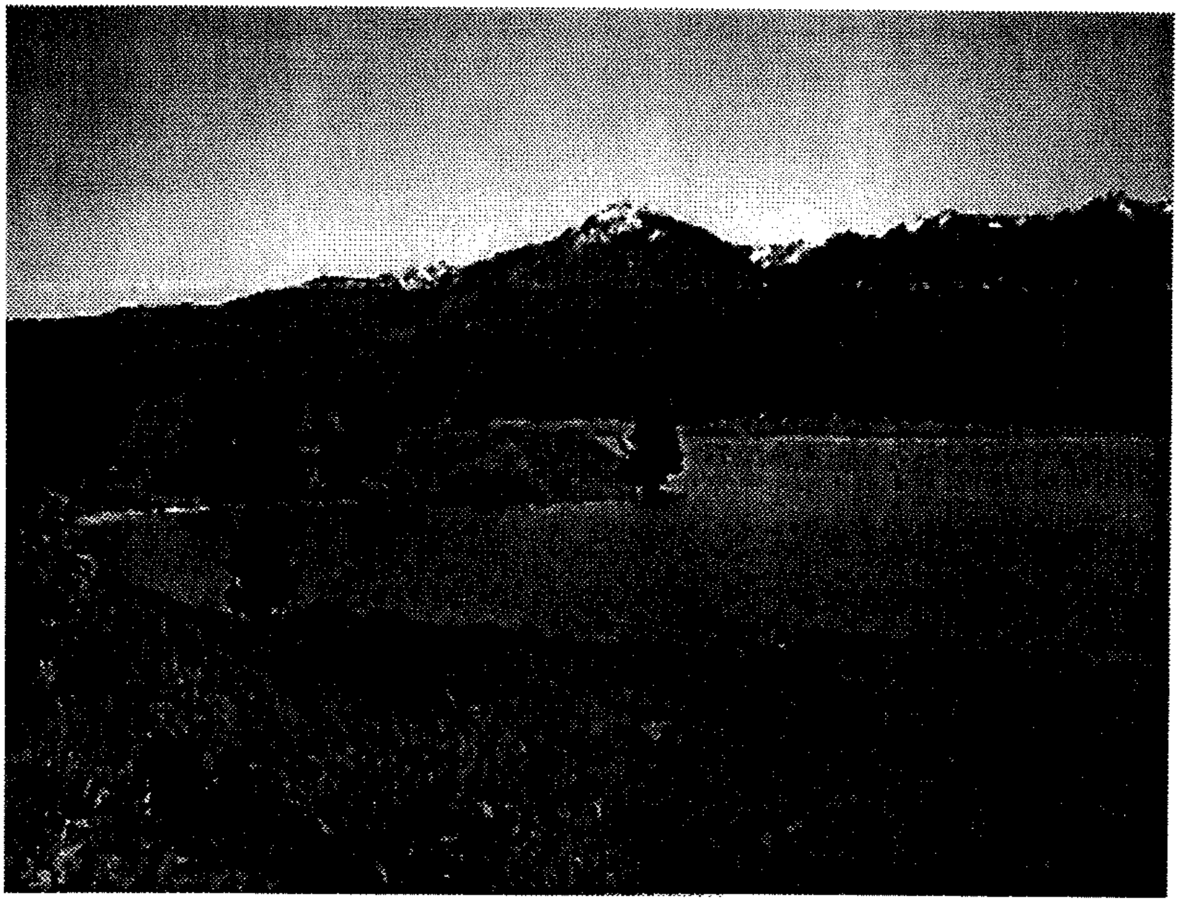
Cascade Reservoir
Phase II
Watershed Management Plan



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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 (≥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

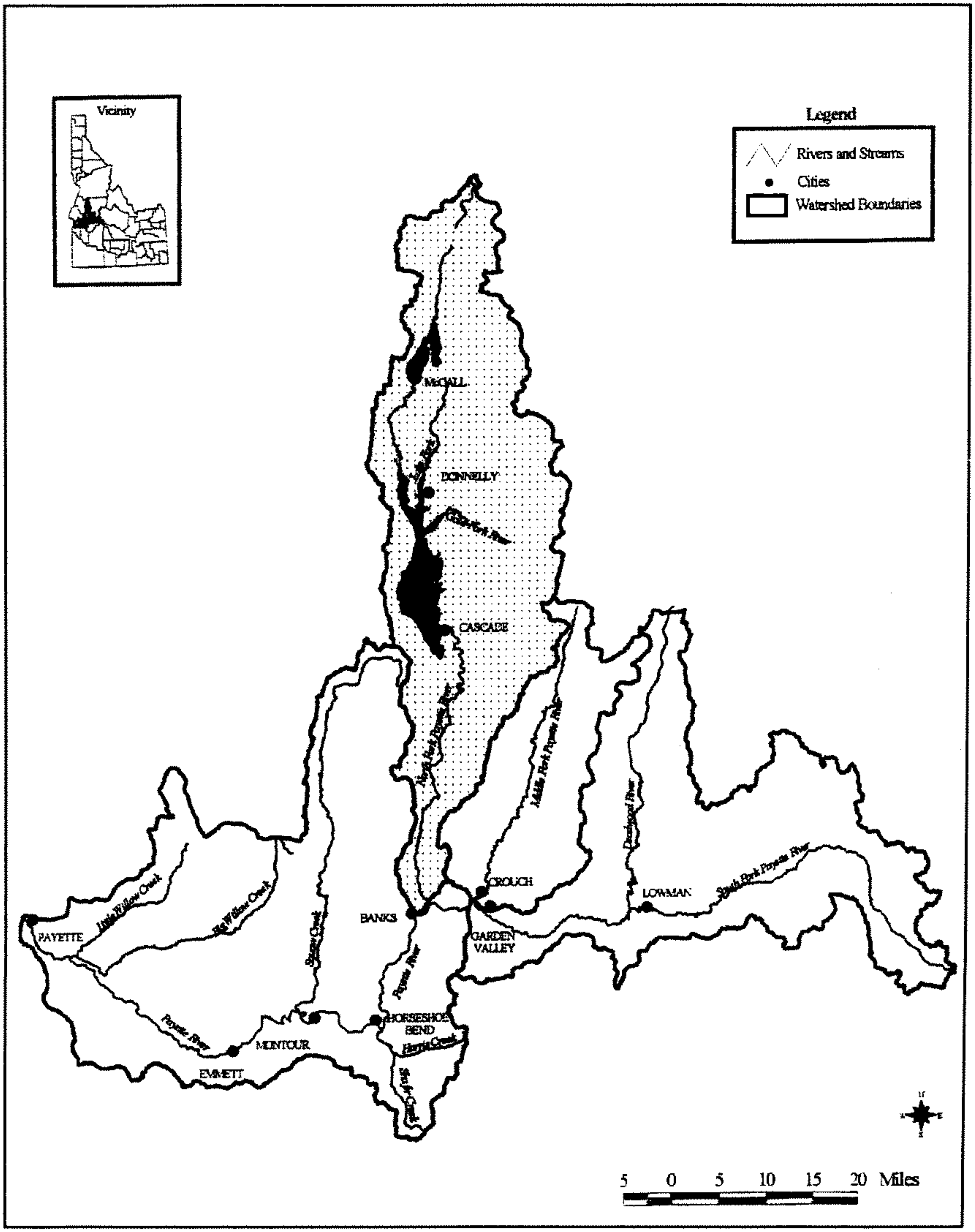


Figure 2.1 Payette River Basin map showing the location of the Cascade Reservoir Watershed.

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

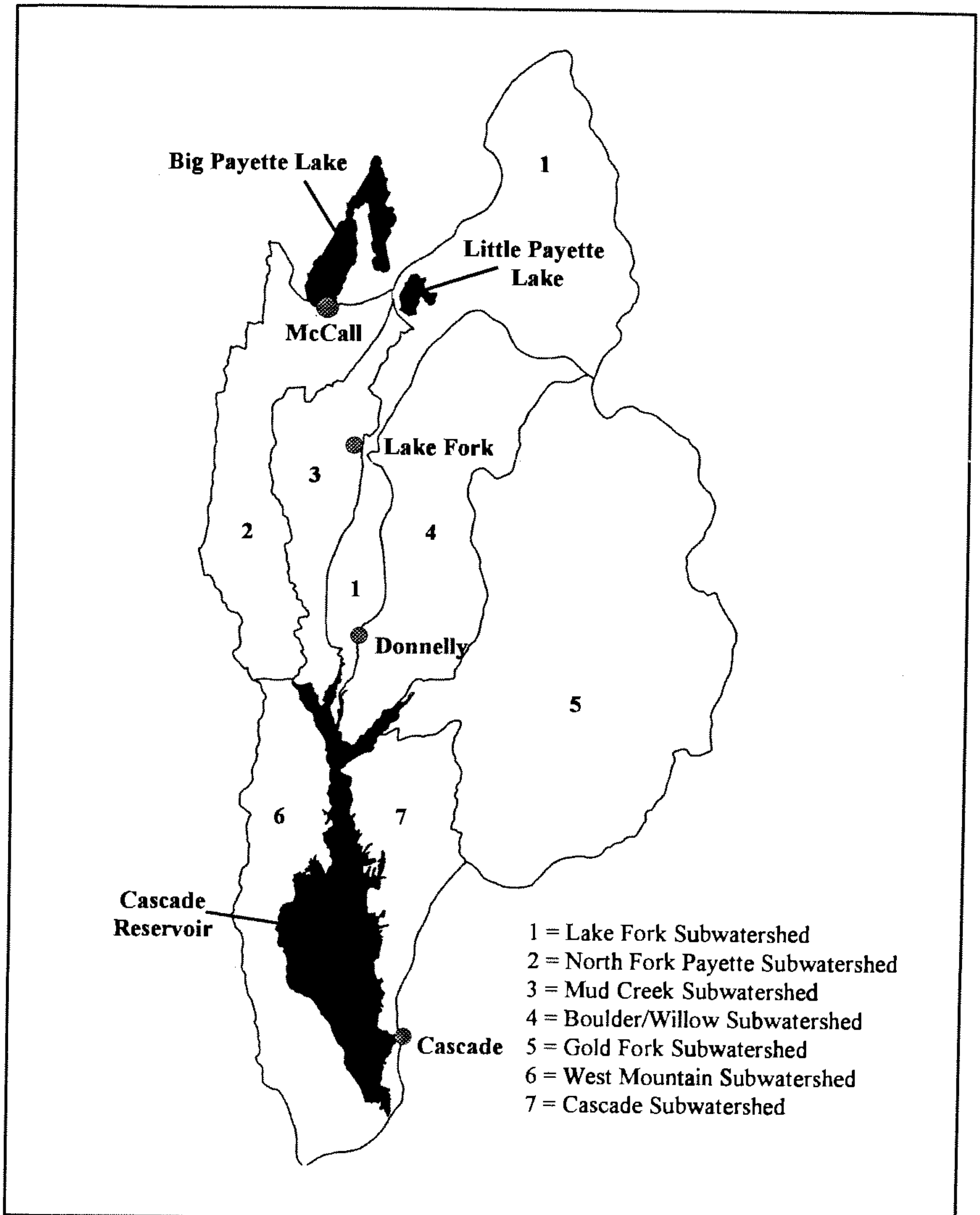


Figure 2.2 Subwatershed boundaries within the Cascade Reservoir Watershed.

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

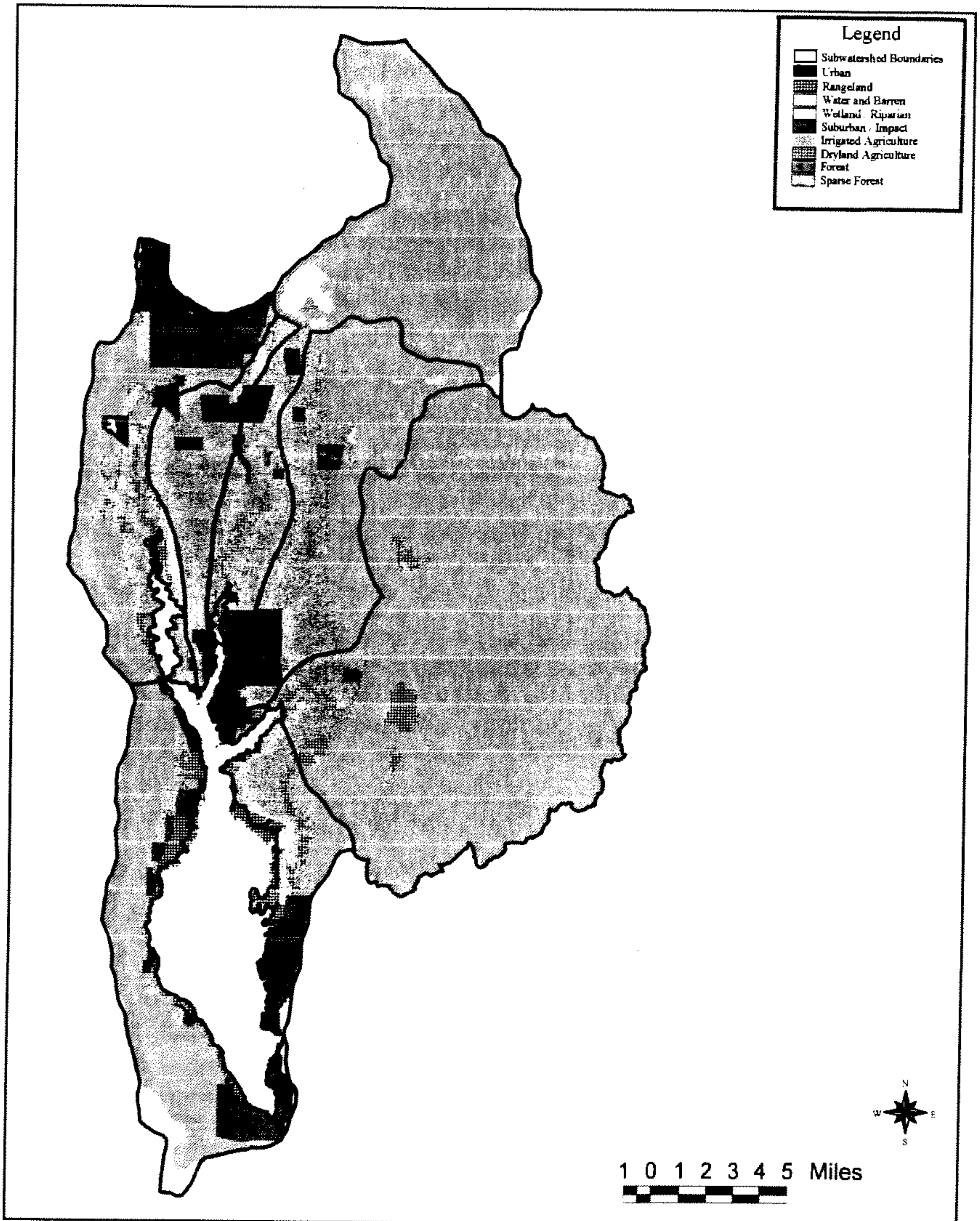


Figure 2.3 Land-use distribution within the Cascade Reservoir Watershed.

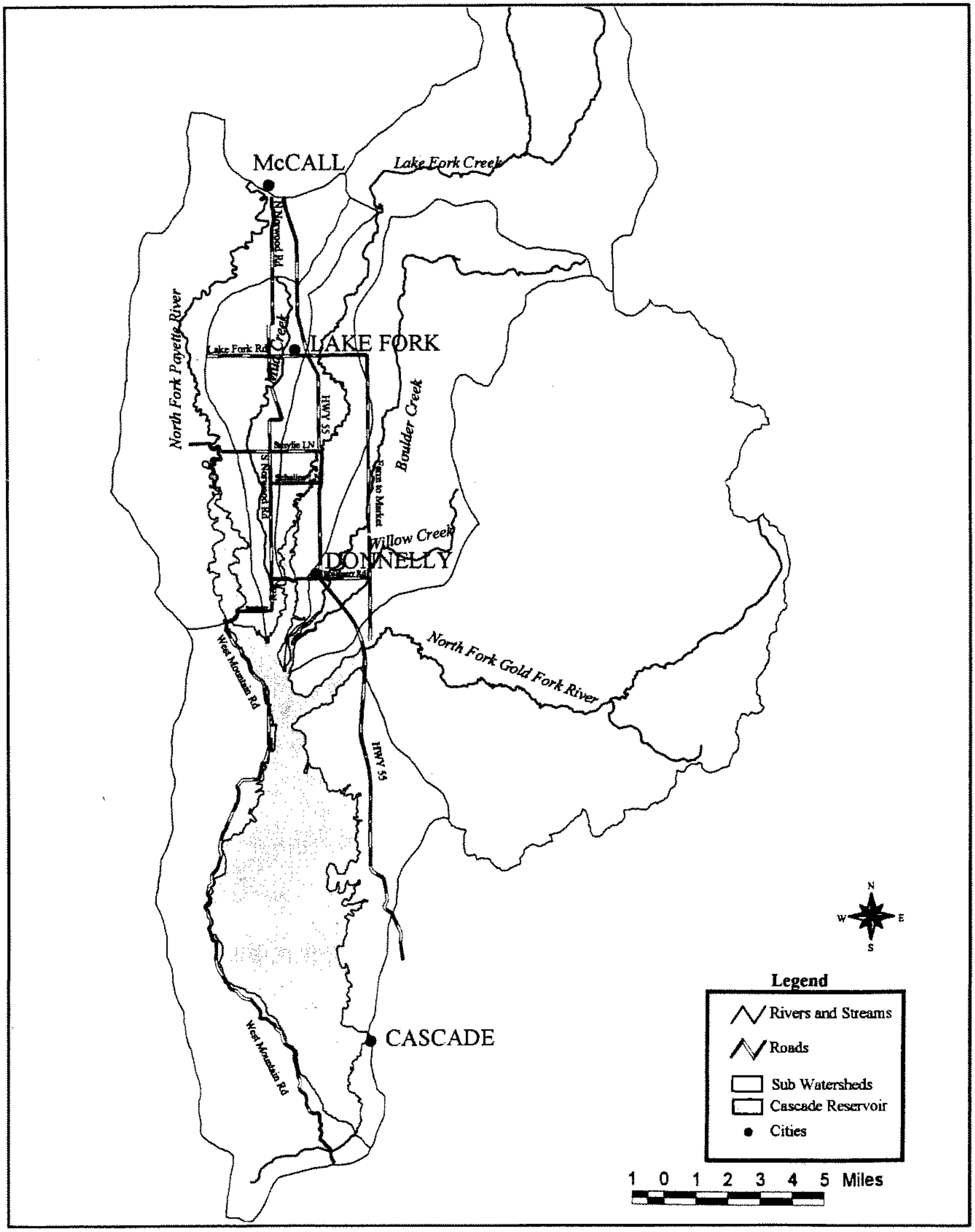


Figure 2.4 Major features of the Cascade Reservoir Watershed.

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

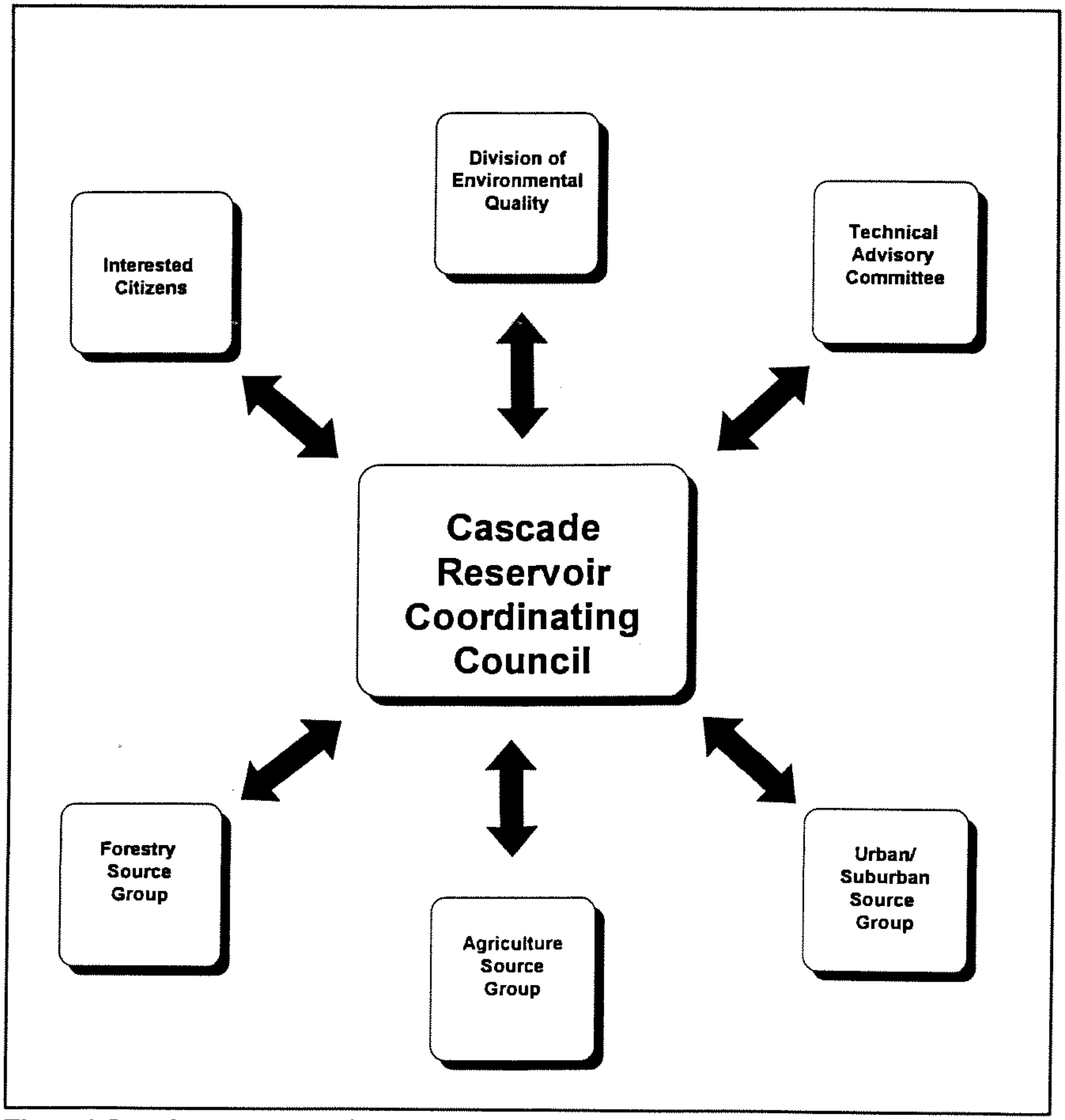


Figure 2.5 Cascade Reservoir Coordinating Council (CRCC) feedback loop.

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

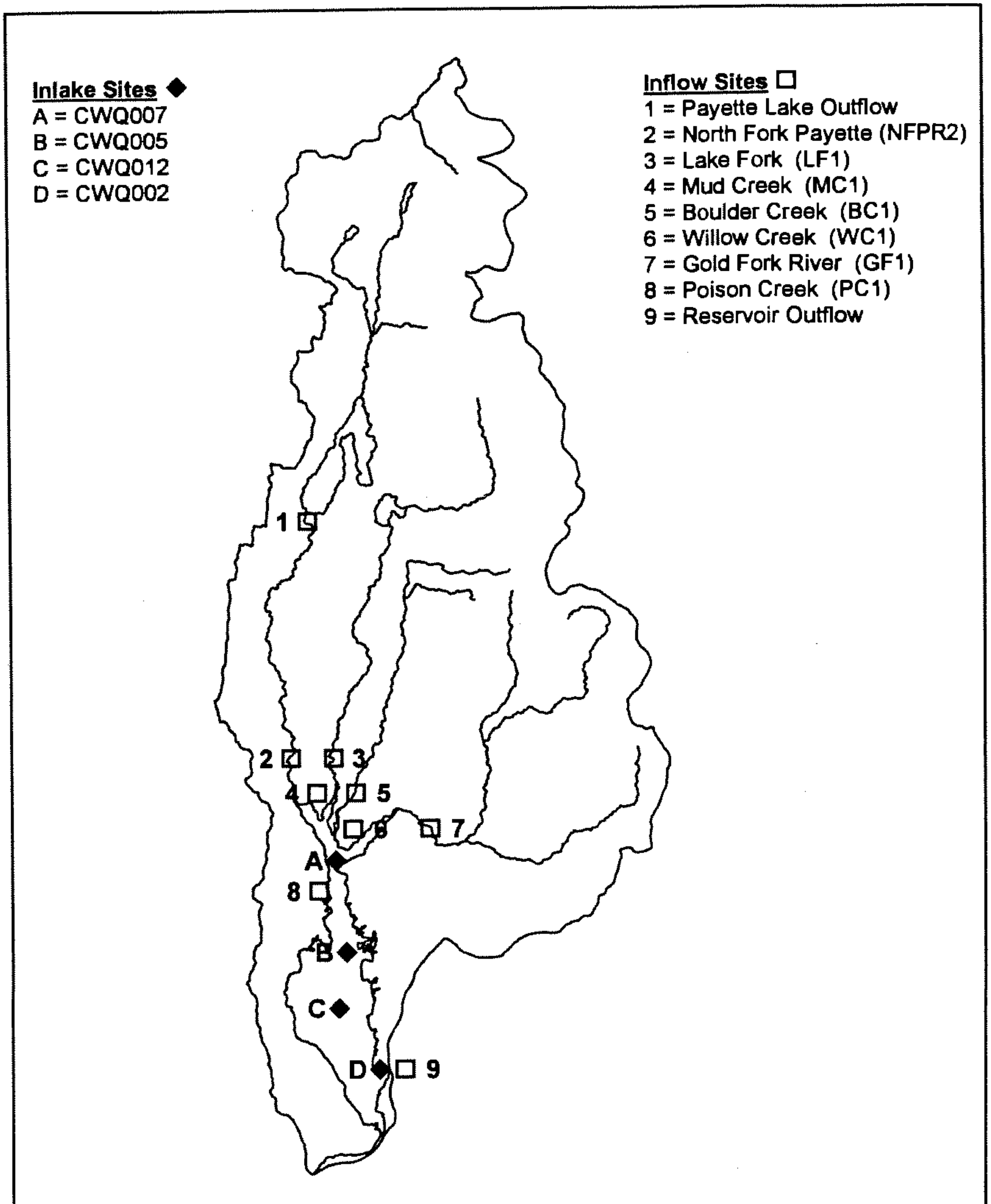


Figure 2.6 Division of Environmental Quality monitoring sites within the Cascade Reservoir Watershed.

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.

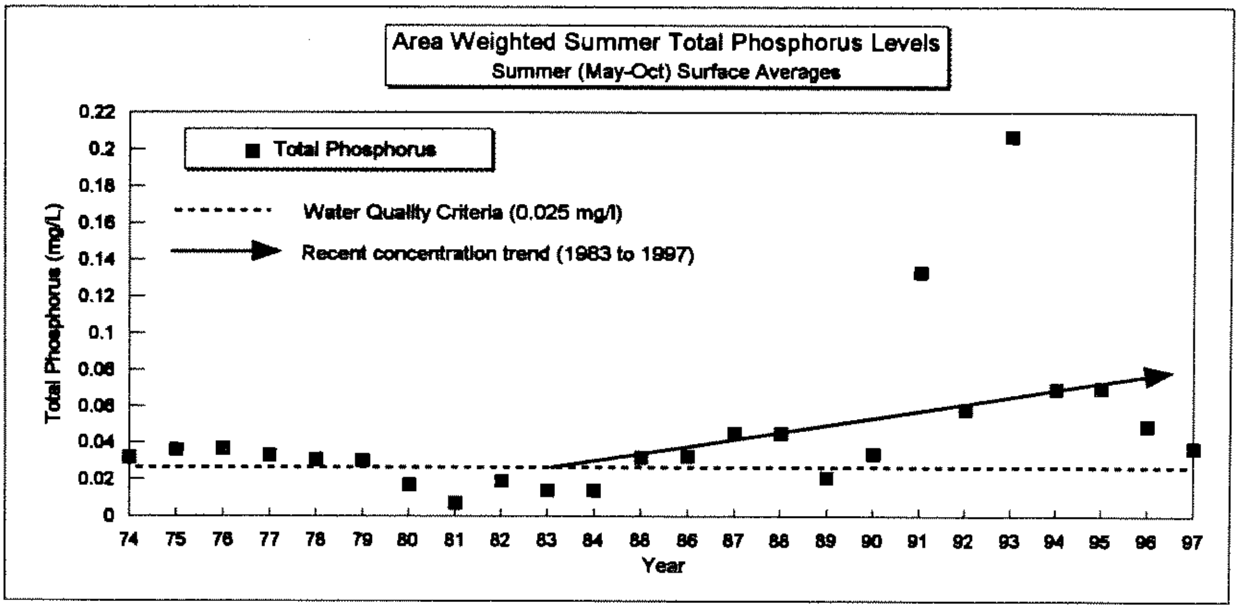
Data collected in 1993, a normal runoff year, indicate poor water quality within the reservoir due to increased inputs of phosphorus which encouraged the growth of excess algae as measured by chlorophyll a concentrations and citizen complaints. Even though total phosphorus loads decreased in 1994, (Figure 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



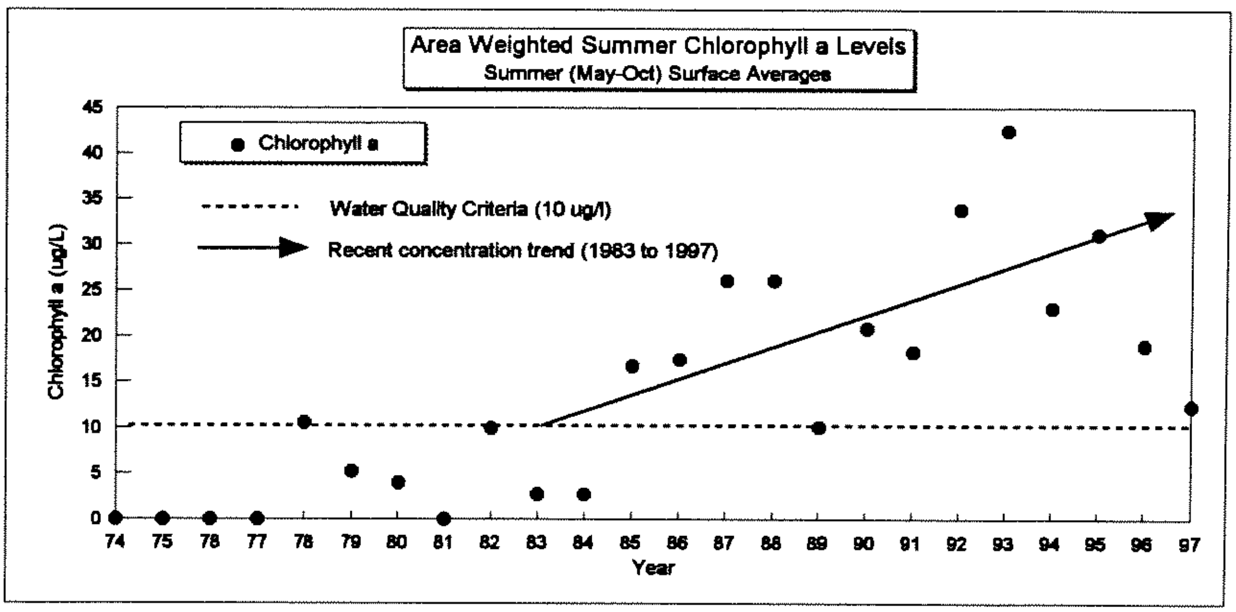


Figure 2.7 Area-weighted summer total phosphorus and chlorophyll a levels for Cascade Reservoir.

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

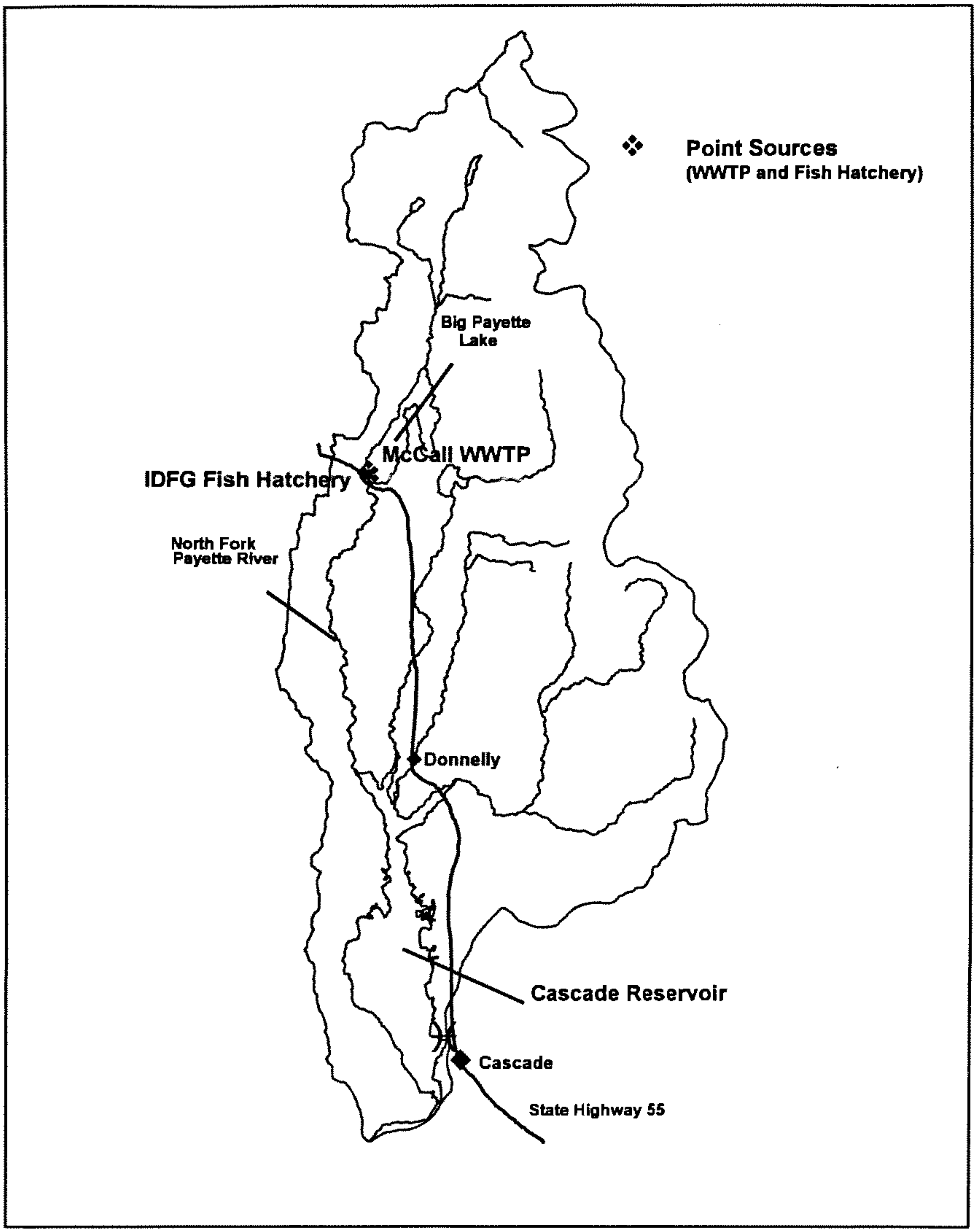


Figure 2.8 Point sources located within the Cascade Reservoir Watershed.

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

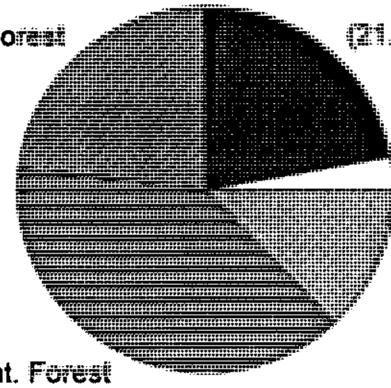


Figure 2.9 Proportional acreage of forestry land by ownership within the Cascade Reservoir Watershed.

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).

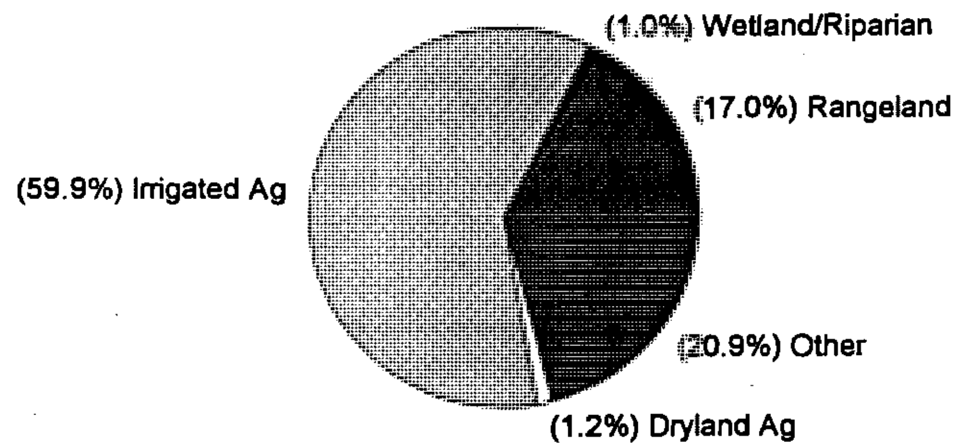


Figure 2.10 Proportional acreage of agricultural land use within the Cascade Reservoir Watershed.

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).

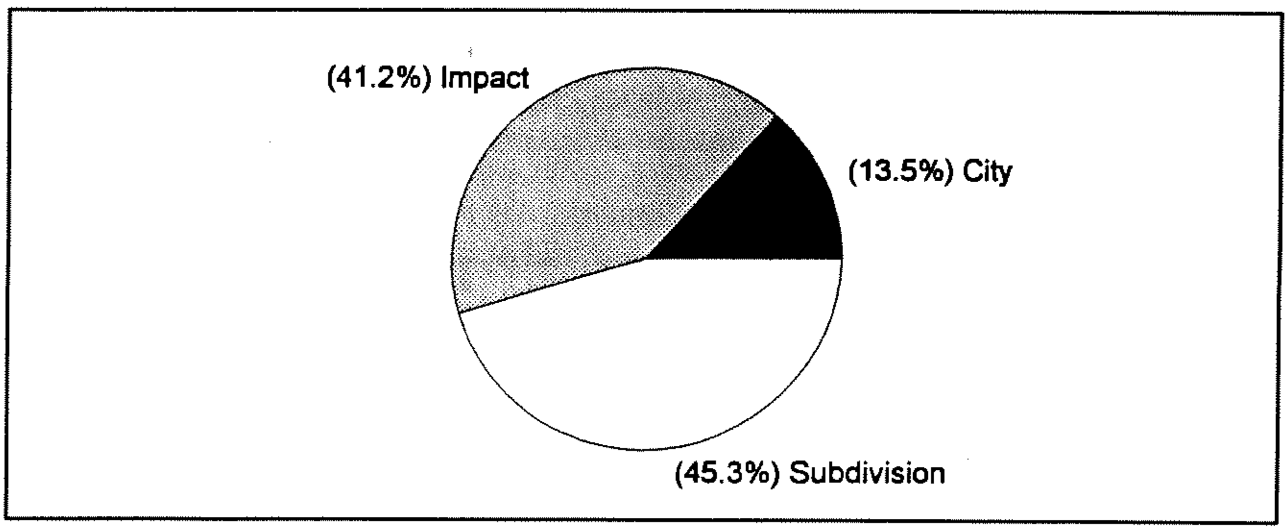


Figure 2.11 Proportional acreage of urban/suburban land use within the Cascade Reservoir Watershed.

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

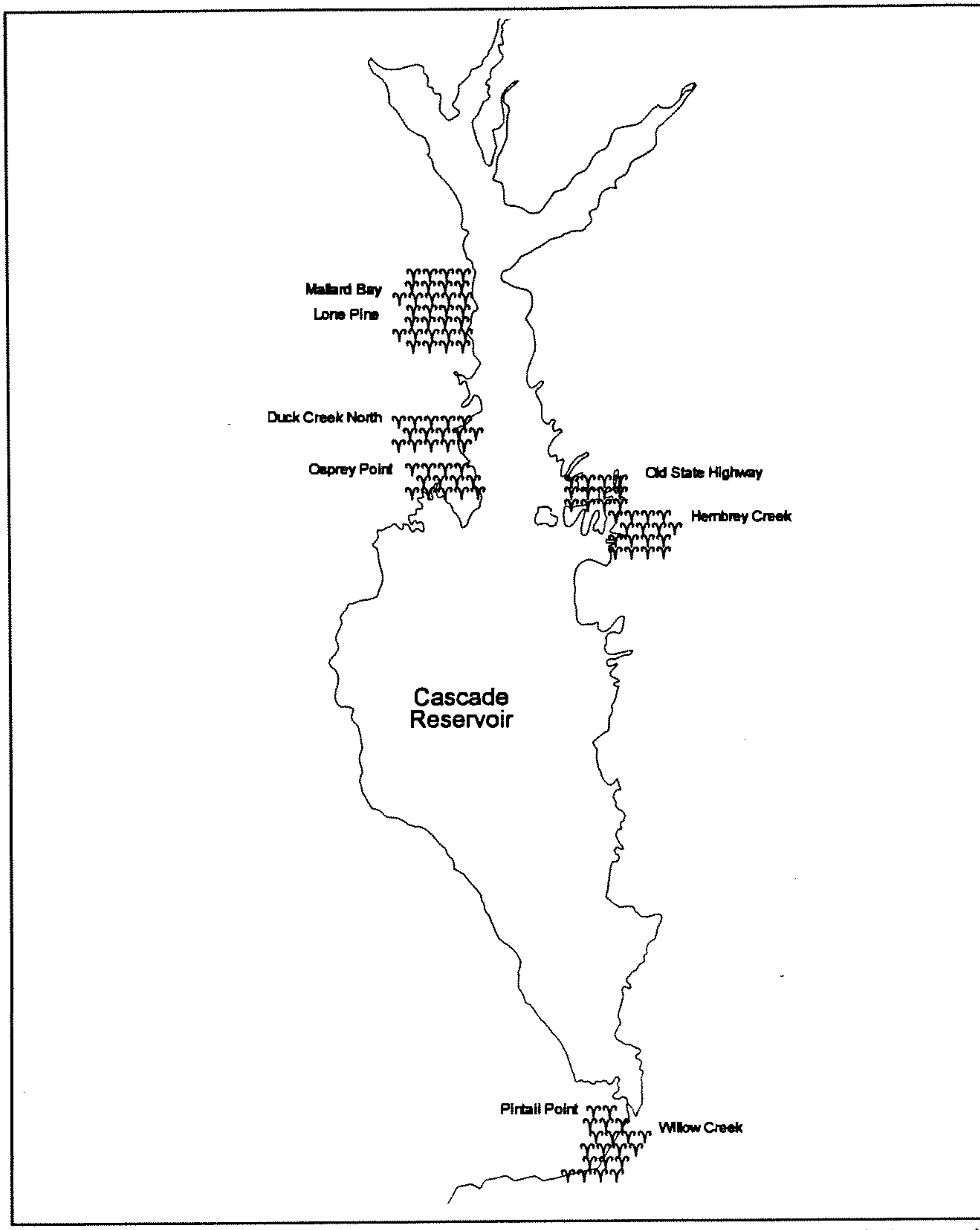


Figure 2.12 Approximate location of major created wetlands within the Cascade Reservoir Watershed.

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

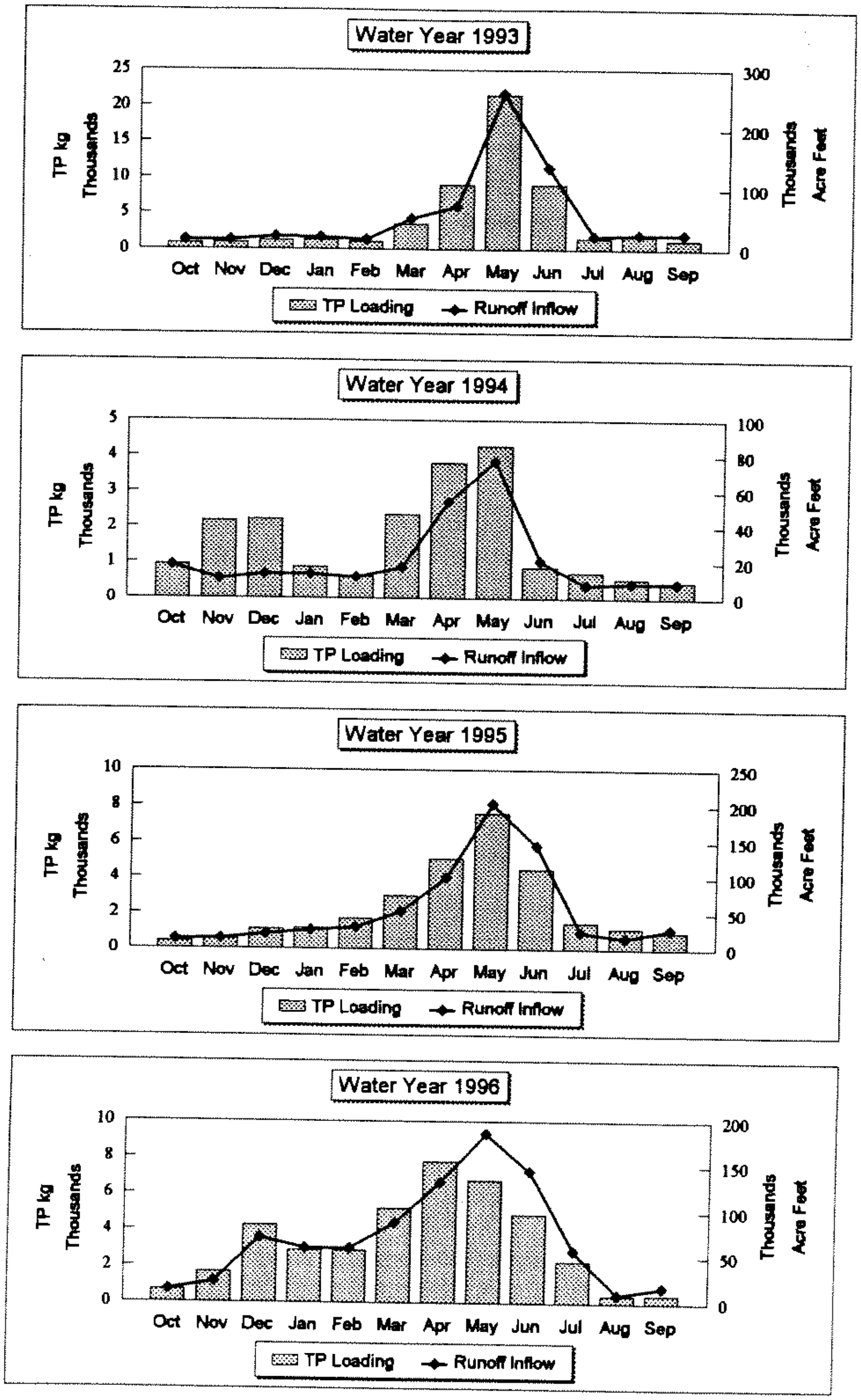


Figure 3.1 Seasonal total phosphorus loading and runoff inflow to Cascade Reservoir.

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

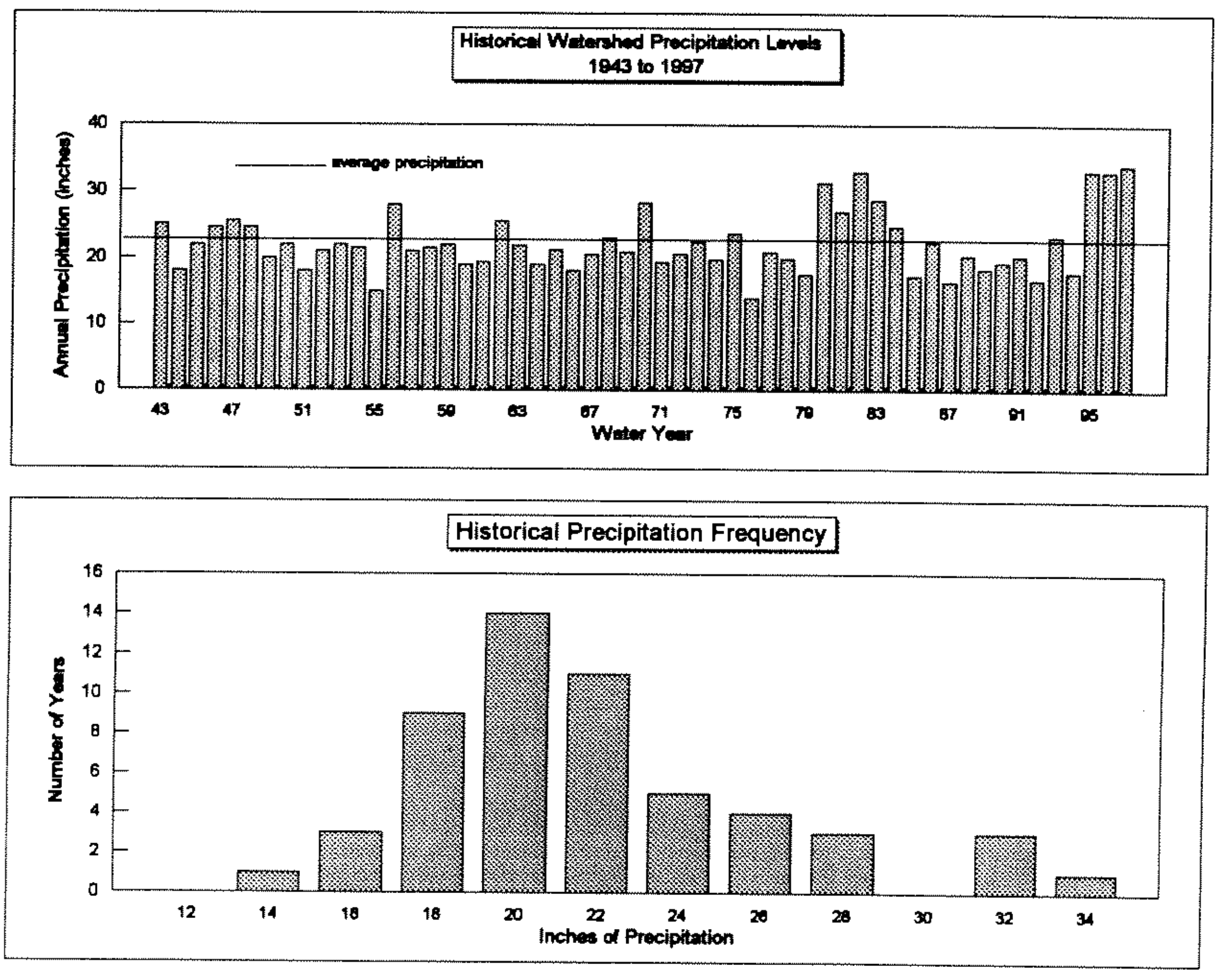


Figure 3.2 Historical precipitation levels and frequency for the Cascade Reservoir Watershed.

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.

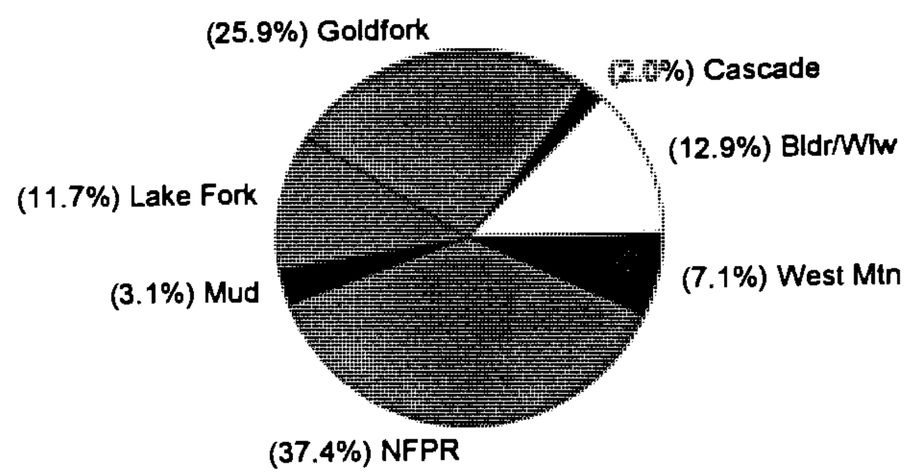


Figure 3.3 Proportional annual total phosphorus loading by subwatershed within the Cascade Reservoir Watershed.

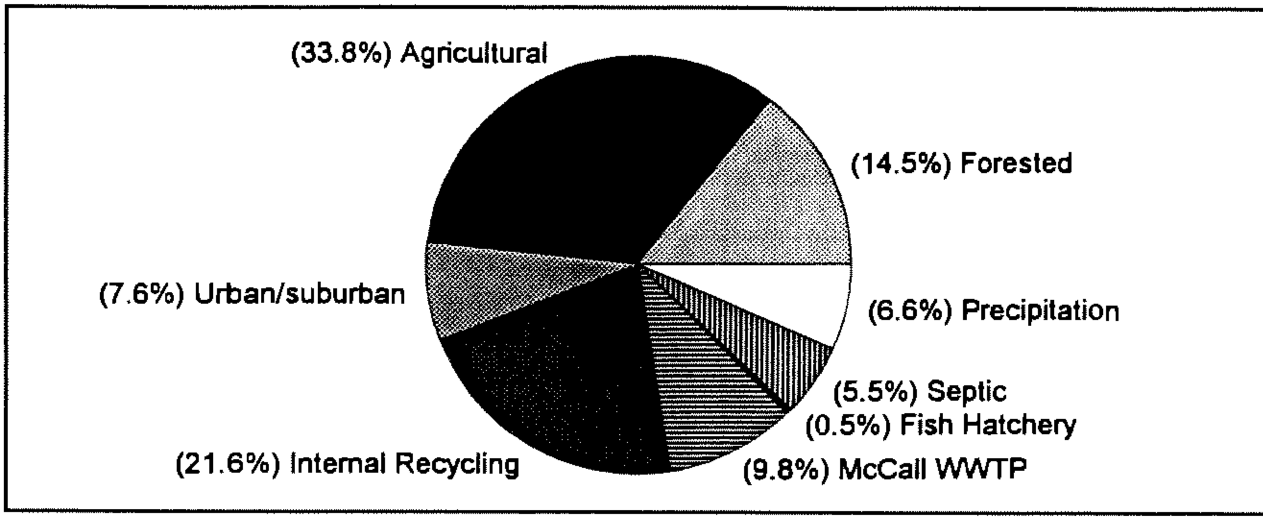


Figure 3.4 Proportional annual total phosphorus loading by source within the Cascade Reservoir Watershed.

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-1995 # 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			537	952		4410	2205	736

* 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	0.8 kg/yr Med	0.3 kg/yr Low
TOTALS	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.

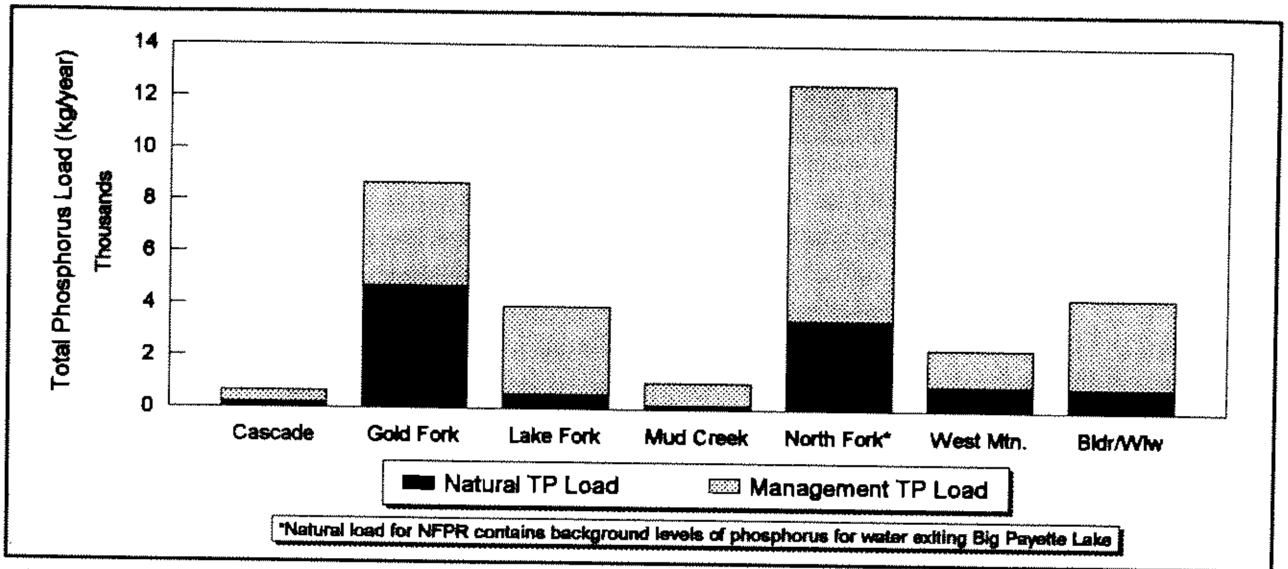


Figure 3.5 Relative annual total phosphorus contributions from natural and management sources by subwatershed for the Cascade Reservoir Watershed.

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

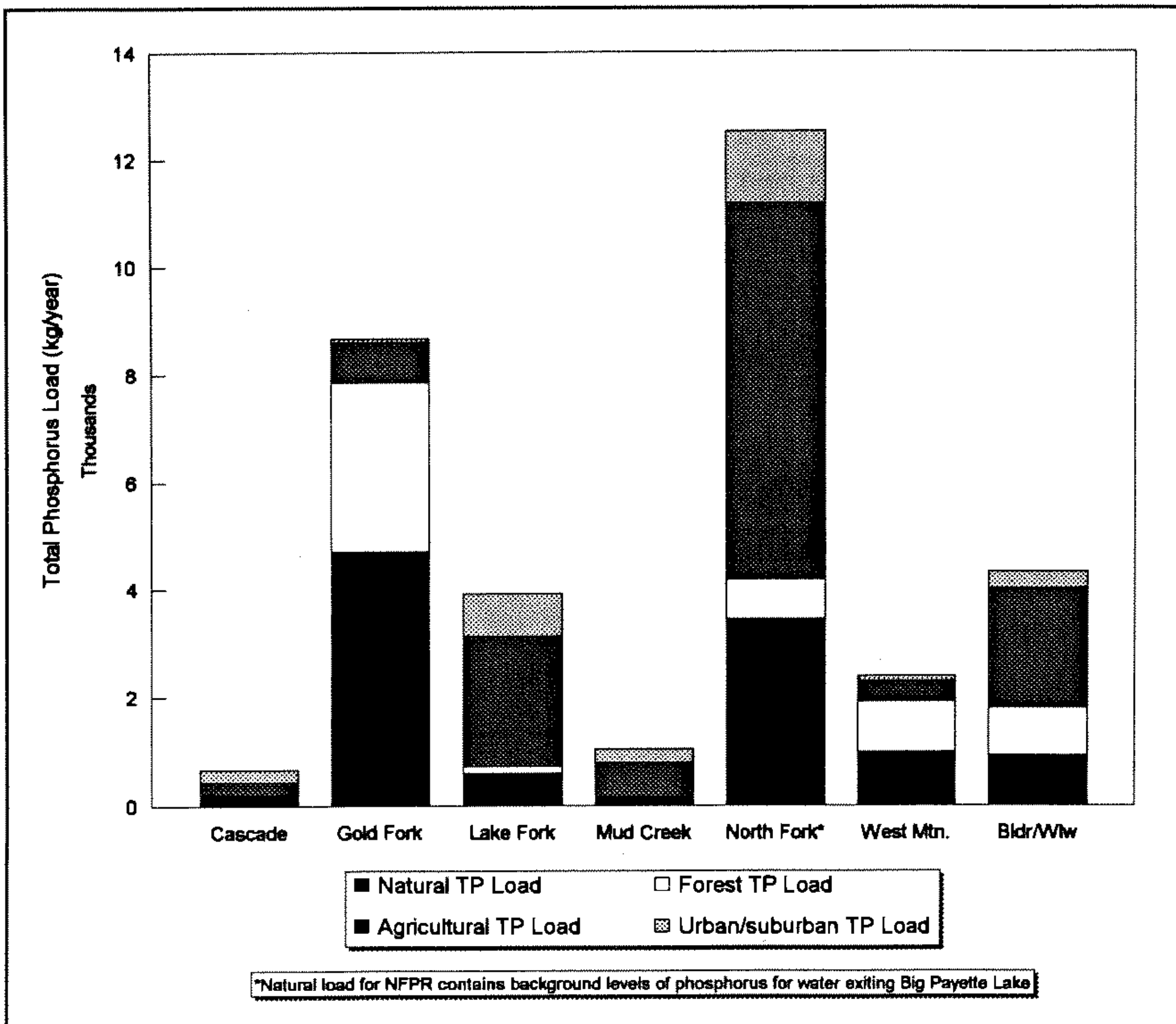


Figure 3.6 Annual total phosphorus loads allocated to nonpoint, land-use sources by subwatershed for the Cascade Reservoir Watershed.

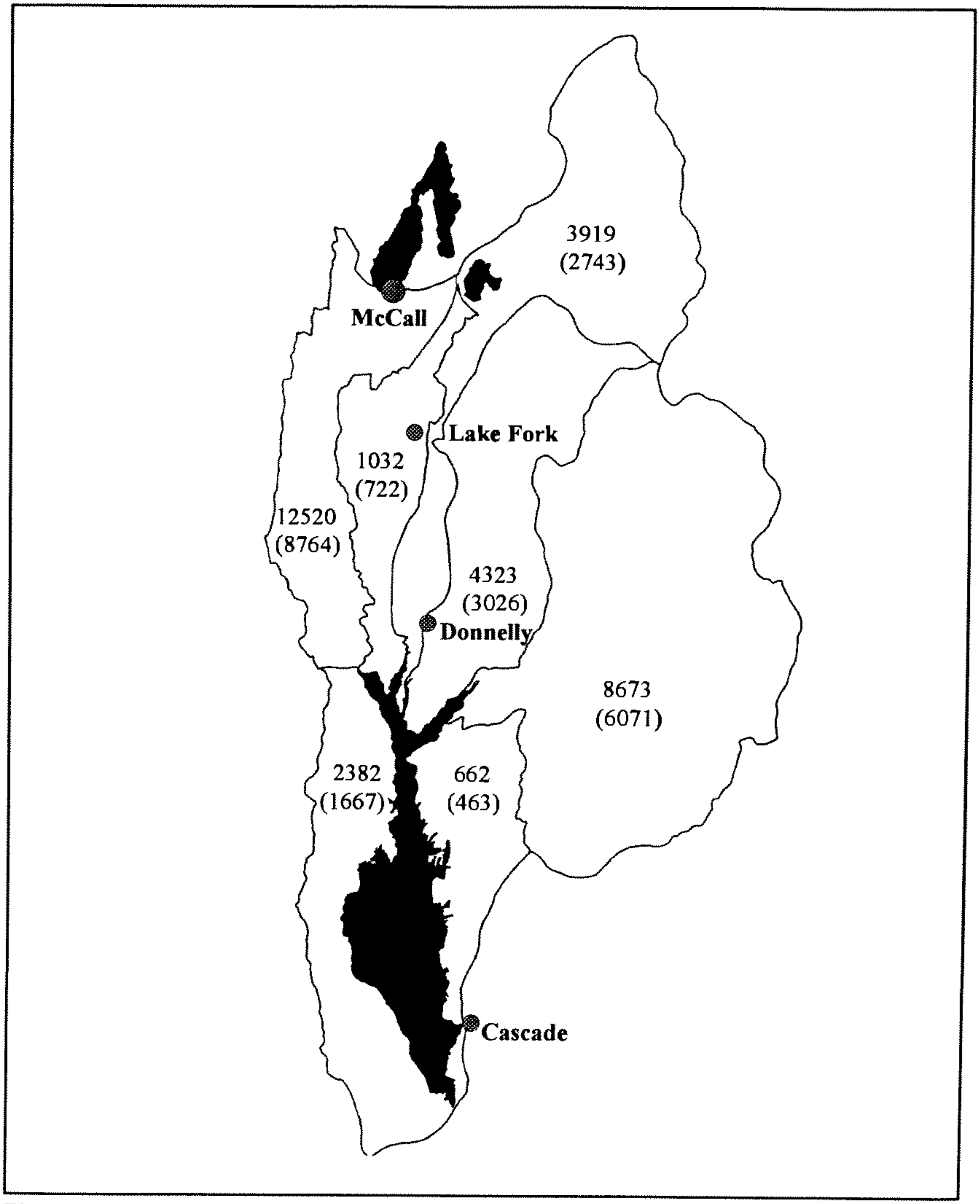


Figure 3.7 Annual nonpoint source total phosphorus load allocation and reduced load (in parentheses) by subwatershed for the Cascade Reservoir Watershed.

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.

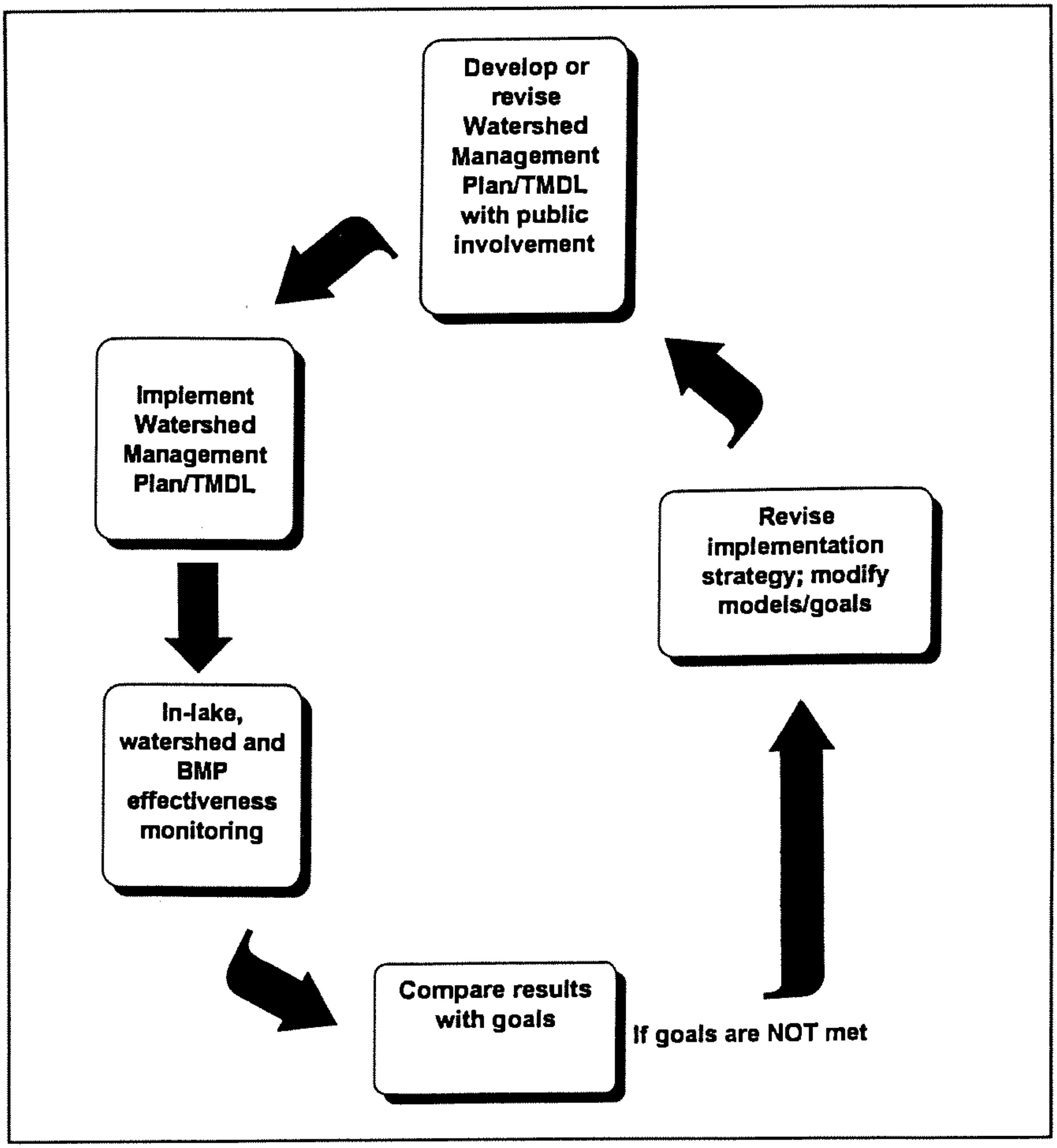


Figure 3.8 Feedback loop for the evaluation of best management practice (BMP) effectiveness.

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.

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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	cm^2	in^2	ft^2	m^2	acres	km^2	mi^2	
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	cm^3	in^3	liter	us gal	ft^3	m^3	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	ft^3/sec	m^3/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.