead if nonpoint pollution problems need addressing. For agricultural activity it assigns the local SCDs to assist the landowner/operator to develop and implement BMPs to abate nonpoint pollution associated with the land use. If a voluntary approach does not succeed in abating the pollutant problem, the state may provide injunctive relief for those situations that may be determined imminent and substantial danger to public health or environment (IDAPA 16.01.02350.02 (a)).

If a nonpoint pollutant(s) is determined to be impacting beneficial uses and the activity already has in-place referenced BMPs, or knowledgeable and reasonable practices, the state may request the BMPs be evaluated and/or modified to determine appropriate actions. If evaluations and/or modifications do not occur, injunctive relief may be requested (IDAPA 16.01.02350.2, ii (1)).

It is expected that a voluntary approach will be able to achieve LAs needed. Public involvement along with the eagerness of the agricultural community has demonstrated a willingness to implement BMPs and protect water quality. In the past, cost-share projects (many of which are cited in Appendix F) have provided the agricultural community technical assistance, information and education (I & E), and the cost share incentives to implement BMPs. The continued funding of these projects will be critical for the LAs to be achieved in the Cascade Reservoir Watershed.

In 1995 the State of Idaho passed Senate Bill 1284, now incorporated into the Idaho Code Section 39-3613 and Section 39-3615). This bill established the formation of the WAGs and BAGs to assist state and federal agencies with water-quality planning in high priority watersheds. The Cascade Reservoir Coordinating Council, which functions as the WAG for the Cascade Reservoir Watershed, was formed in January of 1995 in response to Idaho Code Section 39-3615 and public interest in the development of a TMDL for Cascade Reservoir. The Cascade Reservoir Coordinating Council was recognized as the representative body for the watershed by DEQ in that same year.

5.0 References

Bauer, S.; 1989; *Idaho Nonpoint Source Management Program*; Idaho Department of Health and Welfare, Division of Environment, Boise, Idaho.

Beaty, K.G.; 1994; *Sediment Transport in a Small Stream following Two Successive Forest Fires*; Canadian Journal of Fisheries and Aquatic Sciences; Volume 51; Winnepeg, Canada; pp 2723-2733.

Bender, M.D.; Hauser, G.E.; Shiao, M.C.; Proctor, W.D.; 1997; *BETTER: A two-dimensional reservoir water quality model; Technical reference manual and user's guide;* Report Number WR28-2-590-152; Tennessee Valley Authority Engineering Laboratory, Norris, Tennessee; 160 p.

Big Payette Lake Water Quality Council (BPLWQC); 1998; *Big Payette Lake Management Plan and Implementation Program;* Big Payette Lake Water Quality Council, McCall, ID.

Bjornn, T.C.; Brusven, M.A.; Molnau, M.P.; Milligan, J.H.; Klamt, R.A.; Chacho, E.; Schaye, C.; 1977 (September); *Transport of Granitic Sediment in Streams and Its Effects on Insects and Fish*; University of Idaho, College of Forestry, Wildlife and Range Sciences; Bulletin Number 1; Moscow, Idaho; 43 p.

Boise Cascade Corp. (BCC); 1996 (December); *Gold Fork River Watershed Analysis*; Boise Cascade Corporation, Boise, Idaho; ~250 p + appendix.

Bureau of Reclamation; 1991 (June); *Cascade Reservoir Resource Management Plan*; Central Snake Projects Office, Boise, Idaho; 74 p.

Bureau of Reclamation; 1975; *Water Quality Studies, Payette River Basin and Cascade*; U.S. Department of the Interior, Bureau of Reclamation; 74 p.

Chapra, S.C.; 1990; *A Mathematical Model of Phosphorus, Chlorophyll a, Oxygen and Water Clarity for Cascade Reservoir*; Center for Advanced Decision Support for Water and Environmental Systems, University of Colorado, Boulder, Colorado; Final Report to Entranco Engineers, Inc. and Idaho Department of Health and Welfare; 70 p.

Clark, W.H.; Wroten, J.W.; 1975; *Water Quality Status Report: Cascade Reservoir, Valley County, Idaho*; Water Quality Series Number 20; Idaho Department of Health and Welfare, Division of Environment, Boise, Idaho; 46 p + appendix.

Entranco Engineers, Inc.; 1991 (January); *Cascade Reservoir Watershed Project Water Quality Management Plan*; Idaho Division of Environmental Quality, Boise, Idaho; 101 p + appendices.

Environmental Protection Agency; 1977; *Report on Cascade Reservoir, Valley County, Idaho*; Working Paper No. 777; U.S. Environmental Protection Agency, Corvallis, Oregon; 44 p.

Environmental Protection Agency; 1991; *Guidence for Water-Quality Based Decisions: The TMDL Process;* EPA 440/4-91-001; U.S. Environmental Protection Agency, Washington D.C.; 58 p.

Ferrari, R.L.; 1998 (May) revised; *Cascade Reservoir 1995 Sedimentation Survey*; USDI, Bureau of Reclamation, Sedimentation and River Hydraulics Group, Water Resource Services, Technical Service Center, Denver, Colorado.

Fischer, J.G.; Amacher, M.C.; Clayton, J.L.; *Dissolved and Sediment-bound Phosphorus Transport During Spring Snowmelt - Gold Fork River;* NPS Workshop Presentation; 1997; Boise State University, Boise, Idaho.

Gilley, J.E.; Kincaid, D.C.; Elliot, W.J.; Laflen, J.M.; 1992; *Sediment Delivery on Rill and Interrill Areas*; Journal of Hydrology; Volume 140; Amsterdam; pp 313-341.

Granger, D.E.; Kirchner, J.W.; Finkel, R.; 1996; *Spatially Averaged Long-Term Erosion Rates Measured from In Situ-Produced Cosmogenic Nuclides in Alluvial Sediment*; The Journal of Geology; Volume 104; Chicago, Illinois; pp 249-257.

Hedley, M.J.; Mortvedt, J.J.; Bolan, N.S.; Syers, J.K.; 1995; *Phosphorus Fertility Management in Agrosystems*; Chapter 5; Phosphorus in the Global Environment: Transfers, Cycles and Management; Tiessen, H.; (ed.); John Wiley and Sons, Chichester.

Idaho Department of Agriculture (ISDA); personal communication; May 1998; Boise, Idaho.

Idaho Department of Commerce (ISDC); personal communication; June 1998; Boise, Idaho.

Idaho Department of Health and Welfare (IDHW); Soil Conservation Commission (SCC); Environmental Protection Agency (EPA); 1993; *Idaho Agricultural Pollution Abatement Plan (IAPAP), Ag Plan*; Idaho Department of Health and Welfare; Soil Conservation Commission; Environmental Protection Agency; Boise, Idaho.

Idaho Department of Health and Welfare (IDHW); 1996; *Water Quality Standards and Wastewater Treatment Requirements*; Idaho Department of Health and Welfare, Boise, Idaho.

Idaho Division of Environmental Quality (DEQ); 1994; *Cascade Reservoir Data Summary - Water Year 1993*; Idaho Division of Environmental Quality, Boise Regional Office, Boise, Idaho.

Idaho Division of Environmental Quality (DEQ); 1995; *Cascade Reservoir Data Summary - Water Year 1994*; Idaho Division of Environmental Quality, Boise Regional Office, Boise, Idaho.

Idaho Division of Environmental Quality (DEQ); 1996; *Cascade Reservoir Data Summary - Water Year 1995*; Idaho Division of Environmental Quality, Boise Regional Office, Boise, Idaho.

Idaho Division of Environmental Quality (DEQ); 1998; *Cascade Reservoir Data Summary - Water Year 1996*; Idaho Division of Environmental Quality, Boise Regional Office, Boise, Idaho.

Idaho Division of Environmental Quality (DEQ); 1996 (January); *Cascade Reservoir Phase I Watershed Management Plan*; Idaho Division of Environmental Quality, Boise Regional Office, Boise, Idaho; 86p + appendices.

Ingham, M.; 1992; *Citizen's Volunteer Monitoring Program, Cascade Reservoir, Valley County, Idaho 1988-1991*; Water Quality Status Report Number 103; Idaho Department of Health and Welfare, Division of Environmental Quality, Boise Regional Office, Boise, Idaho; 17 p + attachments.

J.U.B. Engineers, Inc.; 1995; *Facility Plan Report, City of McCall*; Book 1, Chapters 1-5 (Two volumes); J-U-B Engineers, Inc., 250 S. Beechwood, Suite 201, Boise, Idaho.

Ketcheson, G.L.; 1986 (September); *Sediment Rating Evaluations: An Evaluation for Streams in the Idaho Batholith*; USDA, Forest Service, Intermountain Research Center; General Technical Report INT-213; Ogden, Utah; 12 p.

Khaleel, R.; Reddy, K.R.; Overcash, M.R.; 1980; *Transport of Potential Pollutants in Runoff Water from Land Areas Receiving Animal Wastes: A Review*; Water Research; Volume 14; Great Britain; pp 421-436.

Klahr, P.C.; 1988; *Lake Irrigation District Survey and Cascade Reservoir Tributary Assessment, Valley County, Idaho 1986*; Water Quality Status Report Number 79; Idaho Department of Health and Welfare, Division of Environmental Quality, Water Quality Bureau, Boise, Idaho; 46 p.

Klahr, P.C.; 1989; *Cascade Reservoir, Valley County, Idaho 1988*; Water Quality Status Report Number 85; Idaho Department of Health and Welfare, Division of Environmental Quality, Water Quality Bureau, Boise, Idaho; 12 p + appendix.

Lappin, J.L.; Clark, W.H.; 1986 (December); *An Assessment of Water Quality Impacts of Recreational Housing and Livestock Grazing in the Cascade Reservoir Watershed*; Journal of the Idaho Academy of Science; Volume 22; Number 2; pp 45-62.

Lindsay, W.L.; 1979; *Chemical Equilibria in Soils*; John Wiley and Sons, New York; pp 163-205.

Long Valley Advocate; September 15 and 29, 1993; weekly periodical; Stewart, M. (ed.); Poison Creek Publishing, Cascade, Idaho.

Mahoney, D.; Erman, D.C.;1984 (June); *An Index of Stored Fine Sediment in Gravel Bedded Streams*; Water Resources Bulletin; Volume 20; Issue 3; pp 343-348.

McGeehan, S.L.; 1996 (December); *Phosphorus Retention in Seasonally Saturated Soils Near*

McCall, Idaho (Final Report); University of Idaho, Division of Soil Science, Moscow, Idaho; 54 p + appendix.

Megahan, W.F.; 1979; *Channel Stability and Channel Erosion Processes*; Workshop Proceedings: Scheduling Timber Harvest for Hydrolic Concerns; Portland, Oregon; November 27-29; 18 p.

Megahan, W.F.; 1972 (August); *Volume Weight of Reservoir Sediment in Forested Areas*; Journal of the Hydrolics Division, Proceedings of the American Society of Civil Engineers; Volume 98; Number HY8; pp 1335-1342.

Megahan, W.F.; 1976 (March); *Sediment Storage in Channels Draining Small Forested Watersheds in the Mountains of Central Idaho*; Proceedings of the Third Federal Inter-Agency Sedimentation Conference; Denver, Colorado; pp 4-115 to 4-126.

Natural Resources Consulting Engineers, Inc. (NRCE); 1996 (September); *Analysis Summary Report: Cascade Reservoir Irrigation Management Plan*; Fort Collins, Colorado; 51 p.

North Lake Recreational Sewer and Water District (NLRSWD); Personal communication; May 1998.

Olness, A.; Smith, S.J.; Rhoades, E.D.; Menzel, R.D.; 1975; *Nutrient and Sediment Discharge from Agricultural Watersheds in Oklahoma*; Journal of Environmental Quality; Volume 4; Number 3; pp 331-336.

Omernik, J.M.; Abernathy, A.R.; Male, L.M.; 1981 (July-August); *Stream Nutrient Levels and Proximity of Agricultural and Forest Land to Streams: Some Relationships*; Journal of Soil and Water Conservation; pp 227-231.

Omernik, J.M.; Gallant, A.L.; 1986; *Ecoregions of the Northwest*; EPA/600/3-86/033; 39 p.

Platts, W.S.; Nelson, R.L.; 1995 (February); *Streamside and Upland Vegetation Use by Cattle*; Rangelands; Volume 7; Number 1; pp 5-7.

Rasmussen, L.M., 1981; *Soil Survey of Valley Area Idaho*; U.S. Department of Agriculture, Soil Conservation Service, Boise, ID; 146 p.

Reddell, D.L.; Johnson, W.H.; Lyerly, P.J.; Hobgood, P.; 1971; *Disposal of Beef Manure by Deep Plowing;* Livestock Waste Management and Pollution Abatement; ASAE Publication, Proceedings -271, ASAE; St. Joseph, Michigan; pp 235-238.

Reddy, G.Y.; McLean, E.O.; Hoyt, G.D.; Logan, T.J.; 1978; *Effects of soil, cover-crop and nutrient sources on amount and forms of phosphorus movement under simulated rainfall conditions*; Journal of Environmental Quality; Volume 7; Number 1; pp 50-54.

Reininger, B.; Rieman, B.; Horner, N.; 1983 (January); *Cascade Reservoir Fisheries Investigations*, Project F-73-R-4; Idaho Department of Fish and Game, Boise Idaho; 123 p.

Salminen, E.; Beschta, R.; 1991 (December); *Phosphorus and Forest Streams: The Effects of Environmental Condtions and Management Activities*; Department of Forest Engineering, Oregon State University, Corvallis, Oregon; 185 p.

Sharpley, A.N.; Smith, S.J.; Jones, O.R.; Berg, W.A.; Coleman, G.A.; 1992 (January-March); *The Transport of Bioavailable Phosphorus in Agricultural Runoff*; Journal of Environmental Quality; Volume 21; pp 30-35.

Sharpley, A.N.; Hedley, M.J.; Sibbesen, E.; Hillbricht-Ilkowska, A.; House, W.A.; Ryszkowski, L.; 1995; *Phosphorus transfers from terrestrial to aquatic ecosystems*; Chapter 11, In Phosphorus in the Global Environment: transfers, cycles and management; Tiessen, H.(ed.); John Wiley and Sons, Chichester.

Sharpley, A.N.; Jones, C.A.; Grey, C.; Cole, C.V.; 1984; *A simplified soil and plant phosphorus model II: Prediction of labile, organic and sorbed phosphorus*; Soil Science Society of America Journal; Volume 48; pp 805-809.

Shewmaker, G.E.; 1997; *Livestock Grazing Effects on Phosphorus Cycling in Watersheds*; Proceedings: Watershed and Riparian Workshop; LeGrand, Oregon; September 11-13; 25 p.

Sonzongni, W.C.; Chapra, S.C.; Armstrong, D.E.; Logan, T.J.; 1982 (October-December); *Bioavailability of Phosphorus Inputs to Lakes*; Journal of Environmental Quality; Volume 11; Number 4; pp 555-563.

Swanson, F.J.; Janda, R.J.; Dunne, T.; *Summary: Sediment Budget and Routing Studies*; Proceedings; pp 157-165.

Sweeten, J.M.; Reddell, D.L.; 1978; *Nonpoint sources: state of the art overview*; Trans. ASAE; Volume 21; Number 3; pp 474-483.

Tiessen, H. (ed.); 1995; *Phosphorus in the Global Environment: Transfers, Cycles and Management*; Scientific Committee on Problems of the Environment (SCOPE) 54; John Wiley and Sons, Chichester.

Tilstra, J.R.; Malueg, K.W.; Larson, W.C.; 1972; *Removal of phosphorus and nitrogen from wastewater effluent by induced soil percolation;* J. Water Pollution Control Federation; Volume 44; Number 5; pp 796-805.

Toy, T.J.; Osterkamp, W.R.; 1995 (September/October); *The Applicability of RUSLE to Geomorphic Studies*; Journal of Soil and Water Conservation; Volume 50; Number 5; pp 498-503.

United States Department of Agriculture (USDA); 1992 (April); *Agricultural Wastes and Water, Air and Animal Resources*; Agricultural Waste Management Field Handbook; USDA ; Part 651, Chapter 3; Washington, DC; pp 3-8 to 4-11.

United States Forest Service (USFS); 1998 (March); *Cascade Reservoir Watershed Analysis Report*; United Stated Department of Agriculture, Forest Service, Intermountain Region, Boise National Forest, Casade Ranger District, Cascade Idaho.

Van Sickle, J.; 1981(June); *Long Term Distributions of Annual Sediment Yields From Small Watersheds*; Water Resources Research; Volume 17; Number 3; pp 659-663.

Whiting, P.J.; Matisoff, G.; Bonniwell, E.C.; 1997 (July); *Phosphorus Radionuclide Tracing of Fine Sediment in Forested Watersheds*; Case Western Reserve University, Department of Geological Sciences, Cleveland, Ohio; 39 p + appendices.

Worth, D.; 1993-1994; *Cascade Reservoir and tributary water quality data*; Unpublished data; Department of Health and Welfare, Division of Environmental Quality, Boise, Idaho.

Worth, D.; Lappin, J.; 1994; *Blue-green algae blooms on Cascade Reservoir, Valley County, Idaho;* Envir. Health Digest; Volume XX; Number 1; pp 18-21.

Worth, D.; 1998; personal communication; May 1998; Boise, Idaho.

Worth, D.; 1997; *Cascade Reservoir Model: Model Simulations of External Reductions in Phosphorus Loading to Cascade Reservoir*; for Idaho Division of Environmental Quality, Boise Regional Office, Boise, Idaho; 17 p.

Zimmer, D.W.; 1983 (August); *Phosphorus Loading and Bacterial Contamination of Cascade Reservoir, Boise Project, Idaho*; Boise Project Power and Modification Study; USDI, Bureau of Reclamation, Pacific Northwest Region, Boise, Idaho; 143 p.

6.0 Acronyms/Abbreviations/Units Conversion Table

Acronym	Full Name
303(d)	Comprehensive listing of water quality limited stream segments
BAG	Basin Advisory Group
BCC	Boise Cascade Corporation
BETTER	Box, Exchange, Transport, Temperature & Ecology of a Reservoir
BLM	US Bureau of Land Management
BMP	Best Management Practice
BNF	Boise National Forest
BOR	US Bureau of Reclamation
BOD	Biochemical Oxygen Demand
BPLMPIP	Big Payette Lake Management Plan and Implementation Program
BURP	Beneficial Use Reconnaissance Program
CDHD	Central District Health Department
CES	Cooperative Extension System
CFR	Code of Federal Regulations
COE	US Army Corps of Engineers
CRA	Cascade Reservoir Association
CRCC	Cascade Reservoir Coordinating Council
CRP	Conservation Reserve Program
CWA	Clean Water Act
DEQ	Idaho Division of Environmental Quality
DISS.-PO_4	Dissolved Ortho-phosphate
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
EPA	US Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
ESA	Endangered Species Act
FHWA	Federal Highway Administration
FIP	Forestry Incentives Program

Acronym	Full Name
FPA	Forest Practices Act
FWPCA	Federal Water Pollution Control Act
GIS	Geographical Information System
IDAPA	Idaho Administrative Procedures Act
IDFG	Idaho Department of Fish & Game
IDHW	Idaho Department of Health & Welfare
IDL	Idaho Department of Lands
IDWR	Idaho Department of Water Resources
I&E	Information & Education
INFISH	Inland Native Fish Strategy
ISCC	Idaho Soil Conservation Commission
ISDA	Idaho Department of Agriculture
LA	Load Allocation
NFPR	North Fork Payette River
NLRSWD	North Lake Recreational Sewer & Water District
NPDES	National Pollutant Discharge Elimination System
NRCS	National Resources Conservation Service
NURP	Nationwide Urban Runoff Program
P	Phosphorus
PIR	Phosphorus Index Rating
POC	Particulate Organic Carbon
PON	Particulate Organic Nitrogen
POP	Particulate Organic Phosphorus
PNF	Payette National Forest
QA/QC	Quality Assurance/Quality Control
RUSLE	Revised Universal Soil Loss Equation
SLRSWD	South Lake Recreational Sewer & Water District
TAC	Technical Advisory Committee
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load

Acronym	Full Name
TN	Total Nitrogen
TP	Total Phosphorus
USDA	US Department of Agriculture
USFS	US Forest Service
USFWS	US Department of Interior, Fish & Wildlife Services
USLE	Universal Soil Loss Equation
UTM	Universal Transverse Mercator
VCWC	Valley County Waterways Commission
VSWCD	Valley Soil & Water Conservation District
WAG	Watershed Advisory Group
WEQ	Wind Erosion Quotient
WHIP	Wildlife Habitat Incentives Program
WLA	Wastewater Load Allocation
WRP	Wetlands Reserve Program
WWTP	Wastewater Treatment Plant
WY	Water Year

Abbreviations	Meaning
~	approximate
ac	acre
acre-ft	acre foot
cfs	cubic feet per second
cts	counts
ft	foot
ft^3	cubic foot
h	hectare
kg	kilogram
km	kilometer
L	liter
m	meter
MGD	million gallons per day
mi	mile
mL	milliliter
pH	measure of acidity: pH 1-6 = acidic, pH 7 = neutral, pH 8-14 = basic
Phase I	Cascade Reservoir Phase I Watershed Management Plan - published 1/96
Phase II	Cascade Reservoir Phase II Watershed Management Plan - in progress
SU	standard units
T	ton
Tier 1	all land within 150 feet of either side of a stream
Tier 2	low land, mostly irrigated crop and pastureland
Tier 3	upland mostly non-irrigated pasture
mg	milligram
µg	microgram
yr	year
°C	degrees Celsius

Units Conversion Table

LENGTH	mm	cm	in	ft	yd	m	km	mi
millimeters	1.0	10.0	25.4	304.8	914.40	1,000.0	1,000,000	1,609,347
centimeters	0.1	1.0	2.54	30.48	91.44	100.0	100,000	160,935
inches	3.94e-02	0.3937	1.00	12.0	36.00	39.4	39,370	63,360
feet	3.28e-03	0.0328	0.0833	1.0	3.00	3.2808	3,280.8	5,280
yards	1.09e-03	0.01093	0.0278	0.33333	1.00	1.0936	1,093.6	1,760
meters	1.00e-03	0.01	0.0254	0.3048	0.9144	1.0	1,000	1,609.3
kilometers	1.00e-05	1.00e-04	2.54e-05	3.05e-04	9.150e-04	0.001	1.0	1.6093
miles	6.21e-07	6.21e-06	1.06e-05	1.89e-04	5.68e-04	6.21e-04	0.61237	1.0
AREA	**cm²**	**in²**	**ft²**	**m²**	**acres**	**km²**	**mi²**	
sq. centimeter	1	6.452	929	1.0e+05	40,465,284	10.e+11	2.59e+10	
square inches	0.155	1	144	1,550	6,272,640	1.55e+09	4.014e+09	
square feet	1.08e-03	0.00694	1	10.76	43,560	10,763,900	27,878,400	
square meters	1.0e-03	6.45e-04	0.0929	1	4,047	1.0e+07	2,589,998	
acres	2.47e-08	1.59e-07	2.3e-05	2.47e-04	1	247.1	640	
sq. kilometers	1.0e-09	6.45e-10	9.29e-08	1.0e-05	4.047e-03	1	2.59	
square miles	3.86e-11	2.49e-10	3.59e-08	3.86e-07	1.563e-03	0.3861	1	
VOLUME	**cm³**	**in³**	**liter**	**us gal**	**ft³**	**m³**	**acre-ft**	
cubic cent.	1	16.39	1,000	3,785.4	28,317,000	1.0e+07	1.23e+09	
cubic inches	0.06102	1	61.0234	231	1,728.00	61,023.00	75,271,680	
liters	0.001	0.01639	1	3.7854	28.317	1,000.00	1,233,490	
U.S. gallons	2.64e-04	0.00433	0.26417	1	7.4805	264.17	325,851.00	
cubic feet	3.53e-05	5.7e-04	0.03531	0.13368	1	35.3145	43,560.00	
cubic meters	1.0e-05	1.64e-05	0.001	0.00388	0.02832	1	1,233.49	
acre feet	8.11e-10	1.3e-8	8.1e-07	3.07e-06	2.296e-05	8.107e-04	1	
VOLUME/TIME	**usgal/day**	**usgal/min**	**liter/sec**	**acre ft/day**	**ft³/sec**	**m³/sec**		
U.S. Gallons/day	1	1,440.00	22,824	325,850	646,317	22,824,288		
U.S. gallons/min	6.94e-04	1	15.85	226.28	448.83	15,850		
liters/second	4.38e-05	0.063	1	14.28	28.32	1,000		
acre feet/day	3.07e-06	0.004	0.07	1	1.98	70.05		
cubic feet/sec	1.55e-06	0.002	0.04	0.50	1	35.31		
cubic meter/sec	4.31e-08	6.31e-05	0.001	0.01	0.03	1		

(Please note scientific notation example: 1000=1.0e+3)

7.0 Glossary

Word	Definition
Adsorption	The adhesion of one substance to the surface of another.
Aeration	A process by which a water body secures oxygen directly from the atmosphere. The gas then enters into the biochemical oxidation reactions in the water.
Aerobic	Life or processes that require the presence of molecular oxygen.
Alluvium	The deposition of sediment by a river at any point along its course.
Ambient	Surrounding, external or unconfined conditions.
Anaerobic	Processes that occur in the absence of molecular oxygen.
Anoxia	The condition of oxygen deficiency.
Anthropogenic	Caused or produced through the agency of man.
Assimilative Capacity	The rate at which an aquatic system must consume and remove impurities from water to maintain water quality.
Beneficial Uses	Any of the various uses of water, including, but not limited to domestic water supplies, industrial and agricultural water supplies, cold water biota, recreation, wildlife habitat and aesthetics.
Biomass	The weight of biological matter, often measured in terms of grams per square meter of surface area.
Chlorophyll a	A photosynthetic pigment reflecting green light and imparting the typical green color to plants; chlorophyll a is found in all autotrophic plants.
Coliform Bacteria	A group of bacteria predominately inhabiting the intestines of man and animals but also found in soil. Coliform bacteria is commonly used as indicators of the possible presence of pathogenic organisms.
Colluvium	Material transported to a site by gravity.
Critical Acres	In a State Agricultural Water Quality Project area, those areas where BMPs should be implemented to improve water quality.
Effluent	Treated or untreated wastewater that flows out of a treatment plant, sewer or industrial outfall. Generally refers to wastes discharged into surface waters.
Epilimnion	The warm, top-water zone above the thermocline in a lake.
Eutrophic	A body of water of high photosynthetic activity and low transparency.
Fauna	The entire animal life of a given region, habitat or geological stratum.
Fecal Streptococci	A species of spherical bacteria including pathogenic strains found in the intestines of warm-blooded animals.
Flora	The plant life of a given region, habitat or geological stratum.

Word	Definition
Hydrology	The science dealing with the properties, distribution and circulation of water.
Hypolimnion	The cold, bottom-water zone below the thermocline in a lake.
Igneous	Formed by solidification of molten magma.
Influent	A tributary stream to a wastewater treatment plant.
Infusion	The continuous slow introduction of one content into another.
Intergravel D.O.	Dissolved oxygen found in the substrate (usually gravel) of a stream, which is needed to support fish and macro invertebrates during early life stages.
Limnology	Scientific study of fresh water, especially the history, geology, biology, physics and chemistry of lakes.
Mesotrophic	A trophic region in which a lake or reservoir tends to be moderately productive, but nuisance algae blooms do not occur because the nutrient supply is limited.
Nonpoint Source	A geographical area on which pollutants are deposited, dissolved or suspended in water applied to or incident on that area, the resultant mixture being discharged into waters of the state.
Noxious	Physically or chemically harmful or destructive.
Orthophosphate	A form of soluble inorganic phosphorus which is directly utilizable for algal growth.
Pelagic	The open areas of lakes or reservoirs.
Photic Zone	The surface zone of the sea or a lake having sufficient light penetration for photosynthesis.
Phytoplankton	Microscopic algae and microbes that float freely in open water of lakes and oceans.
Point Source Pollution	The type of water quality degradation resulting from the discharges into receiving waters from sewers and other identifiable "points".
Residuum	The by product of a geological process.
Riparian	Living or located on the banks of a natural watercourse.
Secchi Disc	A black and white disc, 20 cm in diameter, used to measure the transparency of water.
Selective Withdrawl	The ability to draft water from a reservoir from differing dam elevations.
SNOTEL	Snow survey telemetry which uses the principle of radio transmissions by meteor burst. Radio signals are aimed skyward where trails of meteorites reflect or re-radiate the signals back to earth.
Stagnation	The absence of mixing in a waterbody.
Stratification	Organization of a lake into horizontal layers due to differences in temperature.
Synclinal	A folded rock structure in which the sides dip toward a common line or plane.

Word	Definition
Thermocline	A horizontal temperature discontinuity layer in a lake in which the temperature falls by at least 1°C per meter of depth.
Total Maximum Daily Load (TMDL)	A measurement establishing the total amount of pollutant(s) allowed in a water body before the water body is considered to be below water-quality standards. In a water-quality plan, the TMDL becomes a guide for determining when a water body meets and maintains the standards set for its beneficial use.
Total Suspended Solids (TSS)	The material retained on a 45 micron filter after filtration.
Trophic State	Level of growth or productivity of a lake as measured by phosphorus content, chlorophyll a concentrations, amount of aquatic vegetation, algal abundance and water clarity.
Trophic State Index	A system used by many states for classification of the degree of eutrophication exhibited by a lake or reservoir. The index combines measures of phosphorus, chlorophyll a levels and water clarity (transparency) to provide a frame of reference for comparing measurements over time.
Turbidity	A measure of the extent to which light passing through water is reduced to suspended materials.
Water Quality Modeling	The input of variable sets of water quality data to predict the response of a lake or stream.
Watershed	A region bounded peripherally by the surrounding topography which ultimately drains to a common lake or stream.

Appendix A

Cascade Reservoir Watershed Advisory Group (WAG) and Technical Advisory Committee (TAC) Membership

Cascade Reservoir Coordinating Council (CRCC)
(Cascade Reservoir Watershed Advisory Group (WAG))
May 1998

Wayne VanCour PO Box 569 Donnelly, Idaho 83615	*Chairman* *Representing the Environmental Interests*
Phillip Morton PO Box 457 Donnelly, Idaho 83615	*Representing the Recreational Industries*
Pat Armstrong 1295 Elo McCall, Idaho 83638	*Representing the Agricultural Interests*
Gerry Ikola 14179 Highway 55 McCall, Idaho 83638	*Representing the Logging Industries* *Resigned February 1998*
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Phil Davis PO Box 737 Cascade, Idaho 83611	*Representing the Valley County Commissioners*
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Bob Jones 505 Iowa Boise, Idaho 83706	*Representing the Citizen's Interests*
Ben Wellington PO Box 713 Cascade, Idaho 83611	*Representing the Cascade Reservoir Association* *Resigned May 1998*

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Appendix B

Beneficial Use Classifications and Water-Quality Standards and Criteria

Appendix B. Beneficial Use Classifications and Water-Quality Standards and Criteria

As stated previously, the CWA requires that each state protect their surface waters from pollution. The State of Idaho has developed and enforced water-quality standards for the protection of state waters. A water-quality standard defines the water-quality goals of a particular water body by designating the use or uses to be made of the water and establishment of numerical and narrative criteria (ambient conditions) necessary to protect the "existing" uses (water-quality standards = designated use + criteria to protect the use). Existing use means those surface water uses actually attained on or after November 28, 1975, whether or not they are designated uses. The state recognizes uses such as public, agricultural and industrial water supplies, protection and propagation of fish, shellfish and wildlife and recreation in and on the water when establishing designated uses for water bodies. Idaho has adopted water-quality standards, which are found under the Idaho Department of Health and Welfare (IDHW) Rules, IDAPA 16.01.02, Water Quality Standards and Wastewater Treatment Requirements.

All waters are protected through general surface water-quality criteria. Narrative criteria prohibit ambient concentrations of certain pollutants which impair designated uses. In Idaho, these criteria include: hazardous materials, toxic substances, deleterious materials, radioactive materials, floating, suspended or submerged matter, excess nutrients, oxygen demanding materials and sediment (IDAPA 16.01.02.200).

Once designated, beneficial uses are protected from impacts that may impair the use through application of numerical and narrative water-quality criteria. Prior to designation, undesignated waters shall be protected for beneficial uses, which includes all recreational use in and on the water and the protection and propagation of fish, shellfish and wildlife, wherever attainable.

Existing uses of waters that are not designated are also protected. Both federal and state rules protect existing uses through the antidegradation policy (See Idaho Code § 39-3603). Impacts to existing uses are best prevented through steps employed in the water-quality standards to protect designated uses.

Surface water beneficial use classifications are intended to protect the uses of the state's surface water. Designated beneficial uses for Idaho waterbodies are listed in the Water Quality Standards and Wastewater Treatment Requirements for the State of Idaho and are divided into five basic categories: aquatic life, recreation, water supply, wildlife habitat and aesthetics.

Aquatic life classifications apply to water bodies suitable or intended to be made suitable for protection and maintenance of viable communities of aquatic organisms and populations of significant aquatic species. Aquatic species include cold water biota, warm water biota and salmonid spawning. Specific criteria include:

Cold Water Biota - aquatic species which have optimal growing temperatures below 18 °C. (IDAPA 16.01.02.100.02.a). Criteria: Numeric criteria for pH, dissolved oxygen, gas saturation, residual chlorine, water temperature, ammonia, turbidity and toxics (IDAPA 16.01.02.250.02.a and c).

Warm Water Biota - aquatic species which have optimal growing temperatures above 18 °C. (IDAPA 16.01.02.100.02.b). Criteria: Numeric criteria for pH, dissolved oxygen, gas saturation, residual chlorine, water temperature, ammonia and toxics (IDAPA 16.01.02.250.02.a and b).

Salmonid Spawning - active self-propagating populations of salmonid fishes (IDAPA 16.01.02.100.02.c). Criteria: Numeric criteria for pH, gas saturation, residual chlorine, dissolved oxygen, intergravel dissolved oxygen, water temperature, ammonia and toxics (IDAPA 16.01.02.250.02.a and d).

Recreation classifications apply to water bodies water bodies suitable or intended to be made suitable for primary and secondary contact recreation. Specific criteria include:

Primary Contact Recreation - activities involving prolonged and intimate contact by humans or for recreational activities when the ingestion of small quantities of water is likely to occur. Such waters include, but are not restricted to, those used for swimming, water skiing or skin diving (IDAPA 16.01.02.100.03.a). Criteria: Numeric criteria for fecal coliform bacteria applied between May 1st and September 30th (recreation season) (IDAPA 16.01.02.250.01.a).

Secondary Contact Recreation - activities which are not included in the primary contact category, such as fishing, boating, wading and other activities where ingestion of raw water is not probable (IDAPA 16.01.02.100.03.b). Criteria: Numeric criteria for fecal coliform bacteria (IDAPA 16.01.02.250.01.b).

Water supply classifications are for water bodies suitable or intended to be made suitable for agriculture, domestic and industrial uses.

Agricultural Water Supply - Waters for the irrigation of crops or as drinking water for livestock (IDAPA 16.01.02.100.01.a). Criteria: Numeric criteria as needed derived from the EPA's Blue Book (IDAPA 16.01.02.250.03.b).

Domestic Water Supply - Waters for use as drinking water supplies (IDAPA 16.01.02.100.01.b). Criteria: Numeric criteria for specific constituents and turbidity (IDAPA 16.01.02.250.03.a).

Industrial Water Supply - This use applies to all waters of the state (IDAPA 16.01.02.100.01.c). Criteria: General surface water-quality criteria (IDAPA 16.01.02.200).

Wildlife habitat classifications (IDAPA 16.01.02.100.04) are for waters suitable or intended to be made suitable for wildlife habitat and applies to all surface waters of the state. Criteria: General surface water-quality criteria (IDAPA 16.01.02.200).

Aesthetics classifications (IDAPA 16.01.02.100.05) are applied to all surface waters of the state. Criteria: General surface water-quality criteria (IDAPA 16.01.02.200).

Special Resource Water: Special Resource water classifications are specific to those segments or bodies of water which are recognized as needing intensive protection to preserve outstanding or unique characteristics. Water bodies designated as special resource waters receive additional point source discharge restrictions (IDAPA 16.01.02.054.03 and 400.01.b), and designation as such recognizes at least one of the following characteristics: a) the water is of outstanding high quality, exceeding both criteria for primary contact recreation and cold water biota; b) the water is of unique ecological significance; c) the water possesses outstanding recreational or aesthetic qualities; d) intensive protection of the quality of the water is in paramount interest of the people of Idaho; e) the water is a part of the National Wild and Scenic River System, is within a State or National Park or wildlife refuge and is of prime or major importance to that park or refuge; f) intensive protection of the quality of the water is necessary to maintain an existing but jeopardized beneficial use (IDAPA 16.01.02.054).

Applicable Water-Quality Standards and Criteria

Numerical standards for pH (6.5 to 9.5 standard units) and temperature (Cold Water Biota: 22 °C daily maximum, 19 °C maximum daily average; Salmonid Spawning: 13 °C daily maximum, 9 °C maximum daily average, during time periods designated for salmonid spawning and incubation) have been established by the State of Idaho (IDAPA 16.01.02). The State of Idaho has established the following standards for minimum concentrations of dissolved oxygen in lakes and reservoirs. These parameters represent regulatory standards for Cascade Reservoir. "Dissolved oxygen concentrations exceeding 6 mg/L at all times. In lakes and reservoirs this standard does not apply to: (1) The bottom 20% of water depth in lakes and reservoirs where depths are thirty-five (35) meters or less, (2) Those waters of the hypolimnion in stratified lakes and reservoirs."

Narrative criteria have been established by the State of Idaho which indicate that surface waters of the state shall be free from excess nutrients that can cause visible slime growths or other nuisance aquatic growths impairing designated beneficial uses (IDAPA 16.01.02.200.06).

Coliform bacteria standards have also been established for state waters (IDAPA 16.01.01.250). These criteria are dependent on level of exposure (primary or secondary contact) and are applicable specified time periods as follows: For primary contact recreation (May 01 through September 30) fecal coliform bacteria colonies may not exceed:

- 500/100mL at any time
- 200/100mL in greater than 10% of the samples taken over a 30 day period
- a geometric mean of 50/100mL in a minimum of five samples taken over a 30 day period

For secondary contact recreation (applicable year round) fecal coliform bacteria colonies may not exceed:

- 500/100mL at any time
- 200/100mL in greater than 10% of the samples taken over a 30 day period
- a geometric mean of 50/100mL in a minimum of five samples taken over a 30 day period

Designated Beneficial Uses for Cascade Reservoir Subwatershed

Idaho has designated the following beneficial uses for specified water bodies within the Cascade Reservoir Watershed:

NORTH FORK PAYETTE RIVER - source to McCall.

> Domestic water supply, agricultural water supply, cold water biota, salmonid spawning, primary and secondary contact recreation and special resource water.

NORTH FORK PAYETTE RIVER - McCall to Cascade Dam (includes the reservoir).

> Domestic water supply, agricultural water supply, cold water biota, salmonid spawning and primary and secondary contact recreation.

LAKE FORK OF THE NORTH FORK PAYETTE RIVER - source to mouth.

> Domestic water supply, agricultural water supply, cold water biota, salmonid spawning, primary and secondary contact recreation and special resource water.

GOLD FORK OF THE NORTH FORK PAYETTE RIVER - source to mouth.

> Domestic water supply, agricultural water supply, cold water biota, salmonid spawning, primary and secondary contact recreation and special resource water.

NORTH FORK PAYETTE RIVER - Cascade Dam to mouth (Banks).

> Domestic water supply, agricultural water supply, cold water biota, salmonid spawning, primary and secondary contact recreation and special resource water.

All other water bodies within the watershed are unclassified. Undesignated waters shall be protected for beneficial uses, which includes all recreational use in and on the water and the protection and propagation of fish, shellfish and wildlife, wherever attainable. As noted, state water-quality standards require that all existing uses are fully protected.

Appendix C

Computer Modeling Summary

Appendix C. Computer Modeling Summary

In an effort to improve understanding of the effect management practices have on future water quality in Cascade Reservoir, a modeling effort was undertaken. Two models, the 2-D BETTER model and the 1-D Cascade model, were used to evaluate both immediate and long-term responses to reservoir management practices and watershed phosphorus reductions. The output data obtained from these models have been used to augment existing data and determine if the proposed phosphorus load reductions could be reasonably expected to have the desired beneficial effects. As the models differ in predictive capacity, and have unique characteristics, this report attempts to compare and contrast the models and their specific capabilities, and to define a framework of applicability for each model and the respective outputs obtained.

For both models, the reservoir geometry evaluated included the main water body, the five major tributary arms (North Fork Payette River, Mud Creek, Lake Fork, Boulder/Willow Creek, and Gold Fork River), and the outflow at the dam. In-reservoir geometry was obtained from the 1995 bathymetric sediment study (Ferrari, 1998).

2-D BETTER Model

The Box, Exchange, Transport, Temperature, and Ecology of a Reservoir (BETTER) model, (Bender, 1997) was designed to calculate flow exchange, heat budget and dissolved oxygen within a water body, and was adapted to account for site specific parameters unique to Cascade Reservoir. The BETTER model was calibrated using existing monitoring data (both in-reservoir and inflow) for the 1989, 1993, and 1994 water-years, which included dissolved oxygen (DO), inflow nutrient loading, temperature (reservoir, release, and inflow), and algae levels (derived from chlorophyll a and Secchi depth measurements) (Table 1, following document). The model was verified using monitoring data from water-year 1995. While these years represent average, above average, and below average precipitation levels, model predictions are based on a combination of all three years and are therefore representative of an average water year only. Model outputs include DO, algae levels, anaerobic sediment releases, and temperature on a depth-specific basis. North Fork Payette River was modeled as the main inflow to the reservoir, Lake Fork was combined with Mud Creek, and Boulder was combined with Willow Creek, while Gold Fork was evaluated separately.

The BETTER model is two dimensional, dividing the water body vertically into epilimnion and hypolimnion layers, and longitudinally into segments (Figure 1). A "floating layer" scheme was employed to ensure that all layers remain at established depths relative to the surface. This approach was used in an effort to allow direct comparison of model output with field data collected at set depths. It also allows the preservation of gradients that exist near the surface.

A significant limitation of this model is that output is available only for the time period extending from reservoir ice-out (day ~90) to ice-in (day ~270). Because it does not model reservoir conditions over an entire year, sequential runs cannot be used to predict changes in water quality over an extended time period.

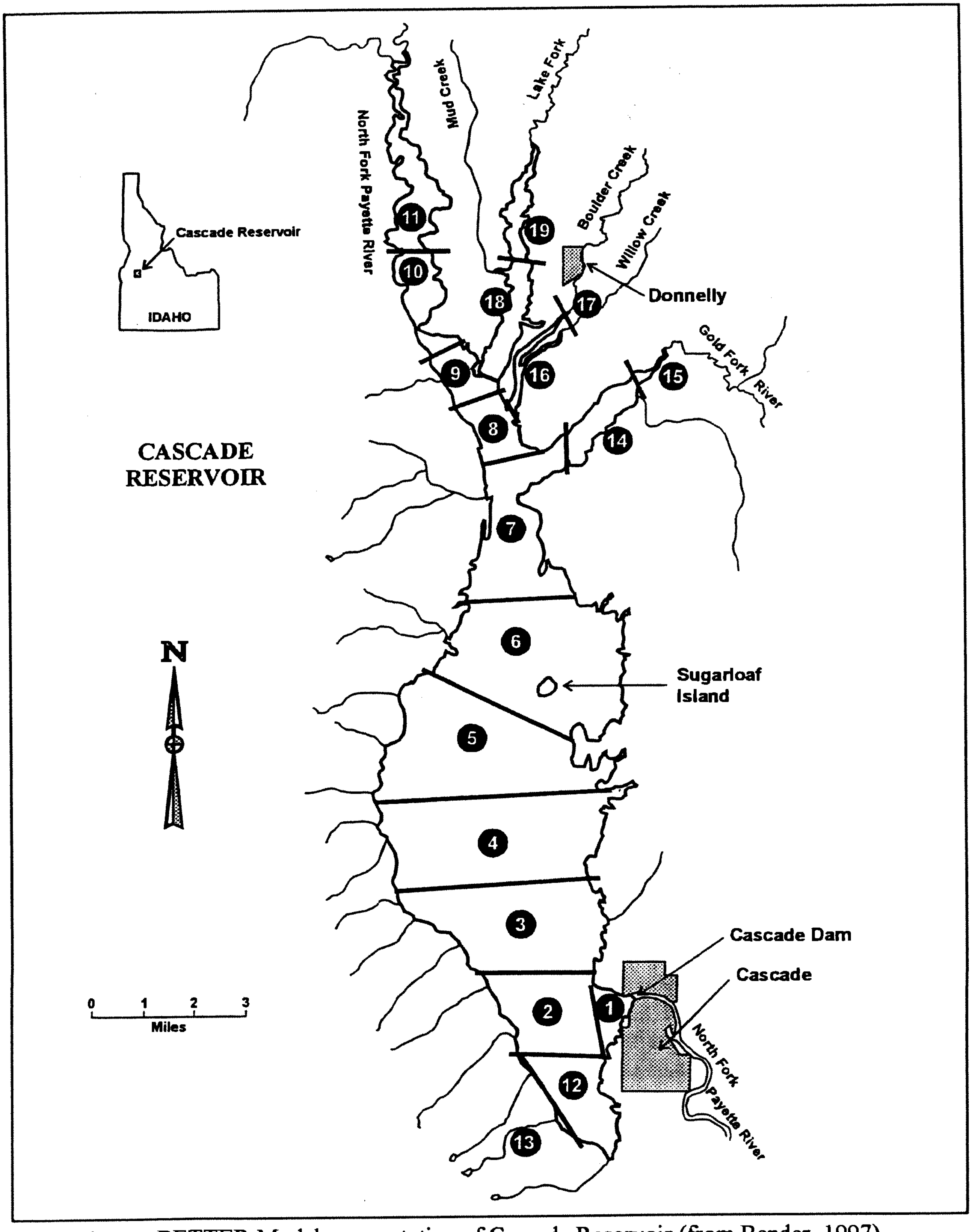


Figure 1 BETTER Model segmentation of Cascade Reservoir (from Bender, 1997).

Data inputs and outputs are defined in a 12-hour time step. Thus the effects of events lasting less than 12 hours (i.e. a 3 hour windstorm that mixes the water within the reservoir) are not within the model's predictive capability. Volume, downstream conveyance area, and surface interfacial area are calculated separately for each segment at each time step.

The primary objective for running the model was the evaluation of potential water-quality effects from proposed management options including: inflow loading reductions, chemical sealing of bed sediments, dredging the trashrack inlet channel, increased spillway discharge, aeration of reservoir water, and reservoir operational changes. Interpretation of the BETTER model output for each of the listed management options is summarized below and in the modeling fact-sheet on page 114 of this appendix.

A 50% reduction in nutrient and organic inflow loading showed only minimal effect on water quality within the reservoir over the single season modeled. This is not surprising as loading reductions would be expected to require more than a single season to show marked water-quality improvements due to the internal recycling of nutrients within the reservoir.

Chemical sealing of the reservoir bed-sediments to the degree that anaerobic nutrient release was removed entirely and sediment oxygen demand was reduced by half, showed improvement in the dissolved oxygen concentration (~2 mg/L increase) over a single season. The actual mechanism used to obtain the above reductions in sediment contributions was not identified directly, and no specific techniques available were modeled, so interpretation of these results should be made with some caution. The feasibility of such large-scale sealing is highly questionable given the current level of technology. Site-specific sealing in areas of higher sediment nutrient concentration (i.e. off Sugarloaf Island), perhaps a more logical undertaking, was not investigated.

Dredging the trashrack inlet channel (often referred to as the "glory-hole") to allow preferential removal of cooler, oxygen-deficient, bottom-water was not shown to be a viable option as increased temperatures from the remaining surface waters resulted in increased rates of organic decay and exacerbation of anaerobic conditions, leading to decreased overall water quality. This practice was also shown to result in higher concentrations of nutrients and organics being released downstream. These releases would have potentially negative effect on downstream water quality.

Increased spillway discharge showed no significant improvements in water quality. Currently, spillway discharges release mixed surface waters. Increase of spillway discharge was shown to result in the loss of oxygen-rich surface waters, increased temperature in the remaining waters, and lower overall DO levels; all of which would significantly decrease water quality and the available trout refuge.

Two major failings were identified for proposed aeration of reservoir water. First, systems modeled, although they were defined so as to represent state-of-the-art aeration equipment, were shown to increase DO levels only within the immediate vicinity of the equipment, so multiple aeration units would be required. Cost for such a project would be prohibitive. Second, if instrumentation were installed which would aerate the metalimnion of the entire reservoir, it would have to be lowered slowly over the course of the summer season as the position of the thermocline deepened. Model results showed this procedure would create a significant risk of re-suspension of bottom sediments, which would increase nutrient levels within the upper layers of the reservoir surface and potentially enhance algal growth.

Model output which simulated the effects of operational changes showed that higher pool volumes (400,000 acre-feet) could be expected to result in an increased volume of water suitable for fish habitat. However, the maintenance of a higher minimum pool volume would reduce the release options available for management of downstream water quality and flow volumes. Maintenance of lower minimum pool volumes (250,000 acre-feet) was shown to have a drastic, negative effect on both water quality and fish habitat as temperatures increased throughout the water column. Increased temperature resulted in increased rates of organic decay and faster depletion of dissolved oxygen. Fish would be compromised by both the increased temperature and lower DO, and substantial losses, especially in the late summer were predicted.

1-D Cascade Reservoir Model

The 1-D Cascade Reservoir Model (Worth, 1997) was designed to evaluate the water-quality impact of nutrient loading reductions within a watershed. The model currently in use was specifically designed to account for phosphorus loading and reductions within Cascade Reservoir. The Cascade model was calibrated using existing monitoring data (both in-reservoir and inflow) for the 1989, 1993, 1994 and 1995 water-years, which included: inflow nutrient loading (total nitrogen (TN), particulate organic nitrogen (PON), ammonia (NH_4) nitrate (NO_3), total phosphorus (TP), soluble reactive phosphorus (SRP), particulate organic phosphorus (POP)), DO, sediment oxygen demand (SOD), particulate organic carbon (POC), dissolved organic carbon (DOC), methane (CH_4), chlorophyl a, zoo-plankton (carnivorous and herbivorous), phytoplankton population estimates (biased to blue-green algae), Secchi depth, flow, and temperature (reservoir, release, and inflow). In addition, sediment phosphorus levels were also included from all available reservoir bed samples. The model was verified using monitoring data from water-year 1996 and the mean of water-years 1993 to 1996. While the calibration data years represent average, above average, and below average precipitation levels, model predictions are based on a combination of all four years. Therefore, long-term predictions represent the time required to reach the defined water-quality parameters given an average water year. Above average water years will most likely reduce the time required, while below average water years will extend the total time frame necessary. This model can be adjusted to reflect a defined type of water-year if necessary, but all predictions made to date were developed using this average-water-year prediction mechanism.

The Cascade model is one dimensional, dividing the water body vertically into epilimnion and upper, middle and lower hypolimnion layers. This approach was used in an effort to generate more accurate data within the reservoir profile whether stratified or well mixed. All tributaries were modeled collectively as "inflow".

An advantage of the Cascade model over the BETTER model is that output is available for an entire year. Thus "end" conditions for one year can be used as "initial" conditions for the following year for repeated iteration, making long-term water-quality prediction possible.

Data inputs and outputs for the Cascade model are defined in a 12-hour time step, and like the BETTER model, cannot account for the effects of events lasting less than 12 hours. Output parameters, which consist of all input parameters (Table I), are calculated separately for each layer at each time step for the epilimnion; upper, middle and lower hypolimnion; and sediment interface layers.

In contrast to the BETTER model, the primary objective for running the Cascade model was specifically the evaluation of potential water-quality effects from a range of phosphorus reduction levels within the watershed. The Phase I Total Maximum Daily Load (TMDL) for Cascade Reservoir (DEQ, 1996) specified that a 37% reduction of phosphorus loading was required for attainment of water-quality goals within the reservoir. The Cascade model was employed as a tool to investigate the applicability of this goal and its potential to result in the required in-reservoir water-quality parameters.

Phosphorus reductions of 20%, 37% and 50% were modeled over a 20 year time frame. All reduction effects were evaluated against a baseline condition defined as "no change in current phosphorus loading rate". The reductions modeled were selected as representing a range of reduction variables around the specified 37% reduction. Model output included an evaluation of changes in TP levels within the reservoir layers directly in contact with the sediment (lower hypolimnion), and the layer where the majority of algal growth takes place (epilimnion). Results in all reduction levels showed that the most marked change in water quality (decrease in water column TP) occurs during the first five years following attainment of the given load-reduction values. This initial, rapid improvement was followed in all simulated cases by a more gradual improvement in water quality over the remaining time period. TP levels in the epilimnion were observed to reach a steady state after approximately 10 years, while TP levels in the hypolimnion did not appear to reach a steady state within the time frame evaluated. Communication between the hypolimnion and the interfacial bed-sediments is predicted to result in an equilibrium release of adsorbed phosphorus that would continue (presumably) until the sediment phosphorus levels had declined to a concentration that could maintain equilibrium with the adjusted loading rate. Model output showed that greater concentrations of phosphorus were released in the spring and summer, when anaerobic conditions dominated on the reservoir floor.

The water-quality improvements observed with a 37% reduction were significant, and showed achievement of the water-quality objectives of 10 µg/L chlorophyll a, and 0.025 mg/L TP in the epilimnion after approximately 5 years of sustained 37% reduction. These levels of phosphorus were modeled and observed to result in attainment of dissolved oxygen ($\geq$ 6.0 mg/l in applicable waters) and pH (between 6.5 and 9.5 units)standards as outlined for the State of Idaho. The model results for 50% reduction showed a more rapid decrease in chlorophyll a and TP, while the 20% reduction showed a longer time period was required to reach water-quality objectives.

Attainment of water-quality objectives in the hypolimnion is expected to take a substantially longer time (15 to 20 years) depending on the recurrence of anoxic conditions and equilibrium release of phosphorus from the sediments. Algal blooms are predicted to occur with the proposed 37% reduction in nutrient loading, but not to the extent that they occur currently. Algal populations are predicted to shift from predominantly blue-green species to green species over the course of sustained reductions.

Overall, the Cascade model shows that the proposed 37% reduction in nutrient loading will result in substantial water-quality improvements over a reasonable time period. If necessary, the calibration of this model could be changed to reflect dry or wet water-years to determine the effect of precipitation on the long-term model results. Similarly, adjustments could be made to the input parameters to reflect most of the in-reservoir management options evaluated by the BETTER model, with the additional capability of predicting long-term effects.

Situation Comparison

Because the BETTER and Cascade models have different input, output and modeling mechanisms, their applicability to specific modeling efforts may vary. A brief comparison of the two models is outlined below for several possible scenarios.

The BETTER model is best suited to situations requiring site specific predictive information. For example, the reservoir bed sediments that have been extracted show elevated phosphorus content near Sugarloaf Island and the Poison Creek inflow. The affect of chemical sealing in an area-directed fashion has not been fully evaluated. The BETTER model would be well suited, on a short-term basis, to determine the outcome of such an undertaking on the water quality of the area immediately affected by chemical sealing, and on the water quality of the reservoir as a whole. Because of the longitudinally segmented reservoir geometry available with the BETTER model, inputs reflecting chemical sealing of bed-sediments within these specific areas could be added to the existing model parameters. Water-quality effects within the specified segments could then be modeled, as well as changes in water quality throughout the reservoir. Such site-specific input and manipulation is not possible with the Cascade model.

Similarly, this model would be well suited to evaluate the effect that aeration or installation of additional drainage would have on water quality within the more sluggish southern end of the reservoir. While the Cascade model could simulate placement of aeration equipment or additional drainage at the south end, water-quality effects would be evaluated on a total water-quality basis. Because of the predominant north to south flow induced within the reservoir by the tributaries and outflow, there is limited communication between the southern end and the major body of the reservoir. The immediate effects of such a project therefore may not be felt in a significant manner throughout the water body in general. An interpretation of the benefits of such an action would be difficult to make accurately, given only the Cascade model.

Conversely, if site-specific chemical sealant of the bed sediments were determined to be a viable option for the reservoir, but cost prohibited the application of chemical sealants at frequencies greater than once in every five years, the Cascade model would be the most applicable method of determining if this frequency would be adequate to result in improved water quality over an extended period of time. Application of chemical sealant to the areas described previously could be modeled in a general sense as an overall internal recycling reduction (the reduction in phosphorus loading would potentially be proportional to the relative percent area of the sealed sediments). Total phosphorus levels within the water column could be simulated over the five year period. The overall affect of repeated applications of sealants on reservoir water quality could in this way be achieved for a total water body assessment. While site specific effects and reductions would not be possible with the Cascade model, overall water quality resulting from generalized reductions could be evaluated for an extended time frame in a reasonably accurate manner.

Similarly, the affect of a single catastrophic event (a forest fire on West Mountain for example) could be evaluated over an extended period of time with the Cascade model, and the beneficial effects of BMPs on overall water quality could be evaluated over time. Such an approach would potentially decrease the time required by trial-and-error methods of on-the-ground phosphorus reduction, and allow management practices which promised the greatest reductions to be put into place within the impact area in a more timely fashion.

Because of the relatively complimentary nature of these two programs, a strong potential exists that they could be synthesized into a single powerful mechanism for site-specific prediction over an extended time frame. Potentially, the output values generated by the Cascade model for day 90 could be input to the BETTER model as initial settings. This model could then be run through the summer season to "ice-in" and output values re-entered to the Cascade model as initial settings for day ~270. This process could be repeated for a given number of iterations to cover the time frame required.

Because reservoir mixing usually occurs before ice-in, and extends through to nearly ice-out, significantly isolated changes would not be expected to occur within the reservoir to a substantial degree within this time period. During summer stratification, when inter-reservoir communication is suppressed by temperature differentials within the reservoir profile, site specific data would be the most valuable. Such a synthesis of the two models may therefore represent an important tool in water-quality evaluation.

This suggestion is not without some risk however, as the error inherent in each model separately, will be compounded in the combination of the two. Statistics have shown that such compound errors are more often the square of the individual errors than the sum. Predictions made using the combined output of both models together would therefore require careful interpretation of accuracy, and clear delineation of all assumptions made. In some cases, such interpretation may represent only a qualitative evaluation of a general trend.

Conclusions

Both the BETTER and the Cascade model have provided valuable information to the TMDL process for Cascade Reservoir.

The BETTER model has the significant capability of allowing simulation of management changes on a site-specific basis within the reservoir, but is limited to a single (~180 day) season of modeled output. The Cascade model has the valuable capability of allowing long-term predictions to be made through multiple iterations of modeling, but provides output on a more general, overall water-body basis.

The BETTER model has shown that while some proposed reservoir management options may have beneficial effects over a season (e.g. chemical sealing of bed sediments), further information is necessary to make a final, informed decision. Other management options (e.g. spillway releases or trashrack removal scenarios) have been shown to result in no water-quality benefits and the potential for further water-quality degradation.

The Cascade model has shown that the 37% phosphorus loading reduction proposed in the Phase I TMDL is an appropriate value that, if attained and maintained, should result in marked water-quality improvement over a reasonablely brief time frame (5 years), and attainment of water-quality goals over a slightly longer but still achievable time period (15 to 20 years).

A combination of the outputs of these two models may be able to provide more site-specific information over an extended time period, but would also carry a potentially wider range of uncertainty in the predicted outcome.

References:

Bender, M.D.; *1997; Two Dimensional Water Quality Modeling of Cascade Reservoir: Special Report*; Bureau of Reclamation, USDI, Technical Service Center, Denver, Colorado; 73 p.

Ferrari, R.L.; 1998 (May) revised; *Cascade Reservoir 1995 Sedimentation Survey*; USDI, Bureau of Reclamation, Sedimentation and River Hydraulics Group, Water Resource Services, Technical Service Center, Denver, Colorado; 29 p.

Idaho Division of Environmental Quality (DEQ); 1996 (January); *Cascade Reservoir Phase I Watershed Management Plan*; Idaho Division of Environmental Quality, Boise Regional Office, Boise, Idaho; 86 p + appendices.

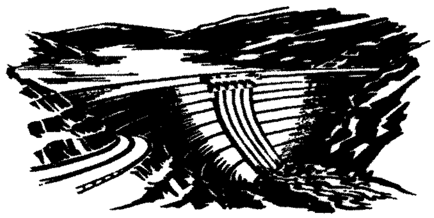
Worth, D.; 1997; *Cascade Reservoir Model: Model Simulations of External Reductions in Phosphorus Loading to Cascade Reservoir*; for Idaho Division of Environmental Quality, Boise Regional Office, Boise, Idaho; 17 p.

Table I. Model Comparison

Parameter	2-D BETTER Model	1-D Cascade Model
Reservoir geometry	depth divisions = top and bottom layer longitudinal = 19 ~North/South segments	upper, middle, lower hypolimnion and epilimnion
Model input and calibration parameters	reservoir geometry, dissolved oxygen, inflow nutrient loading, meteorology, anaerobic sediment releases, algae, temperature (reservoir, release, inflow)	temperature, phytoplankton as chlorophyll a, carnivorous and herbivorous zooplankton, algae population (biased to blue-green), DO, SOD, organic content (POC, DOC), CH_4, nitrogen (TN, PON, NH_4 NO_3), phosphorus (SRP, TP, POP), flow, and Secchi depth
Calibration data (water years)	1989, 1993, 1994	1989, 1993, 1994, 1995
Validation data (water years)	1995	1996 and 93-96 avg.
Model output parameters	dissolved oxygen, algae population, anaerobic sediment releases, temperature	temperature, phytoplankton as chlorophyll a, carnivorous and herbivorous zooplankton, algae population, DO, organic content (POC, DOC), CH_4, nitrogen (TN, PON, NH_4, NO_3) phosphorus (SRP, TP), SOD, and Secchi depth for upper, middle, lower hypolimnion, epilimnion, and sediment interfaces
Time step	12 hours	12 hours
Time cycle	reservoir ice-out (day 90) to ice-in (day ~270)	full year cycle with infinite iterations possible
Predictive life time	single season (~180 days)	infinite (sequential years)
Elevation oriented output	elevation in meters	based on relative position not exact elevation in meters
Site specific output	vertical layers and longitudinal segments	vertical layers
Reservoir management predictions	complete for management alternatives discussed in text	can be done for most management alternatives
Phosphorus reduction levels	possible short term only (one season)	completed for 20%, 37%, and 50% prediction reductions (over ~ 0 to 20 year time frame).

Table I. Model Comparison (cont.)

Parameter	2-D BETTER Model	1-D Cascade Model
Handicaps and advantages	predictions applicable to average water years only	predictions applicable to average water years only
	meteorological and monitoring data limitations	meteorologicalandmonitoringdatalimitations
	cannot be run sequentially because does not cover the entire year (~180 days)	can be run sequentially because time cycle is 365 days
	all phosphorus is assumed to be bioavailable (worst case scenario)	phosphorus is distinguishable as SRP and TP
	shows separate spring and fall blooms for a single season	does not show separate spring and fall blooms, only a single long-term bloom, because of biased plankton parameters. However, this method of simulation is believed to generate late summer concentration predictions which are more accurate than other methods
	segment-specific manipulation and evaluation are possible	whole water-body information only
	two vertical layers were simulated	four vertical layers and sediment interfaces were simulated
	water-quality data only was used for input, available for output	water quality and sediment nutrient data used for input, available for output
	operation requires substantial modeling skill	operation is relatively intuitive
	model currently resides at BOR, Denver	model currently resides at DEQ, Cascade



Cascade Reservoir Modeling Fact-Sheet

Many ideas have been proposed to improve water quality in Cascade Reservoir. Until recently it has been impossible to predict whether or not the solutions proposed would work effectively on such a large-scale project. With the development of computer models that simulate the reservoir and the watershed, new insight is available on which options are the most feasible for Cascade Reservoir. While computer models cannot say exactly how any of these options will perform, they can provide a general sense of what problems or benefits may result within the reservoir if the proposed management options were implemented. Computer modeling studies were conducted to investigate specific changes in the chemical aspects of water quality, for example phosphorus and dissolved oxygen concentrations, temperature and pH; as well as their combined effect on overall fish habitat and other beneficial uses through the proposed management options.

Water-quality Management Options Investigated

The main water-quality management projects proposed were chemical sealing of reservoir bed sediments, dredging of the trashrack inlet channel, increasing the volume of water discharged from the spillway, mechanical aeration of reservoir water, changes in reservoir management, and reduction of phosphorus levels in the water flowing into the reservoir. A summary of the modeling results for each of the listed management options is outlined below. The only two options that showed long-term, positive results were changes in reservoir management, and reduction of inflow phosphorus levels.

Chemical Sealing of Sediments

The practice of "chemical sealing" was proposed for Cascade Reservoir. This entails covering the bottom or "bed" sediments with aluminum hydroxide, and has been shown to reduce phosphorus release in some small lakes. When chemical sealing was modeled, it was predicted that only a complete (100%) seal of the sediments would improve dissolved oxygen levels within the reservoir, and only if the sealing was combined with reductions in phosphorus inputs to the reservoir. The current level of technology for chemical sealing procedures does not provide 100% effective seals, and has not been tried on large bodies of water like Cascade Reservoir, so there is a significant risk that the procedure would not work. In addition, it was estimated to cost between $7 and $11 million to complete. If reductions in phosphorus inputs to the reservoir were not achieved after the chemical sealing, it would have to be repeated periodically.

Dredging of the Trashrack Inlet Channel

Dredging the trashrack inlet channel (sometimes referred to as the "Glory-Hole") was proposed because it was thought that the removal of cold, deoxygenated bottom-water would improve water quality. Computer modeling predicted that when cold bottom water was removed, warmer surface water replaced it and raised the overall temperature of the reservoir water. These increased temperatures in turn caused higher rates of organic decay and even greater depletion of dissolved oxygen in the lower depths of the reservoir. Drawing off the bottom water was also predicted to result in higher concentrations of phosphorus and organics being released downstream. These releases would have a potentially negative effect on downstream water quality.

Increased Spillway Discharge

Increasing the spillway discharge was suggested because it would selectively remove warmer surface waters which encourage the growth of algae. When this option was modeled, no significant improvements in water quality were predicted. Surface water, in contact with the air and containing the majority of microscopic plant life, would be released in greater volume with this discharge option. The increased spillway discharge was predicted to result in the loss of the oxygen-rich surface water, increased temperature in the remaining water, and lower overall dissolved oxygen levels; all of which would significantly decrease water quality and the available fish habitat.

Aeration of Reservoir Water

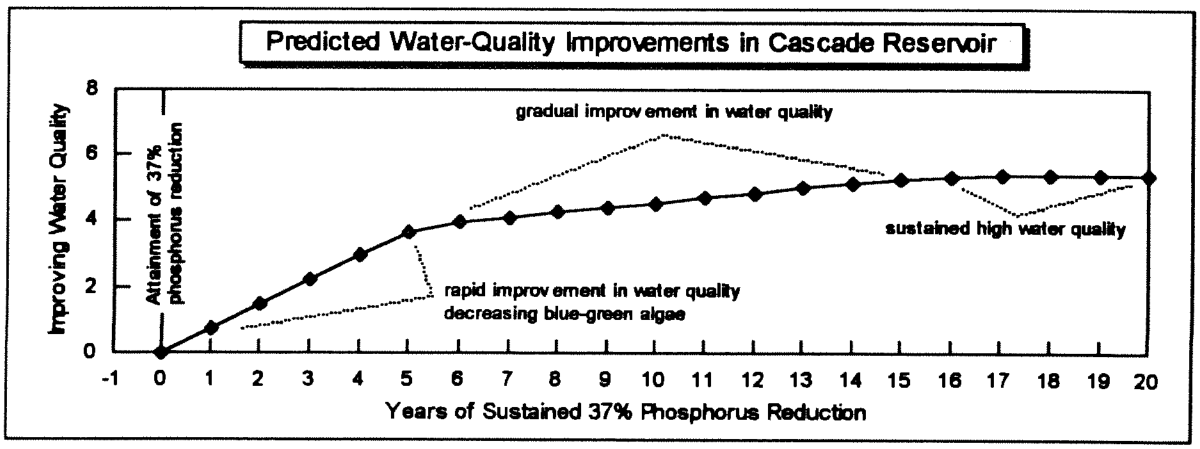
It was proposed that aeration equipment be placed in the reservoir to increase the oxygen content of the water and improve fish habitat. These types of mechanical aeration systems have been used successfully to improve the dissolved oxygen levels in small ponds nationwide. Computer modeling revealed two potential problems with the proposed mechanical aeration of the reservoir. First, because of the size of the reservoir, the aeration systems were predicted to increase dissolved oxygen levels only in the immediate vicinity of the equipment, so several large-scale aeration units would be required. The cost for such a project would be prohibitive. Second, the aeration equipment installed would have to be lowered slowly over the course of the summer season as the level and temperature of the reservoir water changed. Model results showed that this would create a significant risk of stirring up the bed sediments. The sediment that was suspended in the water would increase phosphorus concentrations in the upper layers of the reservoir surface, which would enhance the growth of algae.

Operational Changes

Computer models were also used to simulate the effects of keeping the reservoir levels higher than have been routinely maintained. The current minimum pool for Cascade Reservoir is 300,000 acre-feet. Model output which simulated higher pool volumes (400,000 acre-feet) predicted an increased volume of water where conditions were suitable for fish survival. However, maintaining the minimum pool volume at a higher level would potentially reduce the release options available for downstream water management. Maintenance of lower minimum pool volumes (250,000 acre-feet) was shown to have a drastic, negative effect on both water quality and fish habitat as temperatures increased throughout the water column. Increased temperature resulted in greater organic decay and lower dissolved oxygen. Fish would be at risk from both the increased temperature and lower dissolved oxygen, and substantial die-offs (especially in the late summer) were predicted.

Nutrient Reductions

Model simulations included an evaluation of changes in phosphorus contributions to the reservoir. Results showed that a marked improvement in water quality occurred during the first five years following attainment of a 37% phosphorus load reduction. The initial, rapid improvement was followed in by a more gradual improvement in water quality over a 15 year time period (as illustrated below). The water-quality improvements observed with the 37% reduction were significant, and showed achievement of the water-quality objectives of 10 mg/L chlorophyll a, and 0.025 mg/L total phosphorus in the reservoir water after approximately five years of sustained 37% reduction. Modeled phosphorus reductions of less than 37% did not show these same water-quality improvements.



Given the modeling results and the other considerations within the watershed that are discussed in the Cascade Reservoir Phase II Watershed Management Plan, a 37% reduction in phosphorus loading, combined with maintenance of an adequate minimum pool should result in improved water quality, attainment of water-quality objectives within the reservoir and restoration of beneficial uses.

Appendix D

Summary of Historical Water Quality for the Cascade Reservoir Watershed

Appendix D. Summary of Historical Water Quality for the Cascade Reservoir Watershed

Reservoir Water Quality

The water quality of Cascade Reservoir is of critical concern to the local population. Many private and rural subdivision water supplies utilize surface and ground water sources. Agricultural activities such as stock watering and irrigation, both within the watershed and in downstream communities, depend on the reservoir and local tributaries to meet usage needs. Increasing reliance on recreational activities by local economies represents a significant dependence on actual and perceived water quality within the watershed. The deterioration of water quality within Cascade Reservoir therefore affects not only the local population but a much wider area.

Continuing occurrences of noxious algal blooms, growth of aquatic weeds and fish kills have caused public concern since the 1970s. In 1993, pollutant loads and an unusual runoff pattern combined to produce dense mats of blue-green algae on the reservoir. In September, 23 cattle died as a result of ingesting toxins produced by the blue-green algae. As a result, health advisories were issued by DEQ discouraging contact with the reservoir water. Unfortunately, 1994 was a low water year. The high pollutant loads in 1993, combined with the reduced reservoir volume and lows flows of 1994 resulted in high overall total phosphorus concentrations within the water column. Dissolved oxygen levels decreased due to algal growth and decay, and warmer water temperatures produced by low water levels. This in turn led to anaerobic conditions at the water-sediment interface, increasing sediment phosphorus release. This series of events resulted in a substantial fish kill and impacted beneficial uses for both 1993 and 1994. These events served to focus and enlarge existing efforts for water-quality improvement within the reservoir. The apparent decline in water quality within the reservoir has largely been attributed to excessive nutrient loading from both point and nonpoint sources.

Nutrients

IDFG studies in 1968 (Irizarry, 1970) reported nutrient concentrations for two sites within the reservoir during May and June. Nitrate (nitrogen) concentrations ranged from 1.0 to 1.2 mg/L over three separate collection dates. Total phosphorus concentrations ranged from 0.005 to 0.04 mg/L. During the National Eutrophication Study (EPA, 1977), average reservoir concentrations of total phosphorus were observed to range from 0.019 to 0.031 mg/L, with slightly higher concentrations measured on the reservoir floor as compared to the surface. BOR monitoring of five separate stations during this same year show higher total phosphorus concentrations (0.02 to 0.35 mg/L) and nitrate (nitrogen) concentrations from 0.03 to 0.08 mg/L. Monitoring work reported by Clark and Wroten (1975) showed inorganic nitrogen levels from 0.020 to 0.273 mg/L and dissolved phosphorus levels from 0.01 to 0.315 mg/L. Total phosphorus was not reported. BOR monitoring from 1978 through 1982 (Zimmer, 1983) showed total phosphorus levels ranging from 0.018 to 0.102 mg/L, with the highest concentrations occurring near the reservoir bottom and in surface waters during August and September.

The seasonal increase in total phosphorus near the reservoir bottom and surface waters during late, hot summer months was observed in subsequent studies (Klahr, 1988; Klahr, 1989; Entranco, 1991;

Ingham, 1992; Worth 1993 and 1994) conducted from 1986 to 1994. It is currently observed in recent and ongoing monitoring by the DEQ. The most probable cause of increased total phosphorus levels at depth during summer months is sediment release triggered by anaerobic conditions within the lower levels of the water column. Such predicted releases have been substantiated by computer modeling (Worth, 1997) as shown in Figure 1, and have been observed to occur in laboratory studies using similar sediment matrices (Lindsay, 1979; Shannon and Brezonik, 1972; Sharpley *et al.*, 1984; Tiessen, 1995; Vollenweider, 1968).

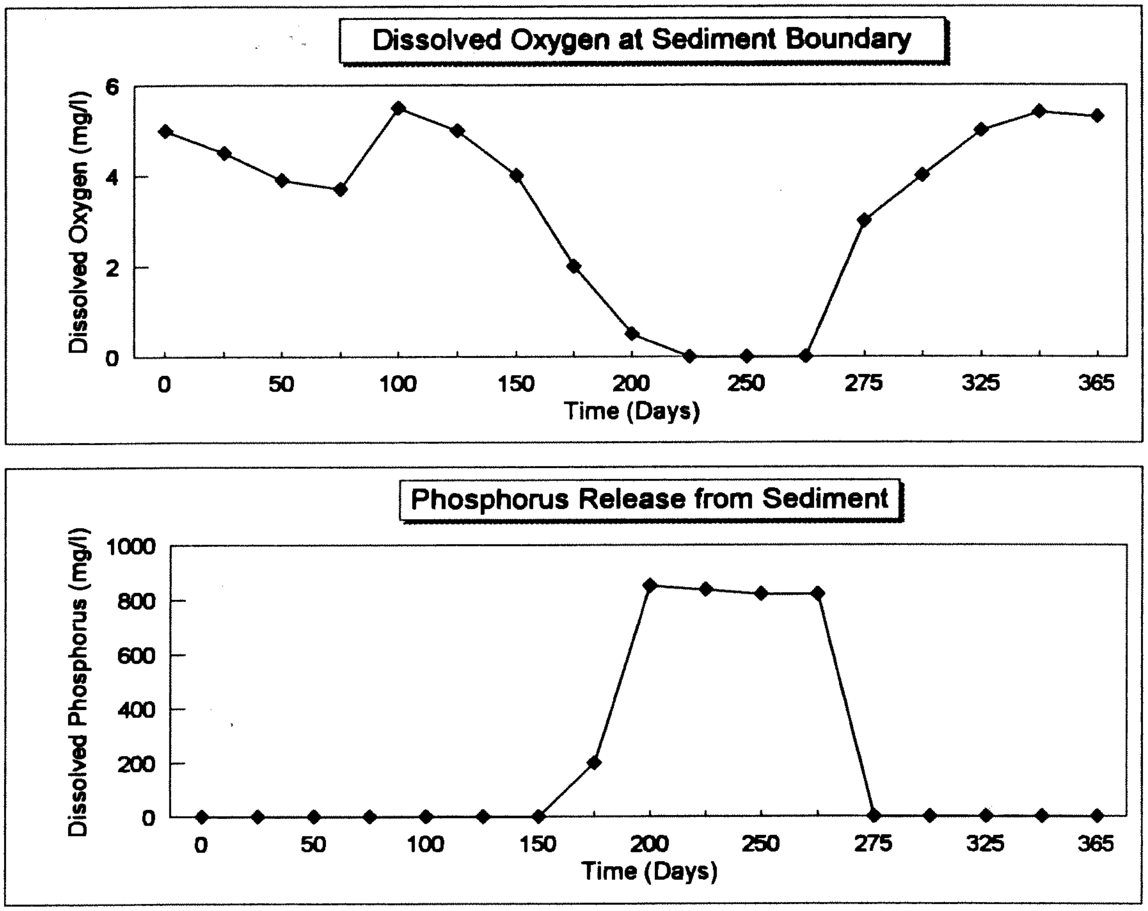


Figure 1 Relationship of low dissolved oxygen levels to sediment phosphorus release at the sediment-water interface.

Chlorophyll a

Chlorophyll a concentrations can be used as an indicator of algal growth and concentration. Monitoring data collected during the National Eutrophication Study (EPA, 1977) show average chlorophyll a concentrations that ranged from 7.0 to 10.1 µg/L, with highest concentrations present in September (14.3 µg/L). Clark and Wroten (1975) also reported peak concentrations present in August, where blue-green algae were the dominant phytoplankton species.

BOR monitoring from 1978 through 1982 (Zimmer, 1983) showed chlorophyll a concentrations that coincided well with high total phosphorus levels during summer months. Chlorophyll a levels were highest in August and September, averaging from 18 to 11 μg/L, respectively. Highest total concentrations observed during this period was 120 μg/L, recorded in August of 1978.

These and subsequent studies (Klahr, 1988; Klahr, 1989; Entranco, 1991; Ingham, 1992; Worth 1993 and 1994) conducted from 1986 to 1994, show a consistent seasonal trend similar to that defined by total phosphorus concentrations. Increasing chlorophyll a concentrations are observed beginning in May and reaching a maximum in August and September. The nutrient supply required to support continued growth of algal biomass (as defined by increasing chlorophyll a concentrations) is augmented by release of sediment-bound phosphorus during anoxic conditions and by resuspension of sediment during wind events. The mixing effect of strong winds on the reservoir result in temporary breakdown of thermal stratification and may deliver additional nutrients to the upper layers of the reservoir. Sunlight penetrates the surface waters and allows photosynthesis and nutrient uptake with algal growth.

Dissolved Oxygen

The earliest available records of dissolved oxygen monitoring are from the late 1960s and 1970s. These studies suggest that reservoir concentrations of hypolimnetic dissolved oxygen begin declining below state standards (6.0 mg/L) during hot summer months, with the lowest concentrations (<5.0 mg/L) occurring in late August and September (Irizarry, 1970; Clark and Wroten, 1975; BOR, 1975; EPA, 1977). Dissolved oxygen sags are observed to coincide with warm surface-water temperatures (≥ 20 °C) occurring as a result of hot summer air temperatures, increased direct solar input to the reservoir and the relatively shallow depth of the reservoir.

More detailed studies performed during the 1980s showed low dissolved oxygen concentrations (≤ 3.0 mg/L) present in July and persisting through August and September (Horner, 1980; Reininger *et al.*, 1983), with the lowest levels (≤ 3.0 mg/L) occurring during summer stratification (July to September) and winter stagnation (February to March). Low dissolved oxygen levels during summer months serve to trigger the release of sediment-bound phosphorus (Figure 1). The low dissolved oxygen levels during winter stagnation could not be attributed completely to low input levels as winter dissolved oxygen levels for tributary inflow were approximately 10.0 mg/L.

Recent, representative dissolved oxygen levels are shown in Figures 2 and 3 for both a spring (pre-stratification) and summer (stratified) monitoring period. The reservoir typically stratifies during June and remains stratified until fall turnover in September or October. Lowest dissolved oxygen concentrations occur during stratified conditions when atmospheric re-aeration of the hypolimnion is inhibited. Dissolved oxygen levels are inversely correlated with both depth and temperature as can be seen in Figures 2 and 3. Dissolved oxygen levels decrease with increasing depth and temperature during stratified summer conditions.

Bacteria

A survey of bacteria concentrations within the reservoir conducted in 1974 (Clark and Wroten, 1975) found that bacteria counts within 30 feet of the shoreline were below state standards. Similar results were reported in 1974 (BOR, 1975). During a more extensive study of the reservoir conducted

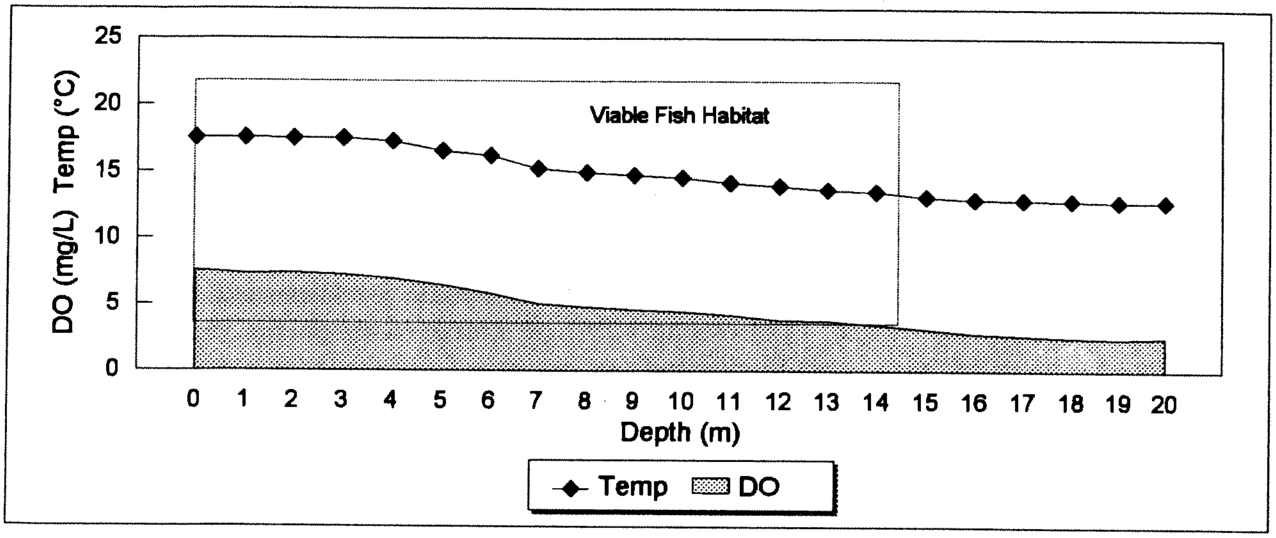


Figure 2. Correlation of temperature and dissolved oxygen levels with depth for spring monitoring.

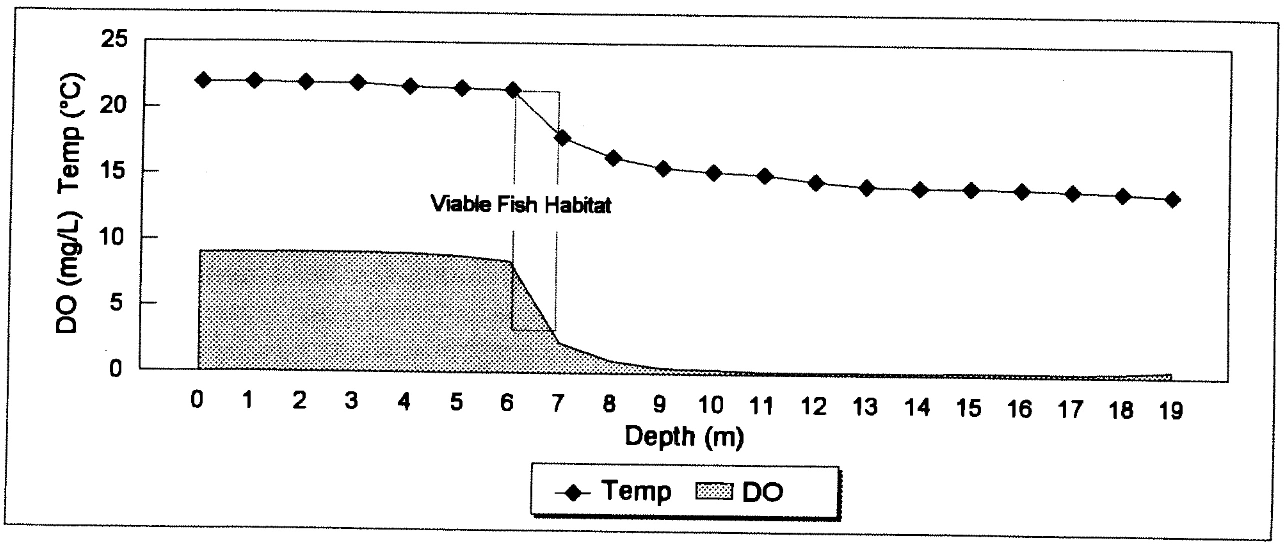


Figure 3. Correlation of temperature and dissolved oxygen levels with depth for summer monitoring.

between 1978 and 1983 (Zimmer, 1983), one violation (>500 counts/100mL) was observed in the Lake Fork arm of the reservoir. Mean counts of all sites combined exceeded the geometric mean standard (50 counts/100mL) in September, 1981. High average coliform counts were recorded in August of 1979 and September of 1981. Recent survey indicate that bacteria counts are below state standards based on 1994 to 1997 monitoring data and this information, combined with existing information on the tributary inflows, led the request for de-listing Cascade Reservoir for pathogens on the 1998 303(d) list.

Data Interpretation and Trend Analysis

While summer levels of total phosphorus and chlorophyll a vary markedly from year to year because of differences in runoff and internal recycling, an average of several years data can indicate specific trends and areas of concern. Long-term monitoring data are available at two sites within the reservoir, near the dam outlet and just above Sugarloaf Island (DEQ sites CWQ002 and CWQ005 respectively, See Figure 2, Appendix E). These sites are important indicators of reservoir conditions due to differences in spatial position along the inflow path of water entering the reservoir. Additional differences in depth and limnological conditions within the reservoir are present. The dam site is one of the deepest monitoring locations available within the reservoir and is close to the lower third of the reservoir where summer concentrations of chlorophyll a are typically high and dissolved oxygen concentrations are typically low. The Sugarloaf Island site is within the upper third of the reservoir where inflow is rapid and volume exchange occurs more frequently than in the lower areas of the reservoir. The data gathered from these two sites has been averaged to yield a comparison of historical data (1978 to 1982) and recent data (1993 to 1994) for total phosphorus, chlorophyll a concentration and Secchi depth (Figures 4, 5 and 6). These graphs show a distinct increase in total

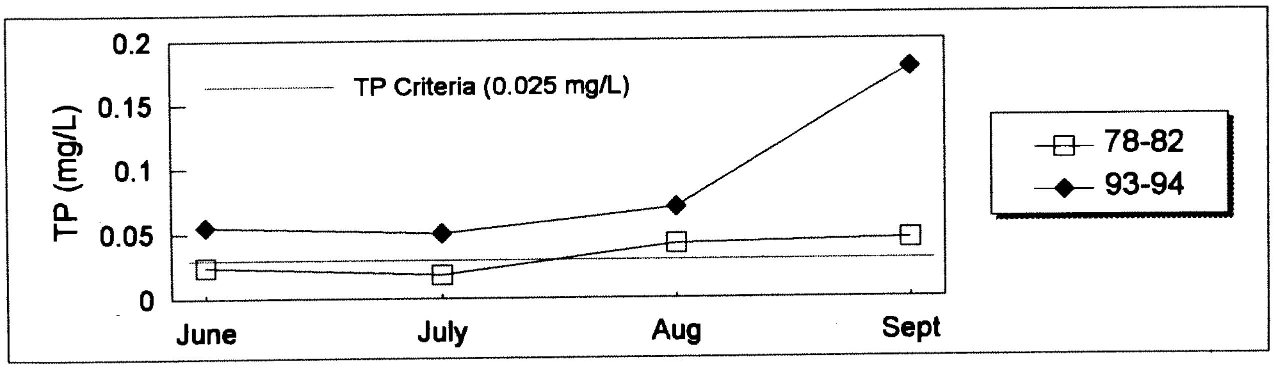


Figure 4. Correlation of historic (1978-1982) and recent (1993-1994) summer total-phosphorus (TP) levels for Cascade Reservoir.

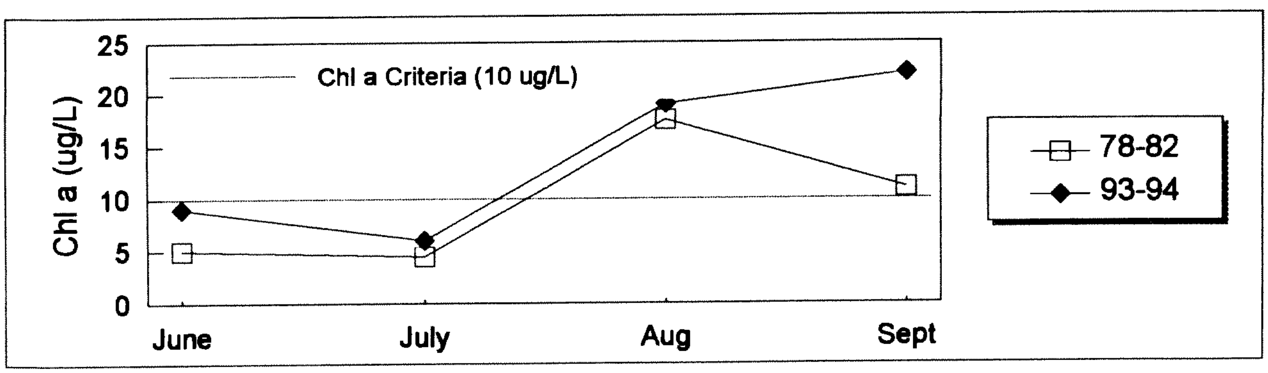


Figure 5. Correlation of historic (1978-1982) and recent (1993-1994) summer chlorophyll a (Chl a) levels for Cascade Reservoir.

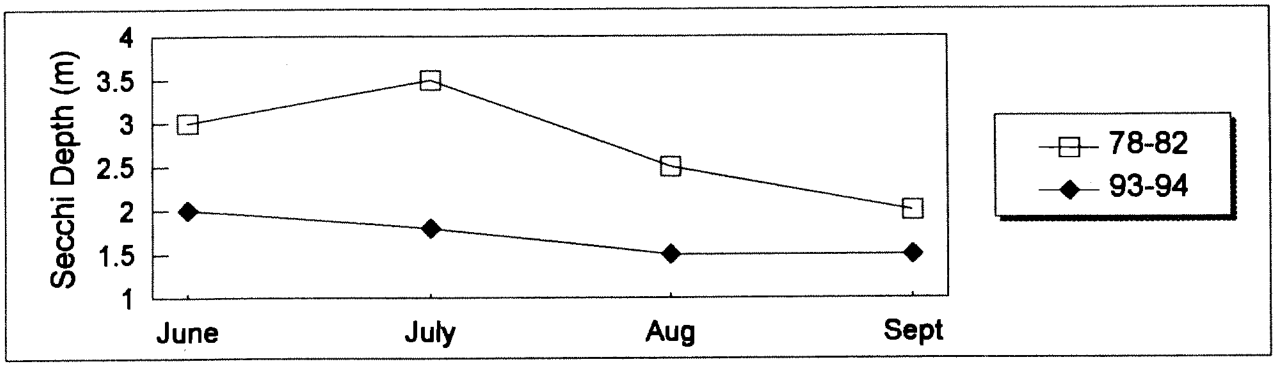


Figure 6. Correlation of historic (1978-1982) and recent (1993-1994) summer Secchi depth measurements for Cascade Reservoir.

phosphorus and chlorophyll a concentration and a corresponding decrease in Secchi depths from past to present monitoring years.

A yearly summer average (June through September) for each site shows similarly increasing trends for total phosphorus with corresponding increases in chlorophyll a over time (Figures 7 and 8). While average summer total phosphorus levels are observed to be lower in recent (1995-1996) than in previous years (1991-1994), they are still above the 0.025 mg/L goal established to restore water quality within the reservoir. The same holds true for chlorophyll a levels, which consistently remain above 10 µg/L. Chlorophyll a concentrations are typically higher and dissolved oxygen concentrations are typically lower at the Cascade Dam site than at the Sugarloaf Island site. Water column concentrations of total phosphorus are similar at the two sites and show a significant increase beginning in 1991. A representative depth-integrated dissolved-oxygen profile of both the Cascade Dam and Sugarloaf Island sites is presented in Figure 9. While the data utilized for this figure was collected in July of 1996, the observed trend is typical of the water years monitored.

Many factors, including wind effects, tributary inflows, hydraulic residence time and intra-annual monitoring frequencies may influence the observed differences at each site, however, the increase in both total phosphorus and chlorophyll a observed from 1978 to 1994 at both sites is of sufficient magnitude to override inherent environmental variability.

Tributary Water Quality

Historical tributary monitoring is not as extensive as historical reservoir monitoring. A survey was conducted in August of 1974 by BOR for selected sites (BOR, 1975). Observed data showed that dissolved oxygen levels generally exceeded state minimum standards for cold water biota (>6.0 mg/L) for North Fork Payette River, Lake Fork and several smaller tributaries along the west shore of the reservoir during the month. Associated water temperatures ranged from a high of 20 °C in Lake Fork to 5 °C for the west shore streams. Similar results were observed during a survey conducted from

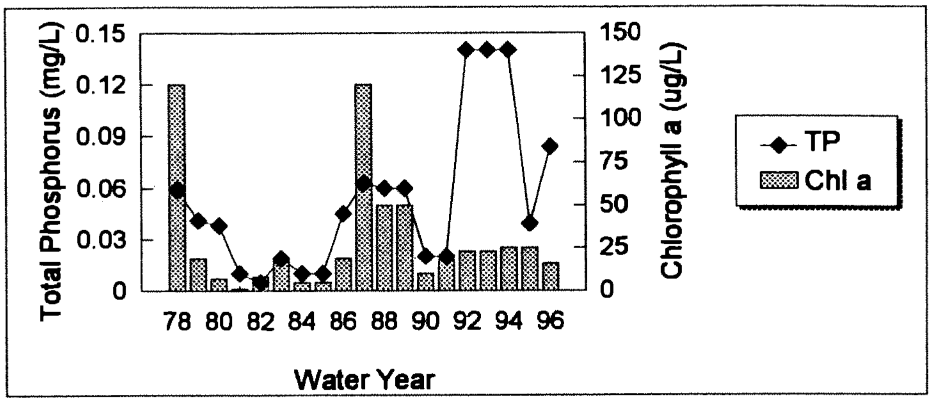


Figure 7. Changes in total phosphorus and chlorophyll a at the Cascade Dam monitoring site (CWQ002) from 1978 to 1996.

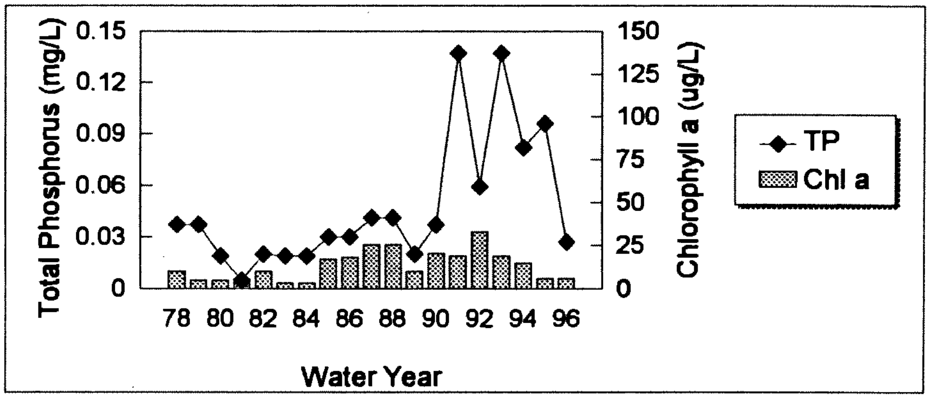


Figure 8. Changes in total phosphorus and chlorophyll a at the Sugarloaf Island monitoring site (CWQ005) from 1978 to 1996.

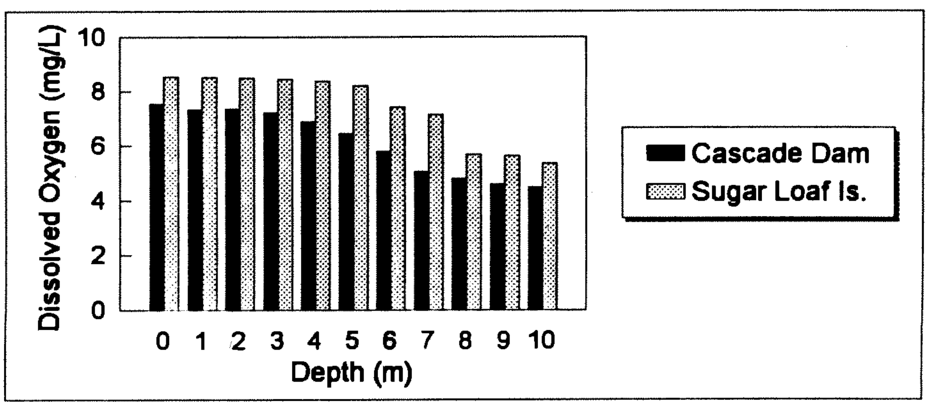


Figure 9. Depth-integrated dissolved oxygen profiles for the Cascade Dam (CWQ002) and the Sugarloaf Island (CWQ005) monitoring sites.

May to November of 1975 (Clark and Wroten, 1975), where recorded dissolved oxygen concentrations for Gold Fork, Lake Fork, Boulder Creek, Mud Creek and North Fork Payette River met state standards for cold water biota. A third study conducted in the winter of 1982 (Reininger,

1983) reported dissolved oxygen concentrations from selected tributaries varied between 9.7 and 10.1 mg/L at temperatures of 1 to 4 °C.

Further tributary monitoring conducted in 1989 (Entranco, 1991) and 1993 through 1996 (DEQ, 1994; 1995; 1996; 1998) show seasonal effects on dissolved oxygen and temperature. For illustration, monitoring data from a representative water year is plotted in Figures 10 and 11.

Seasonal variations show that dissolved oxygen levels in the tributaries to Cascade Reservoir are lower in the late winter, increase with the increased flows during spring-runoff events and then decrease as seasonal temperatures increase. Warmer air temperatures and recharge from flood-irrigation practices contribute to sharp increases in tributary temperatures during summer months. Tributaries lacking adequate riparian cover such as Boulder Creek, Mud Creek and Willow Creek generally show a more rapid increase in temperature and noticeable decrease in dissolved oxygen during summer months as compared to more highly vegetated streams.

Monitoring data suggest that Boulder, Gold Fork, Mud and Willow Creeks have higher concentrations of nutrients as compared to other major tributaries. With normalized stream flows, the contributed total and dissolved-phosphorus load from these tributaries far exceeds that delivered by the other major inflows. These streams drain large surface areas, and, with the possible exception of the upper Gold Fork drainage, flow toward the reservoir over relatively flat topography. This

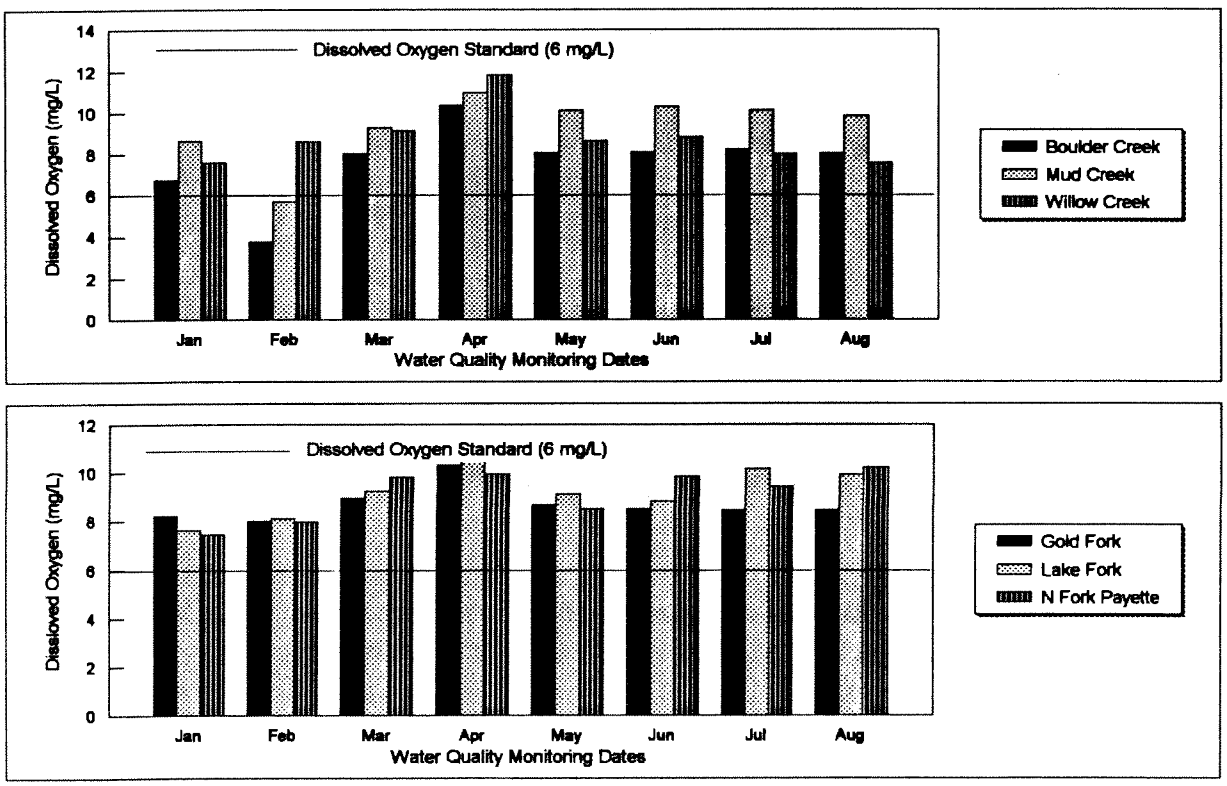


Figure 10. Seasonal variations in dissolved oxygen levels within major tributaries to Cascade Reservoir.

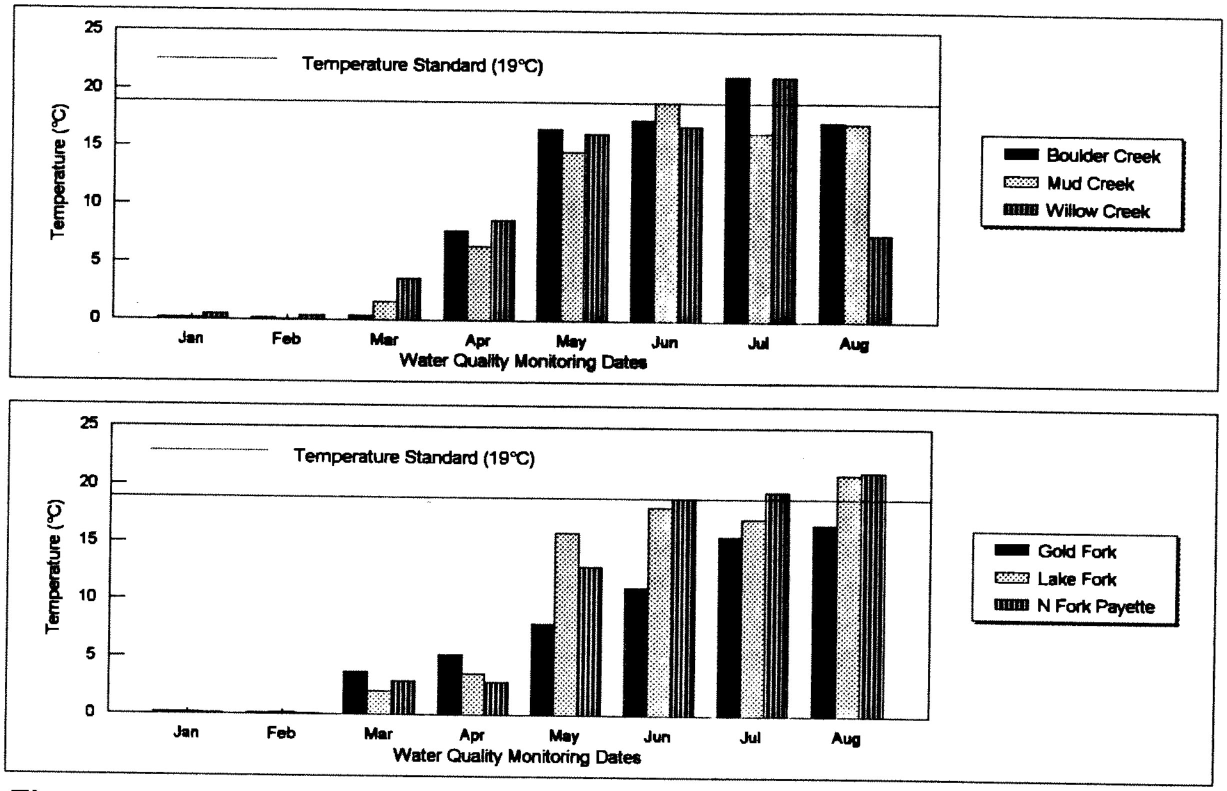


Figure 11. Seasonal variations in temperature within major tributaries to Cascade Reservoir.

allows spreading and warming of the flowing water, increasing its capacity for dissolution of nutrients. Wide, flat flood plains also increase the potential for significant transport of surface-deposited wastes which are typically rich in soluble forms of phosphorus and nitrogen. Increased thermal (solar) inputs also result in decreased dissolved oxygen levels. Tables 1-4, detailing total phosphorus load to the reservoir from tributary inflows as monitored for water years 1993 through 1996, are attached at the back of this appendix.

Overall, the dissolved oxygen levels monitored in major tributaries to the reservoir have generally been good. Only in very low water years (for example 1994) have the dissolved oxygen levels dropped chronically below the established fishery standards (>6.0 mg/l). Temperature standards, however, are periodically exceeded, with most exceedences occurring during the later summer months when air temperatures are higher.

Elevated bacteria counts were also reported (Clark and Wroten, 1975) for areas of the reservoir receiving direct inflow from these areas. A BOR study conducted in 1974 (BOR, 1975) showed several tributaries that exceeded state standards. These elevated levels were attributed to contamination by both animal and human wastes as tributary waters pass through heavily grazed areas and reservoir waters are enriched by septic systems located near the shorelines. At the time of this study, Boulder Creek coliform counts exceeded 9,000/100mL with fecal counts greater than 2,000/100 mL; Campbell Creek was reported to contain coliform counts of 2,400/100 mL. Both areas were heavily grazed at the time of the survey. Zimmer (1983) reported consistently high levels of coliform bacteria for the North Fork Payette River, Lake Fork, Boulder Creek and Gold Fork River from 1978 to 1982.

In a study conducted in 1984 and 1985 to determine the nutrient and bacterial loading attributable to recreational housing and livestock grazing conducted along the southwestern shore of the reservoir, samples were analyzed from both above and below sites for grazing and recreational housing (Lappin and Clark, 1986). Monitoring was conducted immediately following holiday weekends to determine peak recreational usage. High fecal coliform and fecal streptococcus counts were reported for monitored streams, with elevated counts occurring at sites immediately below recreational housing and grazed lands as compared to stream sites located above. The highest counts were recorded immediately below grazed areas (400 to 800/100 mL). Observed nutrient levels showed the same trend; increasing significantly at the sites below recreational housing and grazed lands, with the highest concentrations occurring immediately below the grazed areas. It should be noted that this survey was intended only as an indication of trends. Quantitative interpretation of the collected data should be made with extreme care due to the small number of samples taken. Background effects are difficult to screen out in a survey of this limited size. However, the results clearly indicate that land-use management practices have a significant impact on water quality in both the tributaries and the reservoir. The results obtained have been further validated by USFS monitoring conducted in streams flowing through grazing allotments along the western shores of the reservoir. While variability from stream to stream is high, an overall increasing trend from above to below the allotments is noticeable.

Point Source Monitoring

There are two point sources of pollution to Cascade Reservoir, the McCall wastewater treatment plant (WWTP) and the IDFG fish hatchery in McCall. Both sources discharge nutrients and other pollutants directly to North Fork Payette River upstream of Cascade Reservoir under NPDES permits. The WWTP processes approximately 1.8 million gallons per day (MGD) at full capacity. The average load is roughly 0.7 MGD. Peak flows of 2.3 MGD have been reported however, due to infiltration of ground water and snow-melt. Infiltration is estimated to contribute as much as 1.6 MGD to the base flow. Peak inflow occurs during spring runoff and snow-melt periods and declines during the remainder of the year.

Effluent water quality from the City of McCall WWTP has been routinely monitored since August 1981. Monthly reports are submitted characterizing the average and maximum concentrations of total and dissolved phosphorus, ammonia (nitrogen), total and suspended solids, total and fecal coliform bacteria, chlorine and biological oxygen demand. For the purposes of this document, the major pollutant of concern associated with the WWTP discharge is nutrients, predominantly phosphorus. Effluent concentrations vary seasonally and typically exceed ambient concentrations in North Fork Payette River. In sewage effluent, the majority of the entrained phosphorus is present as dissolved ortho-phosphate, a readily bioavailable form of phosphorus. Proportionately, greater than 85% of the total phosphorus in sewage effluent is in the form of dissolved ortho-phosphate, as compared to

<1% in sediment associated phosphorus. Dissolved ortho-phosphate concentrations in treated effluent range from 1.0 to 6.0 mg/L. Annual total phosphorus loading attributable to the treated effluent rose markedly from the early 1970's to 1988 due to increased population and recreational use. Since 1988, annual total phosphorus loading has remained relatively stable, ranging from 3815 kg to 4751 kg annually (Figure 12).

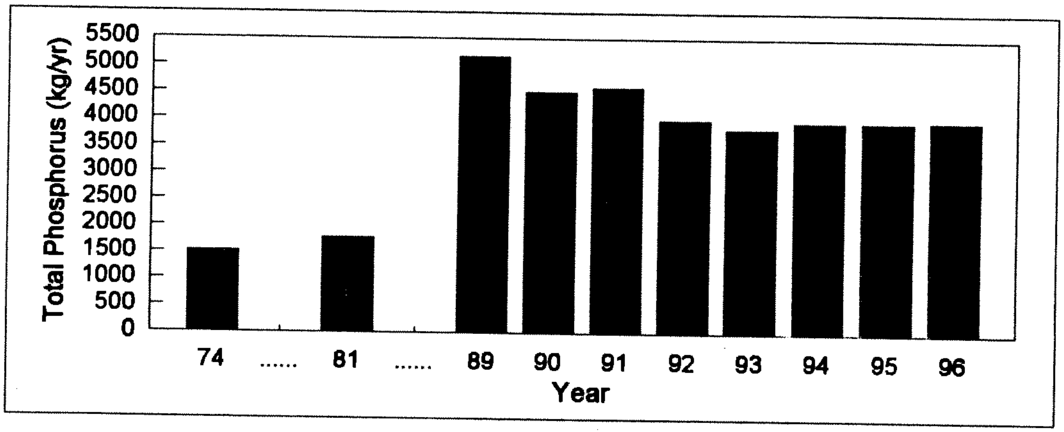


Figure 12. Annual total phosphorus loading from the City of McCall waste water treatment plant (1974 to 1996).

The IDFG Fish Hatchery requires flowing water for growth and maintenance of Chinook Salmon stock and discharges 12.9 MGD (20 cfs) to North Fork Payette River. The major pollutant of concern associated with the hatchery discharge is nutrients, again, predominantly phosphorus.

Analysis of hatchery effluent quality has been sporadically reported to DEQ since 1975. Data is limited and consists primarily of phosphorus concentrations measured in the inflow water diverted from the North Fork Payette River and effluent return water after passing through the hatchery. Ingham and Boyle (1991) monitored hatchery effluent approximately biweekly from July to September, 1988. Additional monitoring was conducted monthly from January to September, 1989, in conjunction with reservoir and watershed monitoring sponsored by the DEQ (Entranco, 1991).

In 1994 the fish food being used (1.7% phosphorus by weight) was replaced by a food type with lower phosphorus content (0.7% phosphorus by weight). This substitution was further augmented by changes in feeding practices. The combination of these changes has resulted in a substantially reduced phosphorus load following 1994. Pre-1994 total phosphorus loads were evaluated at 726 kg/yr (average). Post-1994 loads have been evaluated at 218 kg (average) total phosphorus annually, a 70% decrease.

References:

Bureau of Reclamation (BOR); 1975; *Water quality studies, Payette River Basin and Cascade Reservoir;* U.S. Bureau of Reclamation, Boise, Idaho; 74 p.

Clark, W.H.; Wroten, J.W.; 1975; *Water quality status report, Cascade Reservoir, Valley County, Idaho*; Water Qual. Ser. 20; Idaho Department of Health and Welfare, Division of Environment, Boise, Idaho; 120 pp.

Entranco Engineers, Inc.; 1991; *Cascade Reservoir watershed project water quality management plan;* Prepared for Idaho Department of Health and Welfare, Division of Environmental Quality; 101 p + appendices.

Environmental Protection Agency, 1975; *National eutrophication survey method, 1973-1976*; Working Paper No. 175; National Environmental Research Center, Corvallis, Oregon.

Environmental Protection Agency; 1977; *Report on Cascade Reservoir, Valley County, Idaho;* Working Paper No. 777; U.S. Environmental Protection Agency, Corvallis, Oregon; 44 p.

Horner, N.; 1980; *Cascade Reservoir fishery and limnological investigations*; Interim Report; Idaho Department of Fish and Game, Boise, Idaho; 12 p.

Idaho Division of Environmental Quality (DEQ); 1994; *Cascade Reservoir Data Summary - Water Year 1993*; Idaho Division of Environmental Quality, Boise Regional Office, Boise, Idaho.

Idaho Division of Environmental Quality (DEQ); 1995; *Cascade Reservoir Data Summary - Water Year 1994*; Idaho Division of Environmental Quality, Boise Regional Office, Boise, Idaho.

Idaho Division of Environmental Quality (DEQ); 1996; *Cascade Reservoir Data Summary - Water Year 1995*; Idaho Division of Environmental Quality, Boise Regional Office, Boise, Idaho.

Idaho Division of Environmental Quality (DEQ); 1998; *Cascade Reservoir Data Summary - Water Year 1996*; Idaho Division of Environmental Quality, Boise Regional Office, Boise, Idaho.

Ingham, M.; Boyle, L.; 1991; *North Fork Payette River, Valley County, Idaho, 1988;* Water Quality Status Report No. 97; Idaho Department of Health and Welfare, Division of Environmental Quality, Water Quality Bureau, Boise, Idaho; 35 p.

Ingham, M.; 1992; *Citizen's volunteer monitoring program, Cascade Reservoir, Valley County, Idaho 1988-1991*; Water Quality Status Report No. 103; Idaho Department of Health and Welfare, Division of Environmental Quality, Water Quality Bureau, Boise, Idaho; 25 p.

Irizarry, R.A.; 1970; *Limnological investigations at Cascade Reservoir*; Project F-53-R-4; Idaho Department of Fish and Game, Boise, Idaho. 13 p.

Klahr, P.; 1988; *Lake Irrigation District survey and Cascade Reservoir tributary assessment Valley County, Idaho 1986*; Water Quality Status Report No. 79; Idaho Department of Health and Welfare, Division of Environmental Quality, Water Quality Bureau, Boise, Idaho; 46 p.

Klahr, P.; 1989; *Citizen's volunteer monitoring program, Cascade Reservoir, Valley County, Idaho 1988;* Water Quality Status Report No. 85; Idaho Department of Health and Welfare, Division of Environmental Quality, Water Quality Bureau, Boise, Idaho; 12 p.

Lappin, J.L.; Clark, W.H.; 1986; *Preliminary assessment of water quality impacts of recreational housing and livestock grazing in the Cascade Reservoir watershed*; Journal of the Idaho Academy of Science; Volume 22; Number 2; pp 45-62.

Lindsay, W.L.; 1979; *Chemical Equilibria in Soils*; John Wiley & Sons, New York; pp 163-205.

Reininger, B.; Rieman, B.; Horner, N.; 1983 (January); *Cascade Reservoir Fisheries Investigations*; Project F-73-R-4; Idaho Department of Fish and Game, Boise Idaho; 123 p.

Shannon, E.E.; Brezonik, P.L.; 1972; *Relationships between lake trophic state and nitrogen and phosphorus loading rates*; Journal of Environmental Science and Technology; Volume 8; pp. 719-725.

Sharpley, A.N.; Jones, C.A.; Grey, C.; Cole, C.V.; 1984; *A simplified soil and plant phosphorus model II: Prediction of labile, organic and sorbed phosphorus*; Soil Science Society of America Journal; Volume 48; pp. 805-809.

Tiessen, H.; (ed.); 1995; *Phosphorus in the Global Environment: Transfers, Cycles and Management*; Scientific Committee on Problems of the Environment 54; John Wiley and Sons, Chichester.

Vollenweider, R.A.; 1968; *Scientific fundamentals of the eutrophication of lakes and flowing waters, with particular reference to nitrogen and phosphorus as factors in eutrophication;* OECD Technical Report DAS/CS1/68.27; 159 p.

Worth, D.; 1993-1994; *Cascade Reservoir and tributary water quality data*; Unpublished data; Department of Health and Welfare, Division of Environmental Quality, Boise, Idaho.

Worth, D.; 1997; *Cascade Reservoir Model: Model Simulations of External Reductions in Phosphorus Loading to Cascade Reservoir*; for Idaho Division of Environmental Quality, Boise Regional Office, Boise, Idaho; 17 p.

Zimmer, D.W.; 1983; *Phosphorus loading and bacterial contamination of Cascade Reservoir, Boise Project, Idaho*; U.S. Bureau of Reclamation, Boise, Idaho; 143 pp.

Other Pertinent References Not Cited Directly:

Boise National Forest; 1993; *Final environmental impact statement Spruce Creek timber sale;* Cascade Ranger District, Boise National Forest, Boise, Idaho.

Boise National Forest and Payette National Forest; 1996; *Requested input to Idaho Department of Health and Welfare, Division of Environmental Quality for Cascade Reservoir Watershed Management Plan, Phased Total Maximum Daily Load (TMDL) January 16, 1996*; On file with Boise Regional Office DEQ, Boise, Idaho.

Bureau of Reclamation; 1981; *Cascade land use management plan environmental assessment*; U.S. Bureau of Reclamation, Boise, Idaho; 54 p.

Bureau of Reclamation; 1982; *Management of the uncontracted storage space in Cascade and Deadwood Reservoirs;* Payette Division, Boise Project, Idaho: Draft Environmental Assessment; U.S. Bureau of Reclamation, Boise, Idaho; 118 p.

EDAW, Inc.; 1991; *Cascade Reservoir resource management plan*; U.S. Bureau of Reclamation, Central Snake Projects Office, Boise, Idaho.

Bureau of Reclamation; 1991; *Cascade Reservoir Resource Management Plan*; U.S. Bureau of Reclamation Central Snake Projects Office, prepared by EDAW, Inc.

Bureau of Reclamation; 1992; *VanWyck Park recreation area development Cascade Reservoir, Idaho*; U.S. Bureau of Reclamation, Central Snake projects Office, Pacific Northwest Region, Boise, Idaho; 48 p.

Bureau of Reclamation; 1995; *Management of the uncontracted storage space in Cascade and Deadwood Reservoirs, finding of no significant impact and final environmental assessment*; U.S. Bureau of Reclamation, Snake River Area Office, Pacific Northwest Region, Boise, Idaho; 133 p.

CH2M-HILL Engineers, Planners, Economists and Scientists; 1977; *Feature design memorandum McCall, Idaho, summer chinook hatchery system design memorandum no. 3*; Prepared for the Idaho Department of Fish and Game and the U.S. Army Engineer District, Walla Walla, with funding by the Pacific Northwest regional Commission, Vancouver, Washington.

Clark, W.H.; 1990; *Coordinated nonpoint source water quality monitoring program for Idaho*; Idaho Department of health and Welfare, Division of Environmental Quality Boise, Idaho; 139 p.

Horner, N.; Rieman, B.; 1981; *Cascade Reservoir fisheries investigations*; Project F-73-R-3; Idaho Department of Fish and Game, Boise, Idaho; 85 p.

Horner, N.; Reininger, B.; Rieman, B.; 1982; *Cascade Reservoir fisheries and limnological investigations*; Final Report; Idaho Department of Fish and Game, Boise, Idaho; 164 p.

Idaho Department of Commerce; 1992; *County profiles of Idaho*; Idaho Department of Commerce, Economic Development Division, Boise, Idaho.

Reid, W.; 1989; *A survey of 1987 Idaho anglers opinions and preferences*; Project F-35-R-13; Idaho Department of Fish and Game, Boise, Idaho; Submitted to the U.S. Fish and Wildlife Service under Federal Aid in Fish Restoration Program; 76 p.

Schmidt, D.L.; Mackin, J.H.; *Quaternary geology of Long and Bear Valleys, West-Central Idaho*; Prepared on behalf of the U.S. Atomic Energy Commission; Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402; Geological Survey Bulletin 1311:A1-A21.

Stevenson, T.K.; 1990; *State geologist's erosion/sedimentation report for Cascade Reservoir SAWQP, Donnelly ID*; Internal report plus addendum 1991; Natural Resource Conservation Service, Boise, Idaho.

USDA Forest Service; 1993; *Spruce Creek Timber sale, final environmental impact statement*; Cascade Ranger District, Boise National Forest, Valley County, Idaho.

USDA Forest Service; 1994; *Sloan-Kennally timber sale, draft environmental impact statement*; McCall Ranger District, Payette National Forest, Valley County, Idaho.

Worth, D.; Lappin, J.; 1994; *Blue-green algae blooms on Cascade Reservoir, Valley County, Idaho*; Envir. Health Digest; Volume XX; Number 1; pp 18-21.

Table 1.0 Total Phosphorus Budget for Cascade Reservoir: Water Year 1993

		Cumulative TP Load in Kg								
Date	**Int. Days**	**Boulder Creek**	**Gold Fork**	**Lake Fork**	**Mud Creek**	**North Fork Payette**	**Poison Creek**	**Willow Creek**	**West Mountain**	**Total**
01-Oct	0	0	0	0	0	0	0	0	0	0
31-Oct	31	2	145	144	23	400	8	24	79	817
30-Nov	30	39	221	141	23	391	8	22	77	914
31-Dec	31	46	286	141	32	555	11	34	109	1,204
31-Jan	31	40	377	188	31	523	11	31	103	1,292
28-Feb	28	46	287	155	25	429	9	23	85	1,050
31-Mar	31	145	1063	483	78	1,342	27	87	264	3,463
12-Apr	11	2,512	370	341	199	636	10	122	113	4,293
27-Apr	15	733	724	393	102	1,113	18	123	71	3,260
12-May	15	362	1,165	1,434	36	1,925	31	18	507	5,446
24-May	12	446	3,416	820	39	3,751	68	30	890	9,393
03-Jun	10	283	1,959	703	20	7,681	54	106	288	11,040
22-Jun	19	301	1,245	1,586	41	1,896	27	101	183	5,352
20-Jul	28	156	436	10	30	417	7	56	69	1,174
17-Aug	28	274	321	49	329	347	6	426	64	1,811
14-Sep	28	119	35	128	73	1,058	9	48	109	1,569
30-Sep	17	51	158	43	21	268	2	6	14	562
Annual	365	5,554	12,208	6,759	1,104	22,732	306	1,257	3,023	52,639

Table 2.0 Total Phosphorus Budget for Cascade Reservoir: Water Year 1994

		Cumulative TP Load in Kg								
Date	Int. Days	Boulder Creek	Gold Fork	Lake Fork	Mud Creek	North Fork Payette	Poison Creek	Willow Creek	West Mountain	Total
01-Oct	0	0	0	0	0	0	0	0	0	0
19-Oct	18	21	78	53	11	206	1	7	14	389
17-Nov	29	43	457	328	41	324	11	27	106	1,325
15-Dec	28	185	1,354	357	82	806	16	58	154	2,995
12-Jan	28	144	146	51	49	582	5	49	44	1,066
01-Mar	48	18	186	83	56	537	11	60	106	1,046
15-Mar	14	37	711	16	18	202	3	19	31	1,034
22-Mar	7	39	42	11	9	66	1	32	8	206
29-Mar	7	172	134	22	55	127	4	190	35	736
05-Apr	7	70	296	46	70	336	2	362	19	1,199
12-Apr	7	99	336	115	50	195	6	38	57	890
18-Apr	6	39	326	53	11	274	10	6	94	803
25-Apr	7	69	164	67	21	438	6	3	56	819
05-May	10	32	279	124	13	354	6	5	62	870
10-May	5	20	174	464	2	1,800	15	1	148	2,609
23-May	13	54	162	55	7	598	7	8	65	948
07-Jun	15	54	100	42	4	278	4	27	34	536
20-Jun	13	8	113	5	15	203	4	11	41	397
12-Jul	22	10	156	7	2	291	1	28	11	505
08-Aug	27	23	40	15	63	389	7	31	67	628
12-Sep	35	38	32	3	38	414	2	1	20	546
30-Sep	18	19	16	2	19	213	1	1	10	281
Annual	364	1,195	5,301	1,919	638	8,629	123	962	1,182	19,827

Table 3.0 Total Phosphorus Budget for Cascade Reservoir: Water Year 1995

		Cumulative TP Load in Kg								
Date	Int. Days	Boulder Creek	Gold Fork	Lake Fork	Mud Creek	North Fork Payette	Poison Creek	Willow Creek	West Mountain	Total
01-Oct	0	0	0	0	0	0	0	0	0	0
20-Oct	19	6	25	3	4	180	0.3	1	5	226
15-Nov	26	21	80	19	34	203	1	6	21	385
07-Dec	22	42	61	35	24	210	1	20	47	440
11-Jan	35	72	289	126	80	711	9	33	107	1,419
15-Feb	35	185	214	100	48	541	13	34	182	1,303
28-Feb	13	103	119	140	31	537	17	44	175	1,150
15-Mar	15	138	451	167	48	703	19	47	202	1,758
28-Mar	13	80	196	38	20	414	4	25	28	802
11-Apr	14	291	489	153	67	891	5	67	87	2,045
25-Apr	14	181	623	166	38	913	6	73	230	2,224
10-May	15	265	973	308	20	1,825	23	57	244	3,692
23-May	13	194	703	434	2	1,928	45	17	297	3,574
08-Jun	16	235	604	199	3	1,705	17	13	325	3,085
27-Jun	19	240	432	178	16	1,382	9	49	449	2,746
11-Jul	14	129	190	62	55	244	4	42	262	984
23-Aug	43	148	23	45	165	807	13	88	274	1,550
07-Sep	15	36	18	66	61	420	2	25	51	677
26-Sep	19	40	10	39	26	365	2	28	33	542
30-Sep	4	9	2	8	5	77	0.47	6	7	114
Annual	364	2,413	5,504	2,288	749	14,057	191	676	3,028	28,716

Table 4.0 Total Phosphorus Budget for Cascade Reservoir: Water Year 1996

		Cumulative TP Load in Kg								
Date	Int. Days	Boulder Creek	Gold Fork	Lake Fork	Mud Creek	North Fork Payette	Poison Creek	Willow Creek	West Mountain	Total
26-Sep	0	0	0	0	0	0	0	0	0	0
18-Oct	22	44	165	95	25	240	5	23	89	681
18-Nov	31	107	334	213	56	783	26	52	113	1,658
13-Dec	25	519	1,672	684	60	1,076	86	63	178	4,252
22-Feb	71	705	1,417	444	510	1,993	19	568	130	5,767
03-Apr	41	1,054	986	660	762	1,823	17	332	121	5,739
25-Apr	22	176	2,980	524	113	2,453	129	50	904	7,200
08-May	13	107	379	326	19	658	5	16	37	1,543
24-May	16	207	1,267	291	37	1,827	23	71	163	3,864
05-Jun	12	219	1,264	480	8	1,323	30	34	209	3,536
20-Jun	15	184	540	427	10	1,392	14	25	100	2,679
03-Jul	13	125	366	131	9	427	26	26	180	1,263
18-Jul	15	77	45	7	26	174	10	54	68	451
31-Jul	13	28	26	7	18	451	3	19	21	569
23-Aug	23	49	8	42	23	234	4	21	28	404
25-Sep	33	35	35	67	28	233	4	23	31	453
Annual	365	3,635	11,484	4,397	1,706	15,087	402	1377	2,372	40,059

Appendix E

Monitoring Summary for the Cascade Reservoir Watershed

Appendix E. Monitoring Summary for the Cascade Reservoir Watershed

Cascade Reservoir and the surrounding watershed have been the focus of many studies over the past 30 years. Initial monitoring consisted of the evaluation of fish-habitat indicators by IDFG in 1968 and water-quality parameters in 1975 by the BOR. Historical monitoring was augmented by further studies conducted by the CRA, IDHW, CDHD, BOR, DEQ and others. Historical monitoring of water quality in Cascade Reservoir (Clark and Wroten, 1975; Klahr, 1988; Klahr, 1989; Entranco, 1991; Ingham, 1992; Worth 1993 and 1994) has indicated significant impairment resulting from excess nutrients entering the reservoir through tributary and diversion inflow and overland runoff. However, while there is an extensive list of historical monitoring available, a concerted watershed monitoring effort was not undertaken until the early 1990s, when routine, scheduled monitoring was initiated for specific inflow and inlake sites.

DEQ has continuously monitored the water quality in the Cascade Reservoir Watershed since 1993. Monitoring is scheduled to continue throughout the phased TMDL process to identify water-quality trends and attainment of water-quality objectives. Concurrent monitoring by USFS personnel (predominantly for tributaries in Gold Fork and West Mountain subwatersheds), and BOR (in-reservoir and created wetlands monitoring) has been ongoing and is scheduled to continue. Specific monitoring sites designated by these agencies may undergo revision to address budgetary changes, but will continue in the most extensive manner possible given availability of funding. A detailed monitoring plan is prepared and/or updated annually for Cascade Reservoir that outlines coordinated monitoring activities for the support, development and implementation of the TMDL allocation to improve reservoir water quality.

Background Information

The Idaho Water Quality Standards designate beneficial uses for Cascade Reservoir as: domestic and agricultural water supply, cold and warm water biota, salmonid spawning and primary/secondary contact recreation. Cascade Reservoir was designated as a Stream Segment of concern in 1989 due to impaired water quality and the perception that beneficial uses were no longer fully supported. Past studies indicate that the reservoir is hyper-eutrophic due to excessive nutrient loading, with phosphorus considered to be the limiting factor. Excessive algal blooms have been reported on Cascade Reservoir since the early 1970s. These algal blooms are the most conspicuous indicator of nutrient pollution problems.

Eutrophication of Cascade Reservoir has been attributed to excess phosphorus and other nutrients carried by various streams and rivers flowing into the reservoir. The source of this phosphorus has been linked to land-use activities within the watershed resulting in point and nonpoint sources of pollution. Point sources of pollution include the McCall Wastewater Treatment Plant and the McCall Fish Hatchery which discharge treated wastewater directly into the North Fork Payette River. These facilities are permitted under the EPA National Pollutant Discharge Elimination System (NPDES). Non-point sources of phosphorus include forested, agricultural and urban/suburban land use. Other important contributions of phosphorus are associated with erosion, stormwater runoff, recreation and septic tanks associated with shoreline development.

Long-term monitoring indicates phosphorus concentrations within the reservoir have increased since 1984 with a corresponding increase in algal production. Although phosphorus loading to the reservoir varies greatly depending on the annual rainfall and snowfall patterns, a comparison of the phosphorus budgets indicates that 80-90% of the phosphorus load is retained within the reservoir. As a result, much of the phosphorus loading accumulates in the reservoir sediments and provides a secondary source of enrichment for algal growth. Reducing the amount of phosphorus in runoff entering Cascade Reservoir is critical for long-term improvement of water quality.

Due to continued violations of water-quality standards, Cascade Reservoir was listed as a water-quality limited water body under section 303(d) of the Federal Clean Water Act (40 CFR Ch.1 130, 1987). The Clean Water Act stipulates that Total Maximum Daily Load (TMDL) allocations must be developed by those states designating a water body as "water-quality limited". A TMDL allocates the allowable amount of pollutants that can be effectively assimilated by a specific water body while continuing to meet state water-quality standards. The TMDL must include all potential sources of a designated pollutant of concern, including those derived as point, nonpoint and natural or background sources. DEQ initiated development of TMDL allocations for Cascade Reservoir in February 1994. Current monitoring projects were implemented under this effort. Historical monitoring projects for both tributary (inflow) and inlake sites (listed in Table 1) have allowed the identification of water-quality trends and the establishment of reasonable baseline conditions.

Table 1 Inlake and Tributary Studies of Cascade Reservoir Watershed

STUDIES OF TRIBUTARIES TO CASCADE RESERVOIR			
Year	**Conducted By**	**Parameters**	**Comments/Location**
1975	EPA[1]	Nutrients, DO, temperature, pH, bacteria	National Eutrophication Study
1975	DEQ[2]	Nutrients, DO, temperature, pH, bacteria	Boulder Cr., Gold Fork R., Lake Fork Cr., Mud Cr.
1980	BOR[3]	Nutrients, DO, temperature, pH, bacteria, stream flow	Expansion to biweekly sampling
1984-present	Boise Cascade[4]	Nutrients, DO, temperature, pH, bacteria, stream flow, suspended sediment	Trend monitoring, Gold Fork R.
1986	DEQ[5]	Nutrients, DO, temperature, pH, bacteria, stream flow, suspended sediment	Focused on streams primarily influenced by agriculture, Boulder Cr., Mud Cr., Lake Fork Cr.
1989	Entranco[6]	Nutrients, DO, temperature, pH, bacteria, stream flow, suspended sediment	Development of a water-quality management plan, all major tributaries
1991-present	BNF[7]	Stream flow, bacteria, nutrients	Monitor impacts to streams from grazing allotments on the Westside

STUDIES OF TRIBUTARIES TO CASCADE RESERVOIR			
1992-1994	DEQ and VSWCD[8]	Nutrients, DO , temperature, pH, bacteria, stream flow, suspended sediment, riparian condition	BMP effectiveness on Boulder Cr.
1993-present	DEQ[9]	Nutrients, DO, temperature, pH, bacteria, stream flow, suspended sediment	Determine mass loading from each tributary
1991-present	PNF[10]	Stream flow, bacteria, nutrients	Trend monitoring in Kennally Creek
INLAKE STUDIES OF CASCADE RESERVOIR			
1968	IDFG[11]	DO	Limnological & fisheries
1974	BOR[12]	DO , conductivity, temperature, nutrients, minerals, chlorophyll a	Concerns for low DO and nuisance algae
1975	DEQ[2]	DO , temperature, nutrients, minerals, chlorophyll a, phytoplankton, bacteria	Study coincided with issuance of the McCall NPDES permit
1975	EPA[1]	DO , temperature, conductivity, pH, nutrients, minerals, alkalinity, chlorophyll a, phytoplankton, bacteria	National Eutrophication Study
1978-present	BOR[13]	Phosphorus, chlorophyll a	Reservoir trend monitoring
1980-1982	IDFG[14]	DO	Develop criteria for winter storage to enhance fish survival
1988-1991	Citizens[8,15]	DO , temperature, nutrients, Secchi depth, chlorophyll a, phytoplankton	Citizen concern
1989	Entranco[6]	DO , temperature, conductivity, pH, Secchi depth, nutrients, chlorophyll a, phytoplankton, bacteria	Phase I Clean Lakes Grant funded study
1993-present	DEQ[16]	DO , temperature, conductivity, pH, Secchi depth, nutrients, chlorophyll a, phytoplankton, bacteria	Expand database to assist in the development of a restoration management plan

1 = EPA, 1977; 2 = Clark and Wroten, 1975; 3 = Zimmer, 1983; 4 = Glass, 1995; 5 = Klahr, 1988; 6 = Entranco, 1991; 7 = Fischer, 1995; 8 = Ingham, 1992; 9 = Worth, 1995; 10 = PNF, 1995; 11 = Irizarry, 1970; 12 = Bureau of Reclamation, 1974 and 1975; 13 = Zimmer, 1983; 14 = Horner and Riemand, 1981, Reininger *et al.*, 1982, Reininger *et al.*, 1993; 15 = Klahr, 1989; 16 = Worth, 1994.

The current monitoring activities discussed herein are consistent with guidelines for implementation of a phased TMDL for both point and nonpoint sources of pollution (EPA, 1991). Under the traditional TMDL process, the state is required to adopt and enforce specific numerical water-quality criteria that when implemented, would result in restoring full support of designated beneficial uses.

Monitoring Objectives

Water-quality monitoring objectives in support of the TMDL process include:

Objective 1	Evaluation of watershed nutrient sources, baseline conditions and reservoir loading.
Objective 2	Obtain adequate flow and pollutant load information during peak runoff season in order to more accurately determine phosphorus loading to the reservoir.
Objective 3	Obtain adequate temperature information on tributaries.
Objective 4	Evaluate the effectiveness of constructed wetlands and detention ponds in reducing phosphorus loading to the reservoir and/or tributaries.

Cascade Reservoir Inflows

Seven major subwatersheds have been identified that directly drain to Cascade Reservoir (Cascade Reservoir Phase II Watershed Management Plan, Figure 2.2). Water-quality monitoring has been conducted on the major tributaries for each subwatershed and several local streams and rivers related to specific timber management activities on endowment state lands and within the national forests. Specific inflow locations designated for DEQ water-quality monitoring are:

GF1	Gold Fork River	-116° 04' 03.63"W/44° 41' 15.00"N
LF1	Lake Fork @ Scheline Road	-116° 05' 03.45"W/44° 37' 18.43"N
BC1	Boulder Creek @ Hwy 55	-116° 00' 32.29"W/44° 43' 39.69"N
BC2	Boulder Creek @ Roseberry Ditch Diver.	-116° 00' 42.23"W/44° 46' 44.45"N
BC3	Boulder Creek @ Potter Road	-116° 01' 36.51"W/44° 50' 48.85"N
MC1	Mud Creek at Norwood Rd.	-116° 06' 31.42"W/44° 43' 39.69"N
WC1	Willow Creek at Old State Hwy	-116° 04' 03.04"W/44° 43' 02.13"N
PC1	Poison Creek at West Mtn. Rd. Crossing	-116° 06' 40.12"W/44° 39' 58.85"N
NFPR2	N. Fork Payette River @ Hartzell Bridge	-116° 00' 59.63"W/44° 46' 43.73"N

The current monitoring of nine inflow stations (Figure 1) by DEQ is designed to quantify nutrient contributions from each of the subwatersheds that drain into Cascade Reservoir. Each of these stations is monitored monthly. Flow, conductivity, pH, temperature and dissolved oxygen measurements are taken in the field and water samples are collected for analysis for the parameters listed in Table 2 below. Appropriate quality assurance measures including blanks, spikes and duplicate sampling are included in all monitoring performed.

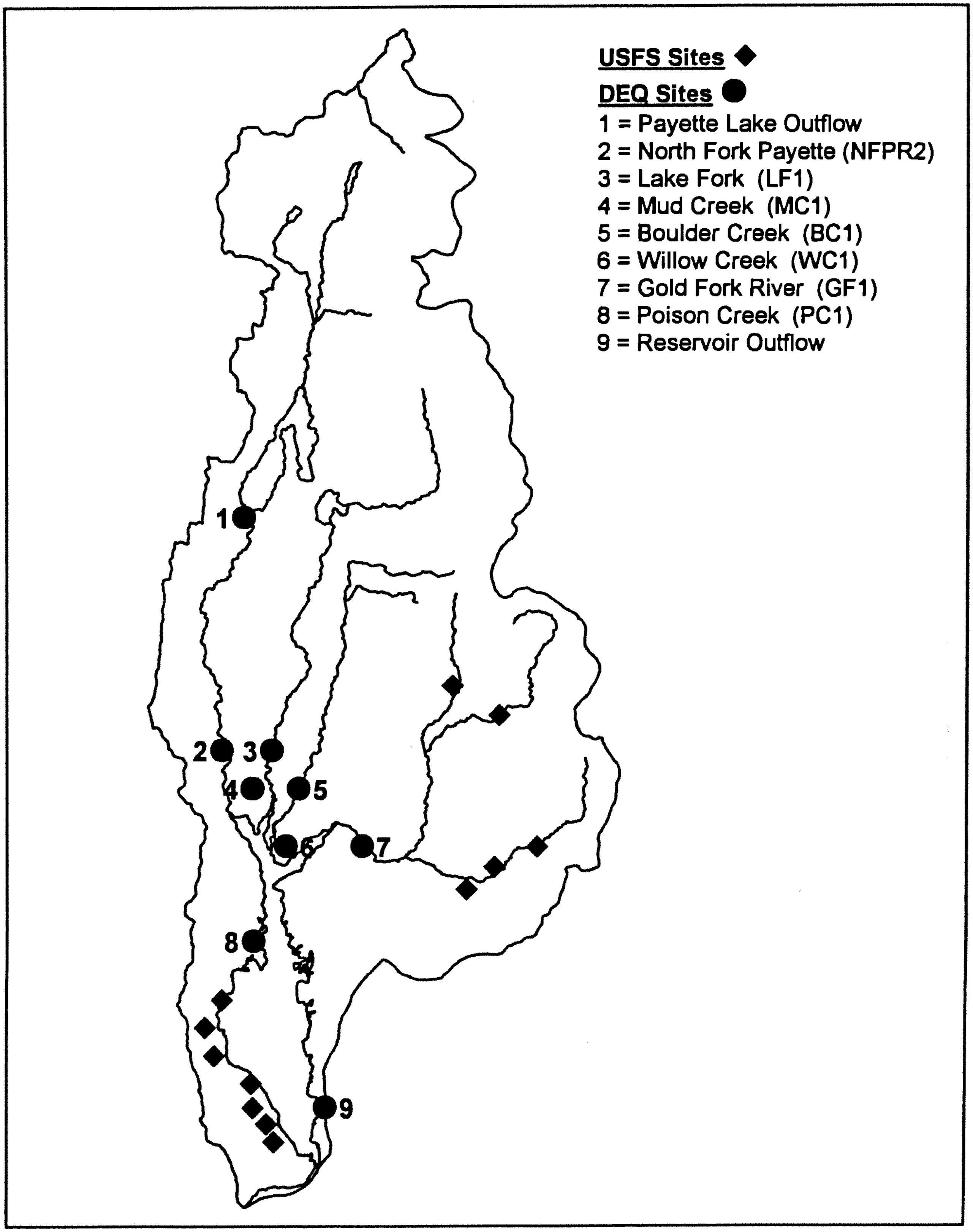


Figure 1 Location of inflow monitoring sites for Cascade Reservoir Watershed.

Table 2 Water-quality monitoring parameters for DEQ inflow stations

Analytical Parameters	Minimum detection limit- units	Methods
NO_2+NO_3 as N	0.005 mg/L	EPA Method 353.2
NH_4 as N, Total	0.005 mg/L	EPA Method 350.1
Total Kjedahl Nitrogen (TKN)	0.05 mg/L	EPA Method 351.2
Total Phosphorus	0.005 mg/L	EPA Method 365.4
Ortho-phosphate	0.001 mg/L	EPA Method 365.2
Suspended Sediment	2 mg/L	EPA Method 160.2
Total Solids	2 mg/L	
Chloride	0.9 mg/L	EPA Method 325.3
Fecal Coliform	2 cts/100 mL	Standard Methods
E. Coli	2 cts/100 mL	Standard Methods
Field Parameters	**Units**	
Flow	cfs	Electronic metering
Temperature	degrees Celsius	Point and continuous
Dissolved Oxygen	mg/L	Hydrolab Dissolved Oxygen Probe
Specific Conductivity	µ mhos	Hydrolab Conductivity Probe
pH	SU	pH meter

Nitrogen. The nitrogen:phosphorus ratio is an important indicator of the trophic condition of a water body. Although phosphorus is often the nutrient which limits the growth of algae in lakes and reservoirs, nitrogen is also an important nutrient. The balance of these two nutrients can influence the type of algae species that grow and dominate a lake or reservoir. While water-quality data from Cascade Reservoir suggests that phosphorus supply is largely responsible for the prevalence of algae, the quantity and concentrations of nitrogen entering the reservoir may also contribute to the growth of algae blooms.

Phosphorus. Eutrophication of Cascade Reservoir has been attributed to excess phosphorus within the water column. Both total and dissolved (ortho-phosphate) are monitored in tributary inflow samples. Both are important indicators of nutrient loading for while soluble forms of phosphorus are more readily available for algal uptake and have greater potential to stimulate growth, particulate forms of phosphorus bound to organic particles and sediments generally comprise the largest source of phosphorus enrichment. Although, particulate forms of phosphorus are kinetically less available for algal uptake, mineralization, microbial activity can convert significant portions of this phosphorus to more soluble forms over time, further enhancing the pool of phosphorus available for algal uptake and growth.

Sediment. Information collected on the sediment/solids mass within inflow samples allows not only interpretation of physical transport and delivery mechanisms for sorbed phosphorus, but also an indirect evaluation of riparian health and streambank erosion processes.

Bacteria. Historically, bacterial contamination has been only infrequently monitored. Data gathered has usually been obtained in conjunction with issues related to sanitary disposal of waste water from septic tanks (Table 1). Monitoring efforts initiated in 1993 provide an expanding data base on bacterial contamination that was not previously available. This information can be used to evaluate both septic and sewer impacts on water quality as well as bacterial contamination resulting from animal wastes.

Flow. Stream-flow measurements are critical to the development of a total annual load for the watershed. They also provide chronological distributions of pollutant delivery. Studies have shown (Entranco Engineers, 1991; Worth, 1993 and 1994) that large amounts of phosphorus enter the reservoir during snowmelt. While this period varies from year to year, it generally occurs during March for snow on the valley floor and mid-May to mid-June for peak runoff from the surrounding mountains. Additional monitoring events during snowmelt periods have been added to routine, monthly monitoring to provide enhanced information on the levels of phosphorus delivered to the reservoir during that time.

Temperature. Temperature is an important indicator of stream quality. Temperature is affected by riparian cover, thermal inputs, flow alterations, ambient temperatures, groundwater recharge and direct sunlight. Obtaining temperature measurements at each of the inflow sites provides information on diurnal temperature variations and information on average daily temperatures. Temperature information can also give some indication of the extent of dissolution of sorbed phosphorus from suspended sediment within the water column.

Dissolved Oxygen. Dissolved oxygen concentration is a fundamental measure of the ability of a waterbody to support aquatic life. Ambient water-quality monitoring indicates that Cascade Reservoir experiences periodic low dissolved oxygen levels during the summer months. Instream dissolved oxygen levels provide a measure of input levels to the reservoir. Elevated temperatures and algal productivity influence dissolved oxygen levels.

Conductivity. Conductivity measurements provide information on the concentration of dissolved solids and buffer capacity of tributary waters. The ion strength and conductivity also influence the form of dissolved metals and other trace constituents in the water column.

pH. The acidity or basicity of natural waters has significant impact on wildlife, plant and fishery populations. The pH also influences the charge state of dissolved trace metals and sorption-desorption mechanisms of sediment-bound phosphorus.

In addition to existing DEQ monitoring, the BNF, Cascade District began monitoring the smaller tributaries on the west side of the reservoir in 1991, and in Gold Fork subwatershed (by both BNF and PNF) (Figure 1). This monitoring has continued through 1998. The streams are monitored to determine the effects of grazing conducted under permits issued on lands managed by the BNF. Monitoring includes stream flow rates, nutrients (total phosphorus, dissolved ortho-phosphate), bacteria (fecal coliform) and physical data (temperature and DO). Measurements are taken above and below the grazing allotments to estimate relative differences ascribed to grazing management.

Boulder Creek Hydrography Delineation and Monitoring. Hydrology of the landscape within this subwatershed is extremely complex due to natural geologic features, presence of extensive wetlands and manmade canals. These physical features create a patchwork of different land uses and hydrologic conditions that affect runoff and related water quality throughout the watershed. These intra-basin differences, however, are not readily distinguished by current method of monitoring water quality as a single aggregate outflow. Consequently, the resulting loading estimates may provide little information concerning which specific portions of a heterogeneous landscape within a watershed actually contribute a greater proportion of nutrients. In addition, the effectiveness of the selection and implementation of BMPs can be greatly enhanced through identification of small sub-basins that can be linked to high sources of nutrients within the larger watershed.

A pilot project targeting the Boulder/Willow subwatershed has been initiated and will be ongoing. The subwatershed has been partitioned into smaller subsets based on hydrologic boundaries (natural and manmade), landscape features and land-use practices to aid in the identification of critical sub-basins. Three separate monitoring sites have been designated along Boulder Creek to evaluate water management practices and related water-quality impacts based on priority of their individual contribution to the net export of watershed nutrients (Ingham, 1992).

Ground Water Monitoring

With the exception of bacterial surveys, very few studies have evaluated the importance of ground water as a nutrient source for Cascade Reservoir. Zimmer (1983) reported concentrations of dissolved ortho-phosphate frequently exceeded concentrations of surface inflows, indicating shallow ground water could be an important source of nutrient loading to the reservoir. Shallow ground water within the watershed is often heavily impacted by agricultural recharge from flood irrigation practices. Good estimates of the total loading impact of shallow ground water are not available due to the significant variability of shallow, perched aquifers within the region. Estimates of deep, natural ground-water loading impacts have been established at 2102 kg/year for the total watershed. This is discussed in detail in section 3.3.1 of the Cascade Reservoir Phase II Watershed Management Plan.

Lappin and Clark (1986) conducted an intensive study of bacteria contamination in surface and ground water related to recreational housing and cattle grazing along the reservoir southwest shore. The area of study included high density use of summer cabins.

Point Source Monitoring

There are two point sources of pollution to Cascade Reservoir, the McCall wastewater treatment plant (WWTP) and the IDFG fish hatchery in McCall. Both sources discharge nutrients and other pollutants directly to North Fork Payette River, upstream of Cascade Reservoir under NPDES permits. Effluent water quality from the City of McCall WWTP has been routinely monitored since August 1981. Monthly reports are submitted characterizing the average and maximum concentrations of total and dissolved phosphorus, ammonia (nitrogen), total and suspended solids, total and fecal coliform bacteria, chlorine and biological oxygen demand.

Analysis of hatchery effluent quality has been sporadically reported to DEQ since 1975. Data is limited and consists primarily of phosphorus concentrations measured in the inflow water diverted from the North Fork Payette River and effluent return water after passing through the hatchery. Ingham and Boyle (1991) monitored hatchery effluent approximately biweekly from July to September, 1988. Additional monitoring was conducted monthly from January to September, 1989, in conjunction with reservoir and watershed monitoring sponsored by the DEQ (Entranco, 1991).

In-Reservoir Monitoring

Several inlake monitoring sites have been established (Figure 2). CWQ sites as shown in Figure 2 were established by DEQ. Additional GAR sites were established and monitored by the BOR. Four sites (CWQ002, CWQ005, CWQ007, CWQ012), are monitored routinely during summer months by DEQ. The remaining CWQ sites are monitored on an as needed basis as indicated by inlake and inflow water quality.

CWQ002	100' from east shore above dam	-116° 03' 09.61"W/44° 31' 22.70"N
CWQ004	Near Hurd Creek on western shore	-116° 08' 26.48"W/44° 35' 04.65"N
CWQ005	Westernmost tip of Surgarloaf Is.	-116° 05' 34.80"W/44° 38' 36.50"N
CWQ007	Center of res., near Poison Creek	-116° 05' 59.10"W/44° 39' 35.90"N
CWQ009	Near North/Lake Fork confluence	-116° 07' 05.23"W/44° 41' 54.46"N
CWQ010	Center of Lake Fork arm	-116° 06' 11.70"W/44° 42' 12.46"N
CWQ011	Center of Gold Fork arm	-116° 05' 00.20"W/44° 40' 28.43"N
CWQ012	Center of res., near VanWyck Creek	-116° 05' 00.20"W/44° 32' 32.50"N

DEQ inlake monitoring is carried out monthly and includes all water-quality parameters discussed previously for inflow monitoring with additional depth distribution measurements for temperature, dissolved oxygen, conductivity, pH and phosphorus. Chlorophyll a and phytoplankton samples are also taken at these locations to monitor algal distribution and relative organism population counts (respectively). Concurrent Secchi depth measurements are recorded at each site. Appropriate quality assurance measures including blanks, spikes and duplicate sampling are included in all monitoring performed.

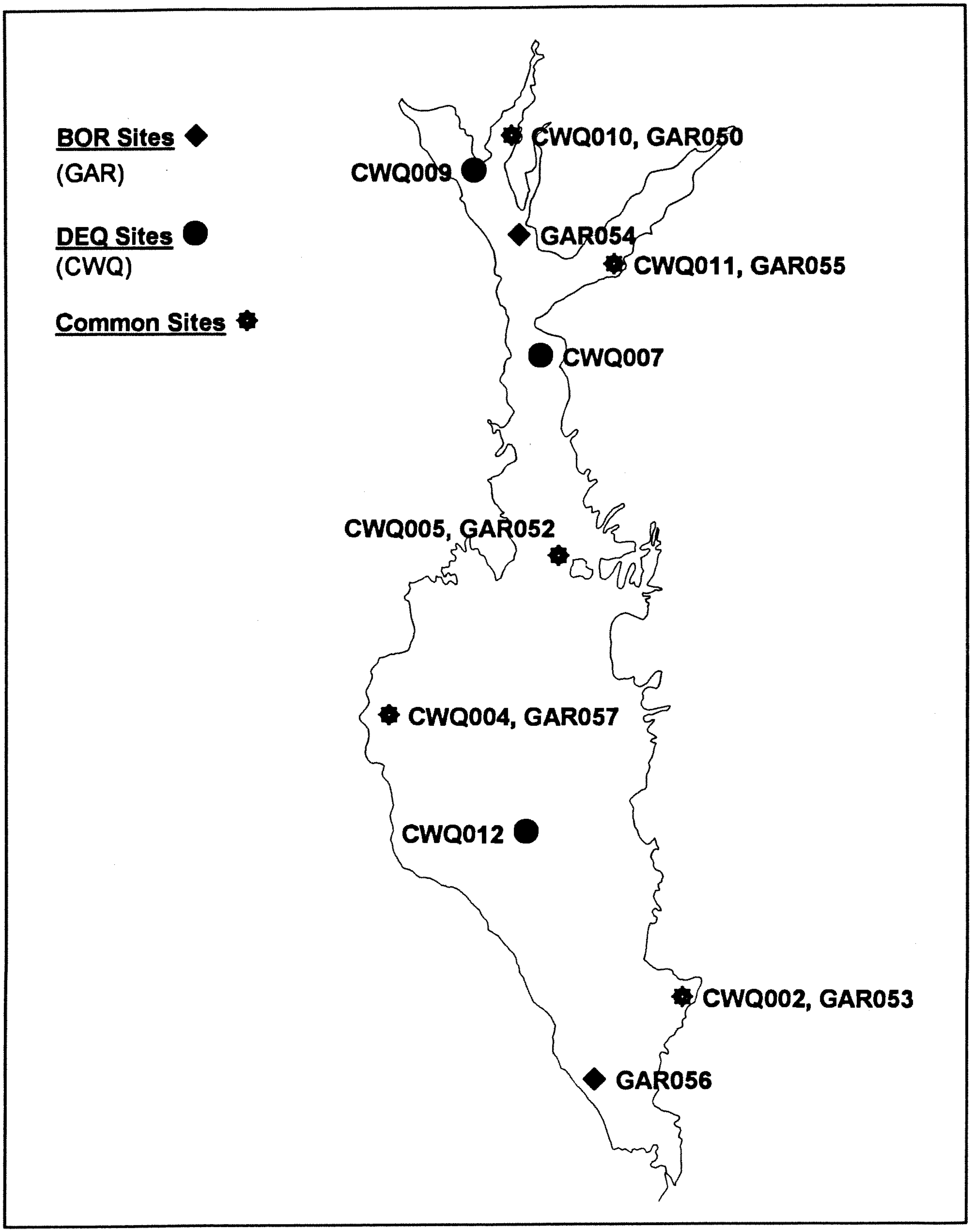


Figure 2 Location of in-reservoir monitoring sites for Cascade Reservoir.

Determining nutrient levels in the reservoir establishes baseline conditions, phosphorus storage and recycling capacity information for reservoir model development. Measuring the oxygen and temperature levels provides the information necessary to determine when the lake is stratified and when it is mixed. Winter dissolved oxygen is measured periodically during the months when ice covers the reservoir as an assessment of winter fish habitat and potential oxygenation levels of reservoir water at ice-out.

Constructed Wetlands/Detention Ponds

In 1995, six wetlands (see Figure 2.12, Cascade Reservoir Phase II Watershed Management Plan) were constructed by DEQ and BOR . Each of the wetlands has a variable quality of source water, retention time and different design characteristics as dictated by the local topography.

The created wetland project was initiated to evaluate the practical feasibility and effectiveness of using wetlands as management practices to improve water quality and provide habitat benefits in the Cascade Reservoir watershed. Since wetland characteristics can vary considerably according to site conditions and mechanisms, information derived from real wetland projects is essential in developing realistic criteria for undertaking wetland projects at other sites and to determine appropriate methods to integrate wetlands as part of coordinated, long-term watershed management plans.

The wetland investigation utilizes small wetland systems that were constructed to intercept water from tributary streams and overland inflows near Cascade Reservoir. Wetland sites were established by using fairly simple, inexpensive construction methods and by adapting the design approach and system configuration according to the conditions at each site. Characteristics of the selected sites represent distinct water management strategies and techniques that could be applied either at a larger scale or at other locations in the contributing watershed area.

Monitoring of the wetlands for nutrient and sediment removal as well as other parameters is being conducted over a three year hydrologic cycle (October-September) with timing specific to the construction of each designated site. Monitoring is designed to quantitatively determine reduction in the export of phosphorus and sediments using a paired upstream and downstream sampling technique. The three year design is necessary to segregate transient changes in nutrient uptake efficiency resulting from construction/disturbance and more stable post-construction conditions. The three years allows vegetation to become established and also accounts for normal, seasonal variations in inflow and outflow volumes. A project report will be prepared at the end of the third year to summarize the wetland water-quality transformation processes, estimate phosphorus and sediment removal and characterize habitat associated with the created wetlands.

Monthly or biweekly monitoring is scheduled during the summer months of each water year for the parameters shown in Table 2, with the addition of chlorophyll a monitoring. Flow, pH, conductivity, temperature and dissolved oxygen are measured at each inflow and outflow site. Appropriate quality assurance measures including blanks, spikes and duplicate sampling are included in all monitoring performed.

Annual sediment deposition is measured using sediment traps or cross-section surveys to estimate the amount of sediment deposited within the wetlands. Phosphorus associated with this deposited sediment can be estimated by phosphorus fraction techniques.

Soil and Sediment Analyses

Studies of Cascade Reservoir have identified sediment bound phosphorus as an important source of this limiting nutrient (EPA, 1977; Zimmer, 1983; Entranco, 1991; Chapra, 1990). Efforts to measure and quantify phosphorus sources and distribution of sediments have been conducted (Worth, 1993) to enhance accuracy and utility of a simulation model previously developed for Cascade Reservoir (Chapra, 1990; Worth, 1997). Ongoing studies will provide a direct measure of the quantity and form of phosphorus available in the sediments of Cascade Reservoir.

Watershed Soil Monitoring. Soil erosion estimates were initially made by the U.S. Soil Conservation Service based on a field survey in 1988. This survey focused on some of the larger tributary rivers to Cascade Reservoir. Additional data on rates of erosion have since been collected by USFS studies for Gold Fork, West Mountain and southern North Fork Payette River subwatersheds since this initial survey. Potential phosphorus loads associated with these sediments were quantified to the extent possible.

Further studies have been undertaken by DEQ (Worth, 1993) to analyze the phosphorus content of surface soils representing the major soils series (Rasmussen, 1981). Major soil series of interest include Archabal, Gestrin, Roseberry, Donnel and Melton. Submerged soils, soils collected from stream cross sections, and reservoir sediment samples were collected for comparison of their phosphorus content with surrounding soils in the watershed.

Watershed soil phosphorus content was evaluated by both USFS and DEQ monitoring personnel. Soil-type to soil-type phosphorus content was not found to be statistically different, as the sample to sample variability was high. The only significant differences identifiable for soil phosphorus content within the watershed was between the A and C horizons sampled. The A horizon soils showed significantly higher concentrations of both bioavailable and total phosphorus (4.9 and 617 mg/kg of soil, respectively), than the C horizon soils (2.5 and 417 mg/kg of soil, respectively). Stream bottom sediments showed phosphorus levels that were 50% (average) lower than the C horizon soils, indicating that fine particles with high levels of adsorbed phosphorus are preferentially transported in stream flow once sediment enters the channel. Stream bottom sediments from the western side of the reservoir showed significantly higher levels of both bioavailable and total phosphorus than those collected on the eastern side of the watershed (Gold Fork River). It can be observed from these studies that total phosphorus levels are commonly orders of magnitude higher than the related bioavailable phosphorus levels, with bioavailable phosphorus accounting for between 1.0 and 0.1% of the total phosphorus associated with the sediment.

In-reservoir Sediment Monitoring. To determine levels and distribution (both spatial and depth) of phosphorus within reservoir bed-sediments, sediment samples were collected from over 40 sites within the reservoir. Samples were collected in 10 cm depth-increments that ranged from the surface (0-10 cm) to 40-50 cm (total sediment depth). Available data show that phosphorus concentrations decrease with increasing depth. The greatest phosphorus concentrations are distributed within the top 10 cm of the reservoir bed sediments. Both the total phosphorus and the bioavailable phosphorus data echo this trend, indicating that deeply buried sediments do not represent a significant source of total or bioavailable phosphorus for the overlying water column. The most logical explanation for this trend is that the available or loosely-bound ortho-phosphate within the older (deeper) sediments has already leached to the water column, leaving the lower sediment layers somewhat depleted of available ortho-phosphate relative to sediments that were deposited more recently. Sediment phosphorus distribution was observed to be relatively static across the reservoir.

Local soil characteristics and erosion of surface materials can have a significant impact on the phosphorus loading rates of a watershed. Sediment bound phosphorus may contribute more than 60% of the estimated phosphorus load to Cascade Reservoir. Efforts to reduce phosphorus should be targeted only to those areas where phosphorus loads exceed the natural levels contributed by soils.

References:

Chapra, S.C.; 1990; *A Mathematical Model of Phosphorus, Chlorophyll a, Oxygen and Water Clarity for Cascade Reservoir*; Center for Advanced Decision Support for Water and Environmental Systems, University of Colorado, Boulder, Colorado; Final Report to Entranco Engineers, Inc. and Idaho Department of Health and Welfare; 70 p.

Clark, W.H.; Wroten, J.W.; 1975; *Water Quality Status Report: Cascade Reservoir, Valley County, Idaho*; Water Quality Series No. 20; Idaho Department of Health and Welfare, Division of Environment, Boise, Idaho; 46p + appendix.

Entranco Engineers, Inc.; 1991; *Cascade Reservoir watershed project water quality management plan;* Prepared for Idaho Department of Health and Welfare, Division of Environmental Quality; 101 p + appendices.

Environmental Protection Agency; 1975; *National eutrophication survey method, 1973-1976*; Working Paper No. 175; National Environmental Research Center; Corvallis, Oregon.

Environmental Protection Agency; 1977; *Report on Cascade Reservoir, Valley County, Idaho*; Working Paper No. 777; U.S. Environmental Protection Agency; Corvallis, Oregon; 44 p.

Environmental Protection Agency; 1991; *Guidance for Water-Quality Based Decisions: The TMDL* Process; EPA 440/4-91-001; U.S. Environmental Protection Agency; Washington D.C.; 58 p.

Ingham, M.; 1992; *Citizen's Volunteer Monitoring Program, Cascade Reservoir, Valley County, Idaho 1988-1991*; Water Quality Status Report No. 103; Idaho Department of Health and Welfare, Division of Environmental Quality, Boise Regional Office; Boise, Idaho; 17p + attachments.

Ingham, M.; Boyle, L.; 1991; *North Fork Payette River Valley County, Idaho 1988*; Water quality status report no. 97; Idaho Department of Health and Welfare, Division of Environmental Quality, Water Quality Bureau; Boise, Idaho; 35 p.

Klahr, P.C.; 1989; *Cascade Reservoir, Valley County, Idaho 1988*; Water Quality Status Report No. 85; Idaho Department of Health and Welfare, Division of Environmental Quality, Water Quality Bureau, Boise; Idaho; 12p + appendix.

Klahr, P.C.; 1988; *Lake Irrigation District Survey and Cascade Reservoir Tributary Assessment, Valley County, Idaho 1988*; Water Quality Status Report No. 79; Idaho Department of Health and Welfare, Division of Environmental Quality, Water Quality Bureau, Boise, Idaho; 46p.

Lappin, J.L.; Clark, W.H.; 1986 (December); *An Assessment of Water Quality Impacts of Recreational Housing and Livestock Grazing in the Cascade Reservoir Watershed*; Journal of the Idaho Academy of Science; Volume 22; Number 2; pp 45-62.

Rasmussen, L.M., 1981; *Soil Survey of Valley Area Idaho*; U.S. Department of Agriculture, Soil Conservation Service; Boise, Idaho; 146 p.

Worth, D.; 1995; *Coordinated monitoring plan for implementation of a TMDL allocation on Cascade Reservoir and contributing watersheds*; Idaho Department of Health and Welfare, Division of Environmental Quality, Southwest Regional Office; Boise, Idaho; 46 p.

Worth, D.; 1993-1994; *Cascade Reservoir and tributary water quality data*; Unpublished data; Department of Health and Welfare, Division of Environmental Quality; Boise, Idaho.

Zimmer, D.W.; 1983 (August); *Phosphorus Loading and Bacterial Contamination of Cascade Reservoir, Boise Project, Idaho*; Boise Project Power and Modification Study; USDI, Bureau of Reclamation, Pacific Northwest Region, Boise, Idaho; 143p.

Appendix F

Best Management Practices and Current Implementation Measures for the Cascade Reservoir Watershed

Appendix F. Best Management Practices and Current Implementation Measures for the Cascade Reservoir Watershed

BMPs are measures or a combination of measures that have been determined to be the most effective and practical means of preventing or reducing contamination to ground water and/or surface water pollution from point and nonpoint sources. The objective in implementing BMPs is to achieve water-quality goals and protect the beneficial uses of the water body.

Implementation of BMPs and other pollution control measures is the most significant step in the achievement of water-quality objectives within the reservoir and the support of beneficial uses. The phased TMDL process for Cascade Reservoir is unique in that implementation of pollutant control projects was initiated concurrently with the assessment of annual load and the drafting of the watershed management plan. In this respect, steps toward the solution of water-quality problems were taken before a firm, quantitative definition of the reductions necessary were in place. While this may have resulted in some inefficiency initially, it has doubtless reduced the overall time frame required for attainment of water-quality objectives within the watershed.

Local participants in water-quality management projects have shown extraordinary commitment to improving conditions within the reservoir and watershed. Many major, and countless smaller projects have been completed to date. Many others are currently in progress or pending. It is hoped that the current pace of implementation will be accelerated or (at minimum) maintained with the development of the formal implementation plan. This plan is currently scheduled for completion within 18 months of the approval of the Cascade Reservoir Phase II Watershed Management Plan.

Efforts to restore beneficial uses and meet water-quality objectives in Cascade Reservoir are based primarily on a cooperative watershed approach. This means that all the stakeholders within the watershed boundaries work cooperatively with DEQ, on a voluntary basis, to reduce phosphorus loads entering Cascade Reservoir, thus improving conditions for restoring beneficial uses and meeting water-quality objectives.

The identification of nutrient reduction projects is a critical step in the implementation process, one dependant upon local input and experience in order to operate efficiently. Projects to date have been identified by a number of organizations and individuals representing a variety of land-use activities. Specific projects involve the following practices:

- Streambank erosion control/restoration
- Irrigation pumpback systems
- Reservoir shoreline erosion control
- Stormwater management
- Irrigation upgrades (from sub-flood/gravity to sprinkler)
- Canal/ditch delivery upgrades
- Wetland construction
- Sediment pond settling and removal
- Sediment erosion control

When projects are identified they are referred to the appropriate agencies for possible funding.

Implementation of these practices is expected to reduce phosphorus entering the reservoir by reducing phosphorus entering drainage systems, reducing sediment erosion, and filtering and settling irrigation water. Instream monitoring will document the overall effectiveness of these practices to reduce phosphorus loading. It should be noted that implementation depends on the cooperation of the affected landowner and availability of funding. Some of the activities are more cost effective than others and DEQ anticipates implementation of the more cost effective projects first, although again this depends on landowner participation.

The process to control nonpoint source pollution is identified in the Idaho Water Quality Standards and Wastewater Treatment Requirements (Section 350). Nonpoint source activities are required to operate according to state approved BMPs or, in the absence of approved BMPs, activities must be conducted using "knowledgeable and reasonable efforts to minimize water-quality impacts" (Subsection 350.02.a). If monitoring indicates a violation of standards despite use of approved BMPs or knowledgeable and reasonable efforts, then BMPs for the nonpoint source activity must be modified by the appropriate agency to ensure protection of beneficial uses (Subsection 350.02.b.ii). This process is known as the "feed back loop" in which BMPs or other efforts are periodically monitored and modified if necessary to ensure protection of beneficial uses.

DEQ has been and will continue working with the CRCC, TAC, source-plan work groups and other state, federal and local agencies to identify nutrient control projects for implementation. In addition, local governments and citizens have initiated a variety of nutrient control projects such as upgrading sewage treatment facilities and establishing new sewer districts. This appendix summarizes the projects that are currently being planned or implemented.

The following sections on recommended BMPs and implementation measures to date are divided into the identified nonpoint source categories of forestry, agricultural, and urban/suburban land use. While intended to represent currently recommended and utilized BMPs, these lists should not be interpreted as exhaustive or all-inclusive. Knowledgeable and reasonable efforts to achieve water-quality objectives should be employed by all pollutant sources. Existing BMP options and practices should be updated as new information, practices and technology become available.

Appendix F-1 (Forestry)

Recommended Forestry BMPs

1. **Logging Roads**
    - Standards and Use
    - Planning, Design and Location
    - Construction and Drainage
    - Maintenance and Closure

2. **Streamside Management**
    - Streamside Protection Zone (SPZ) Boundaries
    - Harvesting within SPZs
    - Conifer Regeneration
    - Idaho Stream Protection Rules

3. **Timber Harvesting**
    - Harvest System Design
    - Site Preparation Drainage
    - Reforestation Requirements
    - Winter Requirements

4. **Hazardous Substances Requirements**
    - Pesticides
    - Herbicides

5. **Stream Crossings**
    - Legal Requirements
    - Design
    - Installation

Appendix F-1(Forestry)

Forestry Implementation Measures In-Progress/Pending

Roads and Timber Harvest

The effectiveness of the approved BMPs in relation to ***phosphorus*** as a nonpoint source has not been well established through monitoring. Table 1 lists examples of sediment-reduction BMP's for roads.

Table 1 Examples of Sediment BMP Effectiveness for Roads

Area Treated Treatment	Percent Sediment Reduction	Treatment Cost	Cost Effectiveness (tons/$1000.00)	Reference
Road Cut/Fill Slopes				
Hydro mulch Road cut/fill slope	30%	$850/ac	2.10	Burroughs & King (1989)
Slash filter & windrow Hydro mulch Road cut slope	84%	$1,350/ac	4.00	Burroughs & King (1989)
Slash Filter windrow Hydro mulch Road fill slopes	97%	$5,176/ac	1.16	Burroughs & King (1989) Cook & King (1983)
Timbered grid structure	90%	$18,000/ac	0.62	Unpublished Report - Cascade/Krassel RD
Road Surface/Prism				
Dust Abatement - oil	85%	$.50/linear ft	n/a	Burroughs & King (1989)
4 inch Gravel	92%	$7.58/linear ft	n/a	Foltz & Truebe (1994)
Asphalt Paving	97%	$23.50/linear ft	n/a	Burroughs & King (1989)
Armor Ditch Line	92%	$4.96/linear ft	n/a	Burroughs & King (1989)
Road Closure				
Road closure	75%	$2.00/linear ft	n/a	Harvey & Burton (1991)
Road Decommission	n/a	$1.07/linear ft	n/a	Harr & Nichols (1993)

Road improvements on USFS land can be accomplished in three ways: associated with timber harvest, general road maintenance, or outside funding such at a 319 Grant. Future timber sale plans have the opportunity to focus on treatment of existing road sediment sources and follow BMPs during new construction. General road maintenance funding is limited and declining within the USFS lands, but each Forest can prioritize road maintenance activities on an annual basis. Boise Cascade Corporation regularly maintains forest roads and has made a commitment to actively improve road systems.

(County road management is discussed in the Urban/suburban section of this appendix, Section F-3.)

Grazing on Forested Lands

Best management practices (BMPs) for grazing are the same practices used by the Agricultural Source Plan. Tier 1 lands (riparian areas adjacent to streams) and Tier 3 lands (uplands not irrigated) are the two categories that occur on forested lands. Some BMPs that could be used to reduce phosphorus input include, but are not limited to:

- Grazing management plans
- Off-site water developments
- Decreased riparian area use to reduce bank erosion
- Decreased access to stream channel

Schedule

Forest landowners in the Cascade Reservoir watershed have been implementing sediment reduction activities since 1994. A schedule of recent and on-going activities is summarized in Table 2 below. In the 1997 fiscal year, the Forestry Sub-Committee of the TAC received a Section 319 Grant from EPA/DEQ for $100,000 for further implementation of sediment/phosphorus reduction projects. These projects were implemented and monitored beginning in the Spring of 1997 in the Gold Fork River subwatershed.

Table 2 Implementation Schedule for Forestry Source Plan

Description	Location	Date	Funding Source (See Constraints)
Verify modeled road segments Complete BCC grazing plan	Gold Fork	1997	319 Grant (1997) or by ownership
Construction & implementation	Gold Fork	1997	319 Grant (1997) or by ownership
Verify modeled road segments and other sources	All other watersheds	1998	319 Grant (1998-99) or by ownership
Construction & implementation	All other subwatersheds	1998-2005	319 Grant (1998-99) or by ownership
Check on progress & schedule	All subwatersheds	2000-2005	All Managers
Monitoring	Gold Fork All Other All Subwatersheds	1997 1998-99 1997-2005	319 Grant (1997) 319 Grant (1998-99) or by ownership

Higher priority will be given to areas that have the greatest potential for reduction in sediment. An additional benefit of the projects will be improvement of bull trout habitat in the headwaters of the Gold Fork River and improvement of other fish habitat in all tributary waters. Maintenance and road improvement projects will be the responsibility of individual land owners.

Revision of the Boise National Forest, Cascade Reservoir Allotment occurred in 1993/1994. The allotment is located along the toe-slope of West Mountain on the west side of the reservoir. The Allotment Management Plan was revised into a rest-rotation system with other BMPs. Revision of the Boise Cascade Corporation, Gold Fork grazing permit has been completed and implemented in 1998. The revision includes a modification of the grazing plan.

Implementation Constraints by Ownership

All land owners place a high priority on implementation of projects that treat sources of sediment/phosphorus within the Cascade Reservoir watershed. Each ownership will place a high priority on treatment of identified sources as funding becomes available but the following constraints are realistic parameters that must be considered during the implementation phase.

Boise Cascade Corporation. Improvements on Boise Cascade land are not subject to any approval process. Implementation, however, is subject to availability of funds. Boise Cascade annually budgets funds for road improvements and improvements in Cascade Reservoir will be given high priority. Maintenance of other Boise Cascade roads will, however, be necessary and can affect the amount of effort expended in the Cascade Reservoir watershed. In particular, major storm events that take out many roads may necessitate giving maintenance and repair of storm-impacted roads precedence over refinements in the Cascade Reservoir road system. Although such activities may not benefit Cascade Reservoir, the activities will be necessary to provide access to company lands and to reduce sediment effects on aquatic resources in other basins.

Idaho Department of Lands. Funds for implementation come from two (2) sources both of which are tied to the harvest of forest products:

- Major improvements (i.e. bridges, graveling, surfacing, etc.) are appraised directly against the value of the timber harvested.
- Minor improvements and routine maintenance are funded through a deferred maintenance account which accumulates at a rate of 1% of the net value of all timber harvested.

Maintenance projects are prioritized on an annual basis and accomplished as funds are available. Since the Department has maintenance responsibilities outside the Cascade Reservoir watershed in any given year, all or none of the available funds may be exhausted elsewhere.

U.S. Forest Service - Boise and Payette National Forests. The Forest Service will continue to follow Land and Resource Management Plans to implement activities. Those activities include: timber harvest, road management, grazing, prescribed fire, watershed improvements, fish habitat improvements and others. The identification of sources of sediment/phosphorus, treatments and implementation of treatments will occur concurrently with activities. Activity plans are finalized and implemented as funds become available. Required NEPA and Endangered Species Act analyses will be necessary before implementation is possible. Scheduling of project implementation is determined by funding and priority on each Forest. Partnership and cooperative efforts will be developed on a project-by-project basis.

Appendix F-2 (Agriculture)

Recommended Agricultural BMPs

TIER 1 - RIPARIAN/WETLAND SYSTEMS

1. **Planned Grazing Systems - High Potential**
   - Deferred Grazing
   - Pasture and Hayland Management
   - Trough or Tank
   - Proper Woodland Grazing
   - Spring Development
   - Fencing
   - Proper Grazing Use, Riparian

2. **Planned Grazing Systems - Low Potential**
   - Deferred Grazing
   - Fencing
   - Heavy Use Area Protection
   - Proper Grazing Use, Riparian
   - Spring Development
   - Pasture and Hayland Management
   - Trough or Tank
   - Proper Woodland Grazing
   - Nutrient Management
   - Pest Management

3. **Non-Grazing Systems - High Potential**
   - Fencing
   - Livestock Exclusion
   - Spring Development
   - Trough or Tank

4. **Non-Grazing - Low Potential**
   - Fencing
   - Livestock Exclusion
   - Spring Development
   - Trough or Tank

5. **Structural Systems**
   - Grade Stabilization Structures
   - Streambank and Shoreline Protection
   - Stream Channel Stabilization
   - Structures for Water Control
   - Channel Vegetation

6. **Vegetation Systems**
   - Streambank and Shoreline Protection
   - Stream Channel Stabilization
   - Channel Vegetation
   - Filter Strip
   - Ephemeral Watercourse Planting

7. **Wetland Development Restoration**
   - Wetland Development Restoration Pond
   - Structure for Water Control
   - Channel Vegetation
   - Filter Strip
   - Sediment Basin

8. **Waste Management and Handling**
   - Waste Management Systems
   - Waste Utilization

TIER 2 - LOWLAND: MOSTLY IRRIGATED CROP AND PASTURE LAND

1. **Grazing Systems**
   - Irrigation Water Management
   - Nutrient Management
   - Pest Management
   - Deferred Grazing
   - Fencing
   - Livestock Exclusion
   - Pasture and Hayland Planting
   - Pasture and Hayland Management
   - Planned Grazing Systems
   - Proper Grazing Use
   - Proper Woodland Grazing
   - Pond
   - Trough or Tank

2. **Cropland Systems**
   - Chiseling and Subsoiling
   - Conservation Cropping Sequence
   - Conservation Tillage
   - Critical Area Planting
   - Filter Strip
   - Irrigation Water Management
   - Nutrient Management
   - Pest Management
   - Irrigation Systems

3. **Non-Grazing Systems**
   - Fencing
   - Livestock Exclusion
   - Grade Stabilization Structures

4. **Irrigation Structures and Water Systems**
   - Diversion
   - Irrigation Pit/Regulating Reservoir
   - Irrigation Storage Reservoir
   - Irrigation Systems
   - Irrigation Water Conveyance
   - Pipeline

5. **Water Structure Systems**
   - Pond
   - Pipeline
   - Spring Development
   - Fencing
   - Trough or Tank

6. **Wetland Development Restoration**
   - Wetland Development Restoration Pond
   - Structure for Water Control
   - Channel Vegetation
   - Filter Strip
   - Sediment Basin

7. **Waste Management and Handling**
   - Waste Management Systems
   - Waste Storage Pond or Structure
   - Waste Utilization

TIER 3 - UPLAND GRAZING LAND: MOSTLY NON-IRRIGATED

1. **Planned Grazing Systems**
   - Pasture and Hayland Management
   - Pasture and Hayland Planting
   - Planned Grazing Systems
   - Proper Grazing Use
   - Proper Woodland Grazing
   - Nutrient Management
   - Pest Management
   - Fencing
   - Pond
   - Trough or Tank
   - Stock Trails and Walkways
   - Livestock Exclusion

2. **Cropland Systems**
   - Chiseling and Subsoiling
   - Conservation Cropping
   - Conservation Tillage
   - Critical Area Planting
   - Filter Strip
   - Irrigation Water Management
   - Nutrient Management
   - Pest Management
   - Irrigation Systems

3. **Non-Grazing Systems**
   - Grade Stabilization Structures
   - Brush Management
   - Range Seeding
   - Pasture and Hayland Planting
   - Nutrient Management
   - Pest Management

4. **Water Structures Systems**
   - Pipeline
   - Pond
   - Spring Development
   - Stock Trails and Walkways
   - Trough or Tank
   - Fencing

5. **Waste Management and Handling**
   - Waste Management Systems
   - Waste Storage Pond or Structure
   - Waste Utilization

RANCHETTE ACREAGES

1. **Planned Grazing Systems**
   - Pasture and Hayland Management
   - Pasture and Hayland Planting
   - Planned Grazing Systems
   - Proper Grazing Use
   - Proper Woodland Grazing
   - Nutrient Management
   - Pest Management
   - Fencing
   - Pond
   - Trough or Tank
   - Stock Trails and Walkways
   - Livestock Exclusion

2. **Non-Grazing Systems**
   - Grade Stabilization Structures
   - Brush Management
   - Pasture and Hayland Planting
   - Nutrient Management
   - Pest Management
   - Fencing
   - Livestock Exclusion

3. **Cropland Systems**
   - Chiseling and Subsoiling
   - Critical Area Planting
   - Filter Strip
   - Irrigation Water Management
   - Nutrient Management
   - Pest Management
   - Irrigation Systems

4. **Irrigation Structures and Water Systems**
   - Diversion
   - Irrigation Pit/Regulating Reservoir
   - Irrigation Storage Reservoir
   - Irrigation Systems
   - Irrigation Water Conveyance
   - Pipeline

5. **Water Structure Systems**
   - Pond
   - Pipeline
   - Spring Development
   - Fencing
   - Trough or Tank

6. **Wetland Development Restoration**
   - Wetland Development Restoration Pond
   - Structure for Water Control
   - Channel Vegetation
   - Filter Strip
   - Sediment Basin

7. **Waste Management and Handling**
   - Waste Management Systems
   - Waste Storage Pond or Structure
   - Waste Utilization

Appendix F-2 (Agriculture)

Agricultural Implementation Measures In-Progress/Pending

For agricultural activities there are no required BMPs. Consequently, agricultural activities must use knowledgeable and reasonable efforts to achieve water-quality objectives. Generally, voluntary implementation of BMPs would be considered a knowledgeable and reasonable effort. A list of recommended BMP component practices, which when selected for a specific site become a BMP, has been published in the Idaho Agricultural Pollution Abatement Plan (1991). To facilitate use of these practices, the state formerly provided cost share incentives through the State Agricultural Water Quality Program (SAWQP). SAWQP projects were directed at improving water quality through control of nonpoint source pollution at the subwatershed level using BMPs developed by the NRCS. Cost share funds were dispersed to private landowners through local Soil Conservation Districts. Contracts with landowners required that BMPs be implemented for 10 years, but changes in management practices should provide longer term benefits.

Although SAWQP funding is no longer available, the VSWCD previously developed and implemented SAWQP projects in three of the critical drainages of Cascade Reservoir: Boulder Creek, Willow Creek, and Mud Creek, which comprise roughly 18% of the total watershed draining to Cascade Reservoir. An implementation plan was developed for each drainage, outlining the critical acres contributing nutrients and sediment to local streams based on the erosion potential of soils (VSWCD, 1991). Priority was given to implementation of BMPs that reduce phosphorus. A summary of the projects planned or implemented as of May 1998 follows. Table 3 summarizes BMPs selected within each drainage area.

The Boulder Creek SAWQP project was initiated in 1991, and established a goal of reducing phosphorous loading from agricultural sources by 50%. This was to be accomplished by treating 6,826 critical acres with BMPs. Critical acres in a state agricultural water-quality project are defined as those areas where BMPs should be implemented to improve water quality. Implementation of agricultural BMPs is voluntary and generally requires a cost share match by the local landowner. In the recent past it has taken several years to negotiate, design, approve and fully implement BMPs. Cooperative agreements with DEQ provide evaluation of BMP effectiveness.

The Willow Creek and Mud Creek SAWQP were initiated in 1995 and were established with the goal of reducing phosphorus loading from agricultural sources by 50%. This involved treating 8,526 critical acres in Mud Creek and 1,411 critical acres in Willow Creek. Additional projects are needed to address agricultural practices in the Lake Fork Creek, Gold Fork River, North Fork Payette River and Cascade subwatersheds.

With the cancellation of the SAWQP project, alternative funding sources are being pursued. Potential funding sources may be tied to creation or protection of riparian areas or wildlife habitat, irrigation improvements for greater conservation of available water supplies, and others.

Table 3 VSWCD Agricultural BMPs Planned or Implemented as of October 1995

BMPs	Units Planned or Implemented		
	Boulder Creek	Mud Creek	Willow Creek
Chiseling, subsoiling (ac)	155	574	
Critical Area Planting (ac)	7		
Channel Vegetation (lf)			500
Conservation Cover (ac)	28		
Conservation Tillage (ac)		499	
Conservation Cropping Sequence (ac)		539	10
Deferred Grazing (ac)	45		
Fencing (lf)	17,300	6,900	9,200
Fertilizer Application (ac)	250	1,062	
Heavy Use Area Protection (ea)	3	4	2
Irrigation System Sprinklers (ac)	278	3676	341
Irrigation Water Conveyance (lf)	20,250	142,727	12,500
Irrigation Water Management (ac)	135	4,271	260
Liming (ac)	176	1,566	
Livestock Exclusion (ac)	235	4	24
Nutrient Management (ac)	425	1,566	
Soil Tests (ea)	16	46	
Spring or Water Development (ea)	3	39	
Pasture and Hayland Management (ac)	498	5,057	106
Pasture and Hayland Planting (ac)	205	1,722	
Planned Grazing Systems (ac)	169	288	
Proper Grazing Use (ac)	46		511
Ponds (ea)	4	1	
Water Control Structures (ea)	5	2	1
Woodland Improvement No Cost Share (ac)	43		
Wildlife Wetland Habitat Management No Cost Share (ac)	7		

Appendix F-3 (Urban/Suburban)

Recommended Urban/Suburban BMPs

Urban/suburban land-use sources fall into three separate categories: stormwater runoff, septic/sewer sources and recreational activities.

Upgrading failing septic systems to meet required codes, or replacement of existing septic systems with sewer hookups are recommended practices for reduction of pollutant loads. Once replaced with sewer hookups, septic tanks should be pumped out and collapsed.

BMPs for both urban and recreational facility stormwater runoff are outlined in the following documents:

1) Technical Memorandum: *Stormwater Retrofit Options for Valley County* (1996)

2) Technical Memorandum: *Procedures and Recommendations for Subwatershed Prioritization of Stormwater BMPs* (1997)

3) *Handbook of Valley County Stormwater Best Management Practices* (1997)

For convenience, a short summary of each document follows.

Stormwater Retrofit Options for Valley County provides a list of applicable BMPs, prioritized retrofit projects, and other recommendations for improving both water quantity and water quality on a subwatershed basis. The scope of the project also includes ways of addressing existing practices and natural features, as well as anticipated future preventative measures. The identified options are based on a two-day field survey conducted in the spring of 1996 throughout the County. The retrofit options and recommendations were subdivided into five main categories: urbanized areas, agricultural areas, residences in surrounding hills, property located at waterside, and transportation corridors.

Procedures and Recommendations for Subwatershed Prioritization of Stormwater BMPs describes a process for prioritizing stormwater BMPs by subwatershed based on the prevailing and site suitable physical conditions. The document is considered a planning tool for assisting in the selection of the most cost effective BMPs by subwatershed. The prioritization procedure ranked BMPs on overall subwatershed characteristics. Final BMP selection is however, more dependent upon site-specific conditions. The technical memorandum concluded that most BMPs are applicable in various portions of all subwatersheds.

Handbook of Valley County Stormwater Best Management Practices is recognized as the technical reference for developers, contractors, design professionals, local agency officials and staff responsible for design, construction, maintenance or the review and approval of stormwater treatment facilities/devices. The BMPs that are contained in the Handbook are those considered appropriate for the physical and climatic conditions of Valley County. Also, the Handbook is a necessary companion for the two previously described technical memorandums.

The majority of BMPs contained in Chapter 4 of the Handbook pertain to controlling pollution at the source; Chapter 5 of the Handbook contains residential and commercial development source treatment measures (summarized in Tables 4 and 5). Source control measures focus on minimizing or eliminating the source of pollution so that pollutants are prevented from contacting runoff or entering the drainage system. Permanent or treatment control measures are designed to remove pollutants after being taken up by runoff.

Treatment controls tend to be more expensive than source controls. Time is the major cost factor associated with minimizing disturbance, preserving vegetation, and other site management measures. However, the cost factor associated with additional time for minimizing or preserving must be considered within context of reduced needs for costly treatment mitigation and operation and maintenance expenditures. For example, the sediment removal effectiveness of preserving native vegetation (BMP #3) and hence keeping phosphorus in place is 100 %.

Storm water management plans for new development should encourage sustaining pre-development runoff volumes through the use of source control BMPs. A local storm water management plan should focus not only on water quantity, but also *water quality*. Storm water management plans vary and include design strategies to protect sensitive open space areas, minimizing site disturbances, and using the land's natural treatment functions.

Existing site topography and vegetation can often be effective in naturally treating and disposing of volume and quality of stormwater runoff, when left undisturbed or intact as much as possible. Typically, non-disturbed dips and depressions within a site are able to collect and store water, coupled with the site's existing vegetation, that provides a filter function for both pollutants and sediment. This natural drainage system works jointly to also regulate water quantity. When a site's hydrology is altered by the loss or the compaction of topsoil; impervious coverage by paving, asphalting, or concreting; post-development drainage, if not controlled through either *source* or *treatment control BMPs,* causes increased runoff. It may not necessarily be the individual development site, but rather, the cumulative effect of numerous site developments that causes a greater volume, and hence, an impact to nearby and local water bodies.

Table 4 Permanent Controls, considerations and comparative cost and applicability taken from the Handbook for Valley County Stormwater BMPs (1997).

BEST MANAGEMENT PRACTICES		CONSIDERATIONS				COMPARATIVE COST & APPLICABILITY*			
No.	Name	Phosphorus Removal (>35% effective)	Sediment Removal (>70% effective)	Area Required	Water Availability	Relative Capital Cost per Acre Served	Relative O&M Cost*		Primary Treatment Mechanism(s)
							Routine	Non-Routine	
38	Vegetated Swale		X	X	X	low	low	mod	Sedimentation/ filtration
39	Vegetative Filter Strip		X	X	X	low	low	mod	Sedimentation/ filtration
40	Sand Filter	X	X			moderate	mod	mod	Sedimentation/ filtration
43	Infiltration Trench	X	X			low to mod	mod	high	Infiltration
44	Infiltration Basin	X	X	X		low to mod	low	mod	Infiltration
45	Wet Pond	X	X			moderate	low	mod	Sedimentation/ biological uptake
47	Wet Extended Detention Pond	X	X		X	moderate	low	mod	Sedimentation
48	Dry Extended Detention Pond			X		moderate	low	mod	Sedimentation/ biological uptake
49	Constructed Wetland	X		X	X	mod to high	high	high	Sedimentation/ filtration
52	Oil/Water Separator					high	low	high	Sedimentation/ infiltration

* Based on the Boise City Public Works Department: Stormwater BMPs Guidance, 1997.

Table 5 Construction/temporary controls, considerations, and comparative cost and applicability taken from the Handbook (1997).

BEST MANAGEMENT PRACTICES		CONSIDERATIONS				COMPARATIVE COST & APPLICABILITY*			
No.	Name	Phosphorus Removal (>35% effective)	Sediment Removal (>70% effective)	Slope Protection	Sediment Collection/ Runoff Diversion	Relative Capital Cost per Acre Served	Relative O&M Cost*		Expected Life based on Longevity Data from Handbook
							Routine	Non-Routine	
3	Preserving Existing Vegetation	X	X	X	X	low	low	low	Becomes Permanent
11	Mulching	X	X	X		moderate	mod	mod	6-8 Months
13/14	Geotextiles & Mats		X	X		high	mod	mod	6-8 Months
22	Check Dams		X			moderate	low	mod	½ -1 Year
24	Straw Bale Barrier		X		X	low	high	high	3 Months
25	Silt Fence		X		X	moderate	mod	mod	2-6 Months
26	Vegetative Buffer Strip		X		X	low	low	low	50 Years
27	Sediment Trap		X		X	low	mod	low	6-18 Months
30	Earth Dike		X		X	moderate	low	mod	2-25 Years
31	Perimeter Dike/Swale		X		X	moderate	low	low	18 Months

*Based on Boise City Public Works Department: Stormwater BMPs Guidance, 1997

Appendix F-3 (Urban/Suburban)

Urban/Suburban Implementation Measures In-Progress/Pending

Stormwater runoff management

Existing conditions suggest that urban land contributes a disproportionate load of phosphorus from a relatively small area of the landscape. Future development without planning and control measures in place will only increase pollutant loading. BMP devices, facilities and systems that are constructed should be selected based on suitable site conditions and targeted pollutant removal effectiveness. More significantly, BMP retrofit projects (summarized in Table 6) should be targeted for urban land and transportation components throughout the Willow Creek, Mud Creek, Cascade, and North Fork of the Payette River subwatersheds. In minimizing impacts to storm water runoff and protecting against further reservoir eutrophication, the selected BMPs should maximize the removal of nutrients from runoff and/or trapping of sediment in-place.

In an effort to address stormwater runoff issues on a watershed scale, the *Handbook of Valley County Stormwater BMPs* (1997) was prepared and has been adopted as a technical reference by resolution by Valley County, and by ordinance by the City of McCall. Applicable ordinances have either been updated or revised to encourage the use of the Handbook for storm water treatment control. Public education has increased substantially in the last two years with the publication of several information brochures (e.g., *User Guide to Reservoir Protection, Site Planning and New Construction Considerations for Water Quality*). Technical education for contractors: "Valley County Storm Water Pollution Prevention Training" has also occurred. The following items are recommended by the Urban/Suburban Sub-committee:

1. Estimate the cost-benefit ratio of potential retrofit options from the "Stormwater Retrofit Options for Valley County"; base prioritization on retrofitting McCall drainage basins 9, 11 and 13, and the cities Cascade and Donnelly. McCall drainage basins 9, 11 and 13, and the cities Cascade and Donnelly, are the greatest potential contributors of total phosphorus and suspended solids based on the current land uses. The greatest cost-benefit can be expected in the Willow Creek, Mud Creek, Cascade, and North Fork of the Payette River subwatersheds.

2. Encourage continued water-quality monitoring to document trends toward meeting water-quality standards. Revise the monitoring strategy and plan to better characterize nonpoint source loading contributed from McCall drainage basins 9, 11 and 13, and the cities Cascade and Donnelly. Future decisions to retrofit BMPs in drainage basins or catchments, believed to be contributing a greater amount of pollutant loading, can be more readily justified with water-quality data.

3. Improve county roads that are immediately adjacent or within the floodplain of Cascade Reservoir or any of its tributaries. Improvements on county roads should be based on a prioritized inventory of all public and private roads and highways. A comprehensive inventory was completed by the Valley County Engineer (1997). Many locations with erosion, predominantly those associated with unimproved roads, were observed during the inventory. Reducing sediment derived from nearby

Table 6 Potential Retrofit BMPs By Watershed

Category/Potential BMPs	Payette Lake	Lake Fork	N. Fork Payette	Mud Creek	Boulder Creek	Gold Fork	Willow Creek	West Side	Cascade
Urbanized Areas									
Stormwater Inlets	X				X			X	X
Wetlands/Swales									X
Ditch Maintenance	X				X			X	X
Construction Erosion Control	X	X	X	X	X	X	X	X	X
Addition Erosion Control	X	X				X			
Raised Roadways	X	X	X	X	X				
Clearing Limits	X	X	X	X	X	X	X	X	X
Wet Ponds	X	X			X	X			
Modify Culverts					X				
Bacterial Control	X								
Agricultural Areas									
Traditional Erosion Control				X	X	X	X		
Fencing			X	X	X		X	X	X
Revegetate				X	X		X		
Filter Strips				X	X	X	X		
Wet Ponds			X	X	X		X		
Ditch Maintenance					X	X	X		X

Table 6 Potential Retrofit BMPs By Watershed (continued).

Category/Potential BMPs	Payette Lake	Lake Fork	N. Fork Payette	Mud Creek	Boulder Creek	Gold Fork	Willow Creek	West Side	Cascade
Streambank Erosion			X	X	X		X		
Surrounding Hills									
Road Stabilization	X	X			X	X			
Slope Protection	X	X			X	X			
Topsoil Addition	X	X			X	X			
Detention Pond	X	X			X	X			
Waterside Property									
Filter Strips	X	X	X	X	X	X	X	X	X
Wetlands	X						X	X	X
Biofiltration Swales			X	X	X		X		
Road Stabilization	X							X	
Berms	X							X	X
Transportation Corridors									
Old State Highway							X		
Street Sweeping	X			X	X		X	X	X
Bridge Maintenance			X	X	X				

roadways would ultimately decrease the amount of sediment loading to the reservoir.

4. Encourage the sewering of the South Lake Recreation and Sewer District or the West Mountain subdivisions. Many of the developed parcels and, hence, their respective septic tank systems in the West Mountain subwatershed are pre-1985 and are out of compliance. Reduced septic tank effluent from pre-1985 septic systems would decrease waste loading to Cascade Reservoir.

5. Support the City of Donnelly facilities plan for the wet-extended detention basin project IF properly designed for a water-quality design storm. Donnelly has the potential to contribute to further surface water-quality impacts to Cascade Reservoir due to its close proximity. A large-scale detention basin would benefit the watershed since it would detain storm water runoff from the city, as well as from the agricultural runoff from adjacent and up-gradient fields.

Preventing Future Impacts

The Handbook should serve as a means of implementing consistent, county-wide site design treatment considerations. As public awareness increases, a broader public acceptance should follow. Rising public awareness can only occur through additional technical education for contractors, developers and land owners. The cities should be proactive and encourage more comprehensive strategies for storm water planning and management. The strategy for preventing future impacts consist of three components. The following items are recommended by the Urban/Suburban Sub-committee:

1. Encourage municipalities throughout Valley County to implement development design strategies that are source-control oriented (i.e., on-site detention program, minimizing directly connected impervious areas, site fingerprinting, local urban forestry, etc.). It is not the individual site development, but rather, the cumulative effect that generates runoff volume during a storm event. Through design, the natural and landscaped site drainage system can work effectively to soak, filter and temporarily pond precipitation. The site drainage system withdraws a small share of the potential cumulative whole, keeping it from running off-site. For example, local on-site detention programs require developers and land owners to manage storm water runoff on commercial, industrial, and often high-density residential sites. These local programs protect water quality through advocating and enforcing when necessary, the assurance that rates of post-development runoff from a given site do not exceed the rate of pre-development runoff.

2. Encourage the adoption of a county-wide erosion and sediment control ordinance that includes provisions for performance standards that allow for a combination removal of both total phosphorus and total suspended solids. Performance standards for removal effectiveness should at least exceed 30% total phosphorus and 70% total suspended solids. Suspended solids cause many problems for water quality in addition to increasing concentrations of total phosphorus in the water column. Also, total suspended solid is a much easier constituent to monitor and the improvement to water moving through a treatment measure will literally be visible to the public. Reduction of suspended solids in runoff will result in broader improvements in water quality because BMP selection will not only be driven by total phosphorus removal effectiveness.

3. Municipalities throughout Valley County should encourage the set aside and/or donation of sensitive lands that possess intact riparian vegetation, 'classified' wetlands, steep slopes, and areas of highly erodible soil types. The varying natural environment includes many areas of the landscape that are well suited for intensive urban development. There are however, other areas which have a low tolerance for this same type of intensive development. These "sensitive" parts of the landscape, when radically altered, lose their function as natural collection, filtering and storage systems. Kept intact, the natural landscape provides these several functions free of charge to society. If properly accounted for early in the design process, sensitive open space can be used as natural treatment areas for adequately dispersed runoff from impervious surfaces such as pavement, asphalt, concrete, compacted soils and rooftops.

Valley County Road and Drainage Management

The Valley County Road Department (the County) currently manages approximately 430 miles of public road. Two hundred, twenty-five (225) miles of road managed by the County are located within the Cascade Reservoir watershed.

Maintenance priorities are based on traffic volumes and safety. Priorities in descending order according to classification are: school bus routes; principle routes; and other roads. The County has been conducting traffic volume counts at 172 locations for more than seven years and are now conducting speed studies at selected locations. That data can provide the basis for setting maintenance priorities. The Road Department is developing a computerized road surface management system. That system will expand the parameters used to set future maintenance priorities to include roadway and roadside conditions and efficiency in investing maintenance dollars. All of the routes with a current average traffic volume in excess of 200 vehicles per day are paved. That includes all the major and minor connectors and other principle routes. Only 30% of the publicly maintained roads are paved.

The County has developed a strategy for improving roads surfaced with aggregates and native materials. Gradient and terrain are parameters used in addition to traffic volume and safety for setting priorities to upgrade those roads. Crushed rock materials 3-4 inches deep are added where road gradients exceed 5% or where the road is locating in rolling terrain with cut banks and fill slopes along the road. The scope of this annual work is limited to availability of personnel, equipment, materials and finances.

The Road Department also maintains the drainage system along public roads. Their policy is to keep the water off the road surface, prevent it from traveling along the side of the road, and to allow surface waters to follow natural swales without diversion. The maintenance of the drainage system is limited to the jurisdictional limits of the right of way.

Keeping the road surfaces in good condition with frequent blading, limiting or eliminating snow removal on certain roads, limited use of sanding materials, and limited use of dust abatement products rounds out the picture of current maintenance practices.

Improving road surfaces with asphalt or crushed rock contributes to the goals of phosphorus removal. The Department's primary concern must remain on traffic and safety. Forty percent (40%) of the Department's system is outside of the Cascade Reservoir watershed. Those roads compete equally for the available maintenance funds. There are no funds available for improving low priority roads with projects aimed solely at phosphorus reduction. Valley County has submitted a proposal for 1999 319 Grant funding to surface and improves roads in the immediate vicinity of Cascade Reservoir. Roads that will be improved if funded are those identified as contributors of significant phosphorus through sediment transport during snow-melt and storm events.

The Valley County Road Department is supported by the Highway User Fund and proceeds from the U.S. Forest Service. The USFS proceeds have been the primary source of funds but they are declining. Road maintenance will likely also decline unless supplementary financial resources are developed.

Valley County has been involved in the development of the *Handbook of Valley County Stormwater Best Management Practices* (1997) with the Urban/Suburban Work Group. This Handbook has not yet been accepted by the County as an ordinance to address the TMDL for new building and road developments. This Handbook is available for use. The hope is that the TMDL issue will be addressed in the County Comprehensive Plan and in the future through ordinances.

Septic/sewer Upgrades

A number of septic and sewer improvement projects have been undertaken within the watershed. The North Lake Recreational Sewer and Water District was formed and is currently providing sewer service to over 500 subdivision residences aggregated around the north end of the reservoir, identified as a significant source of concern in Phase I. By mid-1998, additional residences are expected to be connected to sewer and disconnected from their septic tanks. The North Lake Sewer District connections expect to contribute a 38% *reduction* from the revised Phase I estimate. Table 7 shows the predicted loading reductions given the proposed septic-to-sewer conversions scheduled for 1998.

A second sewer district has been proposed for the southwest shore and is currently seeking sources of funding to establish service. The southwest location has a high ground-water table, evidence of ground-water contamination, a high density of septic tanks and poor soil types.

The City of McCall has installed new and upgraded existing sand filters within existing treatment facilities. In addition, the J-Ditch project, currently in progress, represents a major step in the eventual, 100% removal of the McCall wastewater treatment plant effluent from the NFPR called for in the Phase I document. This project will allow treated effluent from the City of McCall to be mixed with "clean" water and applied at agronomic rates to pasture and crop land during the summer irrigation season. Additional effluent collected during non-irrigation season months will be retained in storage lagoons constructed by the City of McCall. Stored effluent will be land-applied the following irrigation season. Currently, the system as designed will be able to remove all treated effluent from the NFPR during the irrigation season. Work on the winter storage lagoons is on-going. Total (100%) removal of treated effluent from the NFPR will be possible with the completion

Table 7 Sewer Upgrade Total Phosphorus Load Reduction Estimate

	Name	# Septic Tanks	Summer Use Days	Average Use Days							Soil Retention Factor*	Estimated Load Based on Total P Output @ Coef. Value ++		
				Person Use	Pre-1995 # of Tanks	Seasonal Capita/yr	Winter Use Days	Person Use	Occupied # Units	Permanent Capita/yr		1.8 kg/yr High	0.9 kg/yr Med	0.3 kg/yr Low
1	NF Payette R	67	150	4	40	66	215	3	20	36	0.1	165	82	27
2	Mud Creek	11	150	4	7	11	215	3	3	6	0.1	27	14	5
3	Lake Fork Cr	53	150	4	32	52	215	3	16	28	0.1	130	65	22
4	Boulder Cr	53	150	4	32	52	215	3	16	28	0.1	130	65	22
5	Willow Cr	0	150	4	0	0	215	3	0	0	0.1	0	0	0
6	Gold Fork Cr	0	150	4	0	0	215	3	0	0	0.1	0	0	0
7	Cascade	317	150	4	190	313	215	3	95	168	0.1	779	389	130
8	West Mtn.	610	150	4	366	602	215	3	183	323	0.1	1499	749	250
	TOTALS	1111			667	1096			333	589		2729	1365	455

* Soil Retention Factor estimates the adsorption capacity of soils to trap P. Groundwater tables, age of septic systems and soil types affect the retention capacity. Retention values range from 0-1.0; 0=no retention and 1.0=100% retention of P.

++ Typical literature values for P inputs from septic tanks with no phosphate detergent restrictions (Uttomark et al., 1974).

kg/yr TP/single DU/person	@ Effluent Concentrations		
	20 mg/L	15 mg/L	8 mg/L
Septic Output Coefficients	1.0441	0.7831	0.4176

		1.8 kg/yr High	0.9 kg/yr Med	0.3 kg/yr Low
TOTALS	Winter	954	477	159
	Summer	1775	888	296
	%1994 TP	10.8	5.7	2.0
	%1993 TP	6.8	3.5	1.2
	%1989 TP	4.3	2.2	0.7

Soil type, average age of septic system and soil retention factor were considered in the above assessment.

of winter storage lagoons by the City of McCall.

The City of Donnelly has also upgraded their wastewater treatment system. Winter storage lagoons have been constructed and existing lagoons upgraded, aeration and disinfection of waste has been added, and the total area of land application has been increased to 135 acres.

Recreational Management Measures

A mobile pumpout facility has been installed on Cascade Reservoir. This station helps to reduce nutrient loading to the reservoir by providing a contained area for the disposal of wastes that were previously dumped directly into the water. The dump station has been in operation since 1996 and is currently located in the southern portion of the reservoir.

Significant stormwater runoff improvements have been completed at the Blue Heron Campground, and both the Snowbank and Cabarton day-use area facilities by the BOR. Improvements include the installation of staged stormwater runoff filtration systems for the removal/reduction of both sediment and petroleum products. Stormwater management improvements are currently under consideration for the City Ramp and Crown Point facilities.

References:

Brown and Caldwell; 1996 (October); *Stormwater Retrofit Options for Valley County, Technical Memorandum*; Brown and Caldwell Engineering; Boise, Idaho; 9 p + attachments.

Brown and Caldwell; 1997 (March); *Procedures and Recommendations for Subwatershed Prioritization of Stormwater Best Management Practices in Valley County, Technical Memorandum*; Brown and Caldwell Engineering; Boise, Idaho; 26 p + attachments.

Brown and Caldwell; 1997 (April); *Handbook of Valley County Stormwater Best Management Practices*; Brown and Caldwell Engineering; Boise, Idaho; 28 p + attachments.

Burroughs, E.R.; King, J.G.; 1989 (July); *Reduction of Soil Erosion on Forest Roads;* General Technical Report INT-264; USDA - Forest Service, Intermountain Research Station, Ogden, Utah; 21 p.

Cook, M.J.; King, J.G.; 1983 (November); *Construction Costs and Erosion Control Effectiveness of Filter Windrows on Fill Slopes;* Research Note - INT-335; USDA-Forest Service, Intermountain Forest and Range Experiment Station, Ogden, Utah; 5 p.

Foltz, R.B.; Truebe, M.A.; 1994 (November 25); *The Effect of Aggregate Quality on Sediment Production from a Forest Road;* Prepared for Low Volume Road Conference, Transportation Research Board, Washington D.C.; 19 p.

Harr, R.D.; Nichols, R.A.; 1993; *Stabilizing Forest Roads to Help Restore Fish Habitats: A Northwest Washington Example;* Fisheries, Volume 18, No.4; pp 18-22.

Harvey, G.W.; Burton, T.A.; 1991 (June); *Idaho 319 Non-Point Source Program Project Summary, Forest Road Inventory and Stabilization Report;* Idaho Dept. Of Health and Welfare, Division of Environmental Quality, Water Quality Bureau, Boise, Idaho; 22 p.

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