Technical Report on the Water Quality of Big Payette Lake:

An Integrated Watershed and Lake Assessment,

Subtitled

(The Eutrophication Potential of Big Payette Lake)

December 1997

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TECHNICAL REPORT ON THE WATER QUALITY OF BIG PAYETTE LAKE: An Integrated Watershed and Lake Assessment,

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Prepared by:

Payette Lake Technical Advisory Committee

Version Date: December 1, 1997

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Chapter I

1.0 Introduction

The Big Payette Lake Watershed project is a local citizen initiative to protect the high quality environment of Big Payette Lake and its contributing watershed. In support of this effort, the state legislature appointed a special council (Big Payette Lake Water Quality Act; HB. 153) of local citizens and granted it authority to conduct a comprehensive, scientifically based study of the lake and watershed, prepare a water quality management plan to protect the resource and encourage public participation in its implementation.

The Big Payette Lake Water Quality Council and the community of McCall, Idaho believe that a high level of water quality in the Big Payette Lake and its watershed must be preserved for drinking, swimming, fishing, wildlife and other aesthetic purposes while accommodating private, public and commercial activities to the extent prudent and practical and sustaining the economic viability of the area.

Although the lake is generally considered to be of high quality, continued population growth in the area and land use changes in the watershed have increased public concern that lake conditions could be degraded. The watershed is dominated by forest lands managed by the U.S. Forest Service and Idaho Department of Lands. The Idaho Forest Practices Act was passed in 1974 (revised 1992; Title 38, Chapter 13, Idaho Code) and recommends minimum forestry BMPs (Best Management Practices) required to protect state water quality. These regulations govern activities on Forest Service, private and State Lands. These regulations primarily attempt to control erosion of streams impacted by logging activity. Moreover, much of the logging activity on Forest Service land within the watershed took place prior to implementation of current BMPs.
Other issues include urban expansion of the city core and additional residential growth along the lake shoreline. Significant growth of the local economy is expected to continue based on current patterns of development and recreational usage. It is also anticipated that additional nutrient loading of the lake will increase at sporadic rates in response to increased disturbances within the watershed (land clearing, conversion to urban use, logging, etc.). Mitigation of these impacts will be required to maintain existing lake water quality. The quantity and quality of runoff associated with current land uses are largely unknown. In addition, the Department of Lands is responsible for management of undeveloped endowment lands scattered along the lake shoreline. The type and intensity of development on these lands could significantly affect nearshore water quality of the lake.

Attention has also been focused on an apparent decline in the water quality of the N.F. Payette River between Fisher Creek and Big Payette Lake. This section of the river was previously designated as a Stream Segment of Concern by Idaho Division of Environmental Quality (IDEQ, 1992). Increased recreational demands may also be contributing to changes in habitat quality. More recently, a significant fire swept through the watershed in summer 1994. The long term impacts of this fire on the health and future condition of the watershed and that of Big Payette Lake have raised new concerns over future land management in the watershed.

1.1 Previous Environmental Studies

1.1.1 Watershed Studies

Despite a long history of management activities dating back to the 1900's and population growth in the Payette Lake watershed, there is very little scientific data relating these activities to watershed health. With the exception of activity related to isolated timber sales, information concerning the current status of the Payette Lake Watershed is lacking. Very few of the numerous tributaries flowing into the North Fork Payette River have been measured for flow rate or water quality to establish a baseline of existing conditions. Some historical data relevant to this study have been collected by the Forest Service and incorporated as part of the baseline information for the report.

Three assessments have been completed within the North Fork Payette River drainage: The Accelerated Englemann Spruce Harvest Environmental Impact Statement (USDA, 1991); the Blackwell Post-Fire Landscape Assessment (USDA, 1995a, working draft), and; the North Fork Payette Post-Fire Project (USDA, 1995b). The objective of the EIS was to identify alternatives to salvage insect- killed trees within Brush, Hendricks and Copet Creek drainages. The Post-Fire Landscape Assessment analyzed the effects of the Blackwell fire and identified a desired future condition for the watersheds. Finally the Post-Fire Project Assessment identified opportunities in timber harvest and restoration projects to begin implementation and changes toward the future conditions objectives. Portions of these documents have been used in this report.

1.1.2 State Lands Planning Study

The Idaho Department of Lands completed a draft Payette Lakes State Forest Land Use Plan (IDL, 1992). The purpose of this plan was to provide a guide for future development and use of 14,771 acres of State endowment lands near McCall. This land includes forest land for commercial timber and a significant amount of developed and undeveloped lands around the perimeter of Big Payette Lake. The plan intent was to consolidate management activities to better define future management objectives and determine the best use of undeveloped lands adjoining the lake shoreline.

1.1.3 Parks and Recreation Study

The Idaho Parks and Recreation Department completed a *General Development Plan for Ponderosa State Park* (Okerlund, 1994). This plan outlines conceptual development alternatives for the state park and adjoining lake front. Components include future development of recreation sites, protection of natural resources within the park and park expansion to include/improve the North Beach area of Big Payette Lake.

1.1.4 Lake Studies

One of the earliest references to Payette Lake's water quality was made in the 1890's in a report to the U.S. Fish Commission which noted the presence of sockeye salmon (Oncorhynchus nerka) and water-column transparency as much as 9 m (U.S. Forest Service, 1995a). By the late 1960's, water-quality concerns prompted the Idaho Department of Health (DH) to conduct studies on the effects of sewage disposal from nearshore dwellings around Payette Lake. A bacteriological survey conducted during 1964 found many unsatisfactory sewage-disposal systems in the nearshore area (Idaho Department of Health, 1970). A second, more intensive, study was conducted during 1967-69 to determine the extent of bacterial contamination, describe chemical conditions, and determine the general degree of eutrophication (the process by which excessive nutrient imports to a lake stimulate its biological productivity to levels that degrade water quality and thus impair some or all of the lake’s beneficial uses). That study (Idaho Department of Health, 1970) found the lake to be oligotrophic (rich in oxygen at all depths), on the basis of chemical and biological variables, and to have obvious bacterial contamination in some nearshore areas. On the basis of these two studies, the Idaho Department of Health recommended a sewage-collection system be installed at Payette Lake to protect its oligotrophic (low in biological productivity) condition and to reduce the human health risks associated with bacterial contamination.

The U.S. Environmental Protection Agency (EPA) studied Payette Lake in 1975 as part of the National Eutrophication Survey (U.S. Environmental Protection Agency, 1977). Water quality analyses were indicative of excellent conditions and a trophic state of early mesotrophic (moderate biological productivity). This study was the first to estimate the lake's annual nutrient budget. Of the 4,100 kg of total phosphorus estimated to enter the lake during a year of average inflow, about 68 percent was delivered by the North Fork Payette River; nearshore sewage-disposal systems accounted for about 0.5 percent. For total nitrogen, the lake received about 198,000 kg, with 65.6 percent contributed by the North Fork Payette River and 0.3 percent from nearshore sewage-disposal systems.

A comprehensive limnological assessment of Payette Lake was conducted during 1981-82 in response to concerns over possible water-quality deterioration caused by lakeshore and watershed development and to monitor the water-quality impacts from construction of a gravity sewer line along the lake's shoreline (Falter and Mitchell, 1981; Falter, 1984). Concentrations of nutrients and chlorophyll were low in the open areas of the lake, but significant inputs of nutrients and bacteria were measured in nearshore areas, especially in the west and southeast basins. This was also the first study to measure dissolved-oxygen concentrations throughout the water column in the lake's deepest basins. At the southwest basin, dissolved-oxygen concentrations below the 60-m depth were about 4 mg/L in September, indicative of a substantial dissolved-oxygen deficit considering the lake’s apparent trophic status with regard to phosphorus and chlorophyll.

Although this study estimated the lake's annual nutrient budget for 1982, it was not directly comparable to the 1975 nutrient budget because inflow during 1982 was 145 percent of the long-term average. Of the 14,000 kg of total phosphorus input to the lake in 1982, 71.4 percent came for the North Fork Payette River and 1.7 percent came from nearshore sewage-disposal systems. About 87,300 kg of total nitrogen entered the lake in 1982; 42.7 percent came from the North Fork Payette River and 2 percent from nearshore sewage-disposal systems. Based on the lake's nutrient loadings and dissolved-oxygen deficit, the lake's trophic state was deemed mesotrophic.

Over the past decade, limnological data have been collected sporadically at Payette Lake by Idaho agencies such as the Idaho Department of Fish and Game (IDFG) and Idaho Division of Environmental Quality (DEQ); however, the scope of these efforts has been more limited than the 1975 and 1981-82 studies. Of interest are the dissolved-oxygen profiles collected on six occasions over 1992-93 by DEQ. The lowest dissolved-oxygen concentration, 2.8 mg/L, was measured at a depth of 71 m in the lake's west basin in late July, 1992 (D. Worth, Idaho Division of Environmental Quality, written commun., September, 1995).

These prior water-quality studies revealed that Payette Lake has undergone some degree of eutrophication on the basis of symptomatic evidence such as substantial dissolved-oxygen deficits and nutrient loadings. Although a sewage-collection system was completed in the mid-1980's, the reduction in the lake's overall nutrient budget was probably less than a few percent. The continuation of substantial dissolved-oxygen deficits into the early-1990's is evidence the lake is still undergoing eutrophication. Fishery data collected since the early-1980's also indicates the lake may be more biologically productive than in the past. In 1980 and 1988, the biomass of wild kokanee salmon was 0.18 and 0.24 kg/ha, respectively; whereas, from 1990 to 1995, biomass has steadily increased from 1.0 to 4.24 kg/ha (P. Janssen, Idaho Dept. of Fish and Game, written commun., February, 1996).

1.2 Technical Study Plan and Objectives

A Technical Advisory Committee (TAC) was established by the Big Payette Water Quality Council in November 1992 to develop the study scope and geographical extent. Due to the complexity of land and resource management issues, a technical study plan was developed in partnership with academic, state and federal agencies. Table 1.1 lists the member agencies participating as technical advisors in the plan formulation. The full Technical Advisory Committee, as identified in the Big Payette Lake Act, was responsible for final review of the study plan and scientific scrutiny of the technical reports. The technical study plan was presented to and approved by the Big Payette Lake Water Quality Council in McCall, Idaho (December 1993) and informally reviewed by appropriate Idaho Legislative Committees during the 1994 legislative session. Implementation of the technical study was a cooperative multi-agency effort between the Idaho Division of Environmental Quality, Idaho Department of Fish and Game, Idaho Department of Lands and the U.S. Forest Service, Payette National Forest.

Table 1-1. Member agencies and institutions supporting the Payette Lake Technical Advisory Committee.

Peter Johnson, Chairman Big Payette Lake Water Quality Council	Dr. Roy Mink University of Idaho
Robert Christensen Technical Advisory Committee	Don Anderson Idaho Fish & Game
Dewey Worth ID Division of Environmental Quality	Helen Bivens Lake Reservoir Company
Dave Detullio/Jim Woods Natural Resource Conservation Service	David Simmonds Idaho Conservation League
Randy Phelan Natural Resource Conservation Service	Thomas Woodbury Idaho Conservation League
Dave Zimmer Bureau of Reclamation	David Blew Idaho Soil Conservation Commission
Ruth Schellbach Idaho Department of Water Resources	Tom Lance Idaho Soil Conservation Commission
Les Ankenman Valley County Engineer	Douglass Fitting Idaho Department of Lands
Dr. Paul Woods United States Geological Survey	Jeffrey Lappin Central District Health Department
Gerald Elson, Executive Director ID Association of Soil Conservation Service	Leigh Woodruff Idaho Operations Office - EPA
John Kwader Boise Cascade Cooperation	Glenn Logan/Shelby Brownfield Associated Earth Sciences
Ted Whiteman Payette Lakes Water & Sewer District	Tom Kerr Big Payette Lake Water Quality Council
Jim Fitzgerald Payette National Forest	Bill Petzak (succeeded by Sheldon Keifer) Idaho Department of Lands
Glenn Jacobsen Payette National Forest	Jackie DeClue, P.E. City of McCall
John Rygh Payette National Forest	Dieuwke Spencer, E.H.S., R.N. Central District Health Department
Dennis Coyle Idaho Parks & Recreation	

The technical study plan was designed to provide a coordinated assessment of the watershed conditions within the drainage basin and to determine the current trophic status of Big Payette Lake.

Specific objectives for the technical study were:

1. Develop ecological criteria that will preserve trophic status of Big Payette Lake as a drinking water supply and protect other designated beneficial uses.

2. Identify sources of nutrients that may contribute to eutrophication of Big Payette Lake based on potential risk that existing sources may degrade water quality.

3. Prioritize sub-watersheds based on their current contribution of nutrients. Determine the significance of change or intensity of land use and potential contributions of nutrient load.

4. Establish a maximum allowable limit of nutrient contributions for each sub-watershed such that trophic status of the lake will be preserved or enhanced.

5. Determine eutrophication response of Big Payette Lake through development of a nutrient response model to predict future trends based on changes in watershed land use.

Field monitoring would be conducted over two consecutive water years so that water, nutrient budgets and seasonal characteristics could be reasonably ascertained. A lake water quality model would be developed based on field monitoring to partition sources of nutrient loads and simulate lake responses based on future increases and reductions in the source loads. This analysis will be used to identify critical interactions of watershed runoff and expected lake capacity to assimilate these nutrients, develop load allocations to protect existing water quality and target specific sub-watersheds for improved implementation of best management practices (BMPs).

1.3 Overview of Study Components

Wildfires erupted within the study area during summer 1994 coinciding with the initiation of field studies. These fires occurred at the end of a prolonged drought cycle that coincided with an accumulation of ground fuels and standing dead spruce throughout the forest. The extent to which wildfires had modified the Payette National Forest landscape and potential transport of nutrients and water to Big Payette Lake was unknown at the time field studies were initiated.

A variety of field studies were utilized across different landscape scales to collect biotic and physical data. These results would be used to identify relationships between landscape characteristics (geology, land use, management history) and current watershed conditions that affect quality of local streams and productivity of Big Payette Lake. Since recent fire effects would likely mask other environmental variables, this objective has been modified to include an assessment of fire impacts and related changes in water quality and quantity. To the extent possible, pre-burn conditions and related changes in water quality and quantity have been estimated. Overview of the major study components are summarized below.

1.3.1 Mass Balance Budget of Nutrients and Water Entering Big Payette Lake

Inflows to the Big Payette Lake have historically been estimated by the change in storage of Payette Lake and subtraction of the gaged outflows. The North Fork Payette River is the single largest river flowing into Big Payette Lake. Water quality data for inflows have been infrequently monitored by various agencies. Outflow water quality has also been infrequently monitored by the U.S. Geological Survey, Idaho Department of Environmental Quality and the Idaho Department of Fish and Game. The quantity and quality of ground water entering the lake is largely unknown, although some unpublished ground water quality data exists related to development of the Payette Lake central sewage collection system completed in 1980.

Inflows from the North Fork Payette River during the study period were continuously monitored with the installment of a U.S. Geological Survey surface water gaging station. Other tributaries surrounding the lake were monitored for flows using a combination of continuous recording devices and periodic site visits. Water quality was monitored in conjunction with flow measurements of tributary inflows and outflows. Meteorological data is currently measured at the McCall airport.

1.3.2 Limnology

The objective of this study component was to adapt an existing lake model developed by the U.S. Corps of Engineers (Bathtub) for use with Big Payette Lake. In-lake studies were initiated to provide background data concerning the amount and distribution of nutrients, exchange of water and nutrients among major basins within the lake and general productivity of the lake algal populations. This information was used by the model to make inferences about relationships between lake water quality and nutrient inputs. This component of the study was contracted to the U.S. Geological Survey.

1.3.3 Nearshore Assessments

Nearshore water quality, periphyton composition and growth, and littoral plant community development was monitored throughout the perimeter of the lake shoreline. The purpose of this assessment was to determine potential linkages between shoreline development and nearshore water quality. Monitoring stations were selected to represent the full range of existing shoreline development. This portion of the project was contracted to the U.S. Geological Survey.

1.3.4 Watershed Assessments

Monitoring objectives included an assessment of the nutrient and flow contribution of priority streams, stream stability and overall habitat condition as it relates to maintenance of fisheries and water quality. Information from this effort can be used to target specific sub-watersheds for implementation of Best Management Practices (BMPs) or other strategies to reduce nutrient and sediment loading.

A major focus of the watershed study was to characterize the quantity/quality of runoff from the watershed. Two approaches of study and evaluation were employed: 1) evaluating existing conditions attributed to non-point sources in a variety of major sub-watersheds draining to the mainstem of the NF Payette River above Big Payette Lake and other streams directly entering the lake, and 2) evaluation of urban stormwater quantity and quality directly entering the lake.

Stream habitat conditions were monitored using a combination of semi-quantitative habitat and bioassessment techniques. Field monitoring was conducted by Idaho Division of Environmental Quality, Payette National Forest and Idaho Department of Lands. Analysis of the data was contracted to the University of Idaho.

1.3.5 Watershed Sediment Sources and Contributions

Sediment sources and quantities attributed to the recent wildfire and forest management activities were estimated for National Forest and State managed forest lands within the watershed. Sediments attributed to the types of harvest activities, acreages and associated roads were estimated in conjunction with mass wasting (landslides). Field monitoring and analysis was contracted to private consultants.

1.3.6 Sediment Accumulation Rates of Big Payette Lake and Upper Payette Lake

The rate of sediment accumulation rates were determined by lead 210 dating of cores extracted from Big Payette Lake and Upper Payette Lake. Estimates of the rate of sedimentation were compared to past management activities and current estimates of sediment contributions. Field collections were conducted by the Idaho Division of Environmental Quality and Utah State University, Natural Systems Engineering.

1.3.7 Recreational Impacts

Sources of bacterial contamination were monitored in relation to recreation within the watershed and Big Payette Lake. Monitoring focused on high use areas and peak holiday seasons. Field collections were conducted by the Idaho Department of Fish and Game and Idaho State Parks.

1.3.8 Creel Survey and Boating Recreation

The Idaho Department of Fish and Game and Division of Environmental Quality jointly funded a creel census and boating recreation survey on Big Payette Lake. The purpose of this assessment was to determine current fishing activity and potential relationship to current lake water quality. Field monitoring and analysis was conducted by Idaho Department of Fish and Game.

Chapter II

2.0 Watershed Description

2.1 General Description of Watershed

2.1.1 Lake

Payette Lake is a 2,023 hectare (5,000 acre) lake located on the Payette River (Figure 2-1) at river kilometer 121.3 (mile 75.4; lake outlet). Maximum lake depth is about 300 ft (see Figure 3.3 on page 39) (mean 103 ft) with a total volume of 500,137 ac-ft. Total volume of the lake is regulated by a spillway that allows lake surface elevation to vary 5-6 feet annually. Full pool is normally maintained July-September. The lake has a complex shoreline forming four distinct basins (Southwest Basin, Central Basin, North Basin and the Southeast Basin). Daily inflows to the lake are not measured but outflows are estimated by U.S. Geological Survey gaging station located downstream of the dam on the N.F. Payette River. Annual outflows are approximately 266,600 ac-ft. Although groundwater tables are high throughout the valley, the contribution of groundwater to the lake water budget is unknown.

Stratification of the lake occurs around mid summer and the lake remains stratified into December. Payette Lake has been classified as mesotrophic. Chlorophyll values during summer 1993, ranged from 0.5 - 2.5 µg/L (Worth, unpublished data). Water clarity generally exceeds 7 m in all basins. In addition, significant submerged macrophyte growth occurs within a narrow depth range along the lake shoreline. Organic loading of the lake has depressed dissolved oxygen levels in the lake hypolimnion during summer and winter. Continued organic loading could result in development of anoxic conditions and release of sediment stored nutrients and metals.

2.1.2 Watershed

The Big Payette Lake Watershed is approximately 373 km^2 (144 sq. miles; approximately 18 times larger than the lake). Topography of the watershed is mostly mountainous. Elevations range from 5,000 feet around McCall to 9000 feet in the Lick Creek Range. Soils are volcanic in origin and comprised of alluvium and glacial outwash characterized as highly weathered and decomposed. Drainage characteristics are poor to excessive depending on depth to water table and slope. Numerous small creeks flow into Payette Lake. The single largest inflow is N.F. Payette River. Land uses are predominately forest land (federal and state land) which supports commercial logging and extensive recreation. Other land uses are present within the basin but no information exists characterizing their acreage or importance in watershed hydrology and nutrient export. The City of McCall is situated at the south end of the lake [population 2,629 (1994)]. A significant influx of seasonal usage occurs during the summer (summer cottage use) and during the winter (winter sports).

Figure 2-1. Location of study area.

Land ownership (Figure 2-2) and/or regulation within the basin includes but is not limited to four major entities or units of government composed of the Payette National Forest (77,449 acres), state lands (16,184 acres), private (3,000 acres), and City of McCall (1,200 acres).

2.2 Designated Uses and Benefits of the Watershed

The Idaho Water Quality Standards and Wastewater Treatment Requirements designate beneficial uses for Payette Lake as: domestic water supply, cold water biota, salmonid spawning, and primary/secondary contact recreation. The Department of Parks and Recreation, and the City of McCall operate and maintain recreational access to the lake for a variety of uses (boating and fishing are the most popular). Facilities include one public boat ramp (operated by the city) and numerous picnic areas and camping sites associated with the state park. Aesthetic value of the pristine lake conditions make Payette Lake one of the primary destination points of interest. Much of the shoreline is currently undergoing conversion due to increased commercial development and home construction.

2.3 Climate

The climate in the Payette Lake Watershed is characterized by warm, drier summers and cold, wetter winter months. Average annual precipitation at McCall [elevation 1,532 m (5,026 ft.)] is 660 mm (26.4 in.). Precipitation increases with elevation, with up to 914 mm (36.5 in.) per year falling on the mountain peaks (USFS 1995). Precipitation falls as snow in the winter months, and a deep snowpack accumulates, particularly at higher elevations. Mean annual snowfall is 384 cm (153.6 in.). Snowmelt peaks in May and June. Annual evapotranspiration is 940 mm (37 in.) based on climatological data summarized by Myron Molnan and K.C.S. Kpordze (University of Idaho, written communication, 1992). Drought conditions persisted during the period 1987 to 1994. Average annual precipitation during this period was several inches below normal.

2.4 Surface Hydrology - Watershed Delineation

Surface hydrology in the Big Payette Lake drainage basin is dominated by the North Fork Payette River Basin extending from its headwaters near Secesh Summit located on the northern edge of the North Fork Payette River basin boundary to the outlet of the Big Payette Lake (Figure 2-3). Contributing to the mainstem flow of the N.F. Payette River are several tributaries comprised of variable size sub-watersheds (Figure 2-3). The basin is roughly separated into three main sections: 1) Upper Payette Lake basin comprised of the upper reach of the N.F. Payette River and associated tributaries; 2) mainstem N.F. Payette River and its associated tributaries, and; 3) direct drainage of sub-watersheds draining directly to Big Payette Lake. Additional smaller streams flow directly into Big Payette Lake (Table 2-1 and Figure 2-3).

In addition to the above streams, there are numerous high mountain lakes associated with strongly glaciated lands, which include landforms such as headwalls, rocky ridges, granite outcrops, and cirque basins. The majority of lakes lie within the cirque basins. Several larger lakes such as

Figure 2-2. Major land ownership categories of the Payette Lake watershed.

Figure 2-3. Streams and lakes in the Payette Lake watershed.

Granite, Little Granite, Ellis, Squaw, and Upper Payette Lake lie in alluvial landforms. Blackwell Lake is located in Valley Train Land. These lands provide an effective buffer for sediment from upland slopes. Potential productivity for timber and herbaceous vegetation is moderate to high due to the deep soils and high water table associated with this landtype.

The Payette Lakes watershed topography and relative size of the sub-watersheds can be divided into two broad categories depending on whether the landforms are the result of ice sheet or valley glaciation. In general, the watershed ranges in elevation from a low of 1,524 m (5,000 ft.) at the outlet of Big Payette Lake, to a high of 2,768 m (9,081 ft.) at Storm Peak in the northeast corner of the watershed. Four sub-watersheds are in the 4,047 ha (9,996 ac.)-4,857 ha (11,996 ac.) range (Fisher and Twentymile Creeks, the Upper Payette River, and Payette Lake), but in general the rest of the subwatersheds are under 2,000 ha (4,940 ac.). The predominance of smaller watersheds is a reflection of the ice sheet erosion, with an undissected terrain draining to small streams that feed directly into the Payette River. The central part of the watershed, affected by ice sheet glaciation, has a subdued terrain with numerous small lakes and a disrupted drainage system. The general grain of the area is from north to south, with a distinctive north/south jointing pattern visible in aerial photographs. The ice erosion deepened this jointing pattern and the drainage generally follows a checkerboard-like pattern. The higher elevations in the watershed were affected by the valley glaciation. Creeks with the distinctive U-shaped valleys in their headwaters include Fisher, Twentymile, Cougar, and Trail. The upper elevation parts of other creeks, like Box Creek, had smaller valley glaciers that formed cirque valleys in the headward parts of the streams, but merged with the ice sheet at lower elevations.

Table 2-1. Sub-Basins and Subwatersheds in the Big Payette Lake drainage basin.

Upper Payette Lake Basin Tributaries		Mainstem NF Payette River Tributaries		Big Payette Lake Tributaries	
Subwatershed	hectares	Subwatershed	hectares	Subwatershed	hectares
Up Payette Lake	1,596	Deep Creek	1,146	Big Payette	6,287
Upper N.F.	4,542	Pearl Creek	1,323	Deadhorse	1,248
Cougar Creek	973	Middle Reach	1,443	Lemah Creek	1,320
Twentymile	4,141	Fisher Creek	4,648	Fall Creek	1,733
		Brush Creek	2,199	Wagon Bay	563
		Box Creek	2,152	Sylvan Creek	550
		Copet/No-name	1,097		

Upper Payette Lake Basin Tributaries	Mainstem NF Payette River Tributaries	Big Payette Lake Tributaries			
		Twah	1,873		
Sub-Basin Total	11,252	Sub-Basin	15,881	Sub-Basin	11,701

(1 hectare = 2.47 acres)

Some of the subwatersheds, such as Fisher Creek and Upper N.F. Payette River, have the potential for high water-yields and are poorly drained, resulting in many wet meadows and swamps in the upper portions of their watershed. The majority of landforms and stream gradients are fairly gentle. Tributaries draining the steeper side slopes, and the lower three miles of Fisher Creek are exceptions, with gradients from 10-25 percent. The mainstem of Fisher Creek and Lake Creek tend to be high gradient, large substrate channel types. Channel stability is good in those sections of the stream where substrate consists of boulders and rocks. Lower gradient channels are interspersed with finer bed and bank substrate, typical of depositional landforms.

2.5 Agricultural Water/Lake Regulation

In the early part of the twentieth century several irrigation associations - Lower Payette Ditch Company, Farmers Co-operative Irrigation Company, Emmett Irrigation District, Noble Ditch Company, Enterprise Ditch Company and Letha Irrigation Company - filed claims for water rights in Big Payette Lake, Granite Lake, Box Lake and the Upper Payette Lake. They formed the Lake Reservoir Company (Company), an Idaho Nonprofit Corporation, to represent their collective interests in the Big Payette Lake and its watershed.

About the same time the beaches around these lakes became popular due to their recreational and health benefits. To protect these recreational and health benefits, a group of area permanent and seasonal residents formed the Payette Lakes Protective Association (Association), also an Idaho non-profit corporation.

In November 1924, the Company and the Association signed an Agreement (Agreement). The Agreement included a high and low water mark and recognized the Company's storage rights to approximately 31,000 acre feet in Big Payette Lake (Lake) which were issued in 1924. That Agreement in part states that the Company..."draw off said stored waters so as to interfere as little as possible with the bathing beaches on the shores of said Lake, and ....so as not to interfere any more than is absolutely necessary with the natural fluctuation of said waters, that is, any more than is necessary to carry out the intents and purposes of the [Company] under its...permits".

Later in 1926 the Legislature enacted and the Governor signed into law Chapter 43, Title 67 Idaho Code (codified at 67-4301 et seq.) which established Big Payette Lake as a health resort and recreation place. In relevant part, the law provided that:

> "The Governor is hereby authorized and directed to appropriate in trust for the people of the state of Idaho all the unappropriated water of Big Payette Lake, or so much thereof as may be necessary to preserve said lake in its present condition. The preservation of said water in said lake for scenic beauty, health and recreation purposes necessary and desirable for all the inhabitants of the state is hereby declared to be a beneficial use of such water...the preservation of said lake in its present condition as a health resort and recreation place for the inhabitants of the state and said public use is hereby declared to be a more necessary use than the use of said lands as a storage reservoir for irrigation or power purposes."

In 1924, the Company's water rights were issued appropriating 31,000 acre feet of Lake water, thus the Company's appropriation pre-dates by two years the enactment of the 1926 statute which appropriated the remaining unappropriated water in Big Payette Lake.

In the early 1940's the Company, believing its members had rights under their irrigation permits to 50,000 acre feet in Big Payette Lake rather than 31,000 acre feet, challenged the high water restriction imposed by the Agreement. A lawsuit was filed in the Fourth District Court of the State of Idaho. District Judge Koelsch ruled that the Agreement was legally valid and enforceable. He also retained orders concerning the manner of storing, retarding, withdrawing, diverting, measuring and registering the waters of Big Payette Lake...". The Company appealed Judge Koelsch's ruling to the Idaho Supreme Court. The Supreme Court upheld Judge Koelsch by ruling in favor of the Association.

The Company owns the dam on the North Fork of the Payette River where the River leaves the Lake. The Company's water master controls the gates to the dam. The Company during average years has raised the water level in the Lake in mid July to the maximum allowed and thereafter retained it at that level for a few days depending upon snow depths and storm events. As the Company has withdrawn water, the water level in the Lake has dropped steadily through Labor Day but has remained high enough for general recreation, resort and related use. After Labor Day the water level is dropped to a minimum level sufficient to protect the dam from ice damage due to the Lake freezing over.

At the request of the Big Payette Lake Water Quality Council (created under Chapter 66, Title 39, Idaho Code), in 1996 the U.S. Geological Survey prepared a historical hydrograph titled, "Payette Lake - Historical Hydrograph of Mean Daily Lake Surface Elevation for Period of Record to 95 WY" (Figure 2-4). This hydrograph represents an historical average of how the Company has managed its affairs in accordance with the Agreement.

2.6 Lithologic Units

The Payette Lake watershed contains a complex set of lithologic, or rock, types. Within its boundaries are ancient sediments that have been metamorphosed by the large bodies of magma that later intruded much of central Idaho.

Figure 2-5 is a lithologic map that depicts the location of the various lithologies within the area. The map was compiled and generalized from geologic maps by Manducca (1988), Hamilton (1969), Lund (in press), and Othberg (1987). Table 2-2 lists the map symbol and name of each lithologic unit found within the watershed. The following text describes each lithologic unit.

Table 2-2. Lithologic units

Map Symbol	Lithologic Unit
ms	modern sediments, includes stream and glacial sediments
gt	glacial till, unsorted boulders to clay
gs	glacial sediments, sorted sand and clay
gr	granite, glaciated
gn	gneiss, glaciated
sch	schist, glaciated
bs	basalt, glaciated

Figure 2-4. Payette Lake - Historical Hydrograph of Mean Daily Lake Surface Elevation for Period of Record To 95 WY.

Figure 2-5. Major rock types of the Payette Lake watershed.

The Payette Lake watershed lies on the western border of a granitic feature called the Idaho Batholith. This terrain covers large areas of central and northern Idaho, from the Clearwater River on the north to the Sawtooth Mountains on the south. The most recent and detailed geologic mapping of the watershed is by Cathryn A. Manducca (1988) and Karen Lund (in press).

In Manducca's dissertation, she divides this "western border zone" of the Batholith into three areas or terrains of similar rocks. From west to east, these terrains are the Hazard Creek, Little Goose Creek and Payette River Complexes. Each complex contains both granitic rocks of various kinds, and metamorphic rocks, mainly gneiss and schists. The granitic rocks are associated with the larger bodies of granite located to the east of the watershed. The metamorphic rocks are older sedimentary and volcanic rocks that were intruded by the granitic bodies/magma chambers. The majority of the Payette Lake watershed is underlain by the rocks of the Payette River Complex. As shown on Figure 2-5, most of the watershed is underlain by the granitic rocks [17,936 ha (44,301 ac.)]. Smaller areas of metamorphic gneiss [7,489 ha (18,497 ac.)] and schist [2,174 ha (5,369 ac.)] outcrop in north/south trending bodies on the eastern and western edges of the watershed (gneiss) and in the area north of Granite Lake (schist). In general the metamorphic rocks are layered, and include some small areas of quartzite and calc-silicate rocks. The granitic rocks have a salt and pepper look of dark and light minerals, and are unlayered.

After the granitic and metamorphic terrains were created, the area was inundated by the massive basalt flows (unit bs). These volcanic rocks presently occur only in one small part of the watershed, the arm of land that divides the two parts of Big Payette Lake and is the location of Ponderosa State Park. This area is an eastern remnant of much larger area underlain by thick and extensive basalt lava flows, called the Columbia River Basalt (C.B.). Covering most of central and eastern Washington, areas along the western border of the state of Idaho, and areas of northern and eastern Oregon, the flows are called flood basalt. They are voluminous with sequences of flows ranging up to 800 meters thick and encompassing a total volume of 300,000 cubic kilometers (Camp and others, 1982). In central Idaho, the basalt flows are part of what has been called the Weiser Embayment by geologists (Fitzgerald, 1982). Although some of the basalt flows in this area are part of the general C.B. units that erupted from a series of vents in northeastern Oregon, other units were erupted from two vents in the Weiser area. The flood basalt covered the topography like water filling a bathtub and disrupted the drainages. Since their eruption, the basalt sheets have been displaced by the faults that form the sides of Long Valley.

All of the rocks in the entire Payette Lake watershed have been severely affected and reshaped by glacial erosion during the ice age in the Pleistocene era. The glaciation occurred in two periods between 160,000-125,000 years ago and between 25,000-15,000 years ago. In the Payette Lake watershed the glaciation was of two types, ice sheet and valley glaciation. The valley glaciation formed the dramatic U-shaped stream valleys, called troughs, and the steep peaks and smaller cirque valleys found in the higher elevations of the watershed streams. Typical of this type of glaciation are the Twentymile Creek drainage, and the upper parts of the Fisher Creek drainage. Generally the cirque valleys contain small lakes, like Box Lake and the Twentymile Lakes. Small valley glaciers carved the cirque valleys and fed into the larger valley glaciers that filled the major stream valleys, like Twentymile Creek. These troughs were cut to lower elevations than the tributary cirque valleys by the greater thickness and mass of the ice that filled the larger valleys. This action left the cirque valleys "hanging" above the level of the trough floors. The troughs have classic "U" shaped cross sections, with wide floors and steep (50% to >65%) walls.

The ice sheet glaciation affected the central part of the watershed. In this area a large sheet of ice completely covered the terrain, eroding the topography to its present low relief. In addition, it carved out the basins of Upper and Big Payette Lakes. Two types of lithologies that were deposited by the ice and stream melt waters are mapped on Figure 2-5. The glacial till (gt) deposits form the morainal material surrounding the smaller and larger lakes in the watershed. These sediments are basically unsorted, having a size range of particles that varies from clay to boulder. The glacial sediment deposits (gs) are the result of the streams of meltwater that resulted from the annual and final retreat of the glaciers. These units are well sorted and range in size from clay to sand, with a few cobble-sized pieces. Outcrops of these fine-grained sediments are confined to the area surrounding Big Payette Lake. The uncemented and unconsolidated nature of the glacial sediments, and their locations in the cirque valley and trough floors, mean that they are fairly easily eroded by surface erosion processes.

Both surface erosion potential and landslide hazard are enhanced by the steep nature of the glaciated trough and cirque valleys. The oversteepened nature of the trough valley walls lends itself to the creation of debris slides and snow avalanches. In addition, surface erosion processes in glacial terrains move sediments down from the valley walls at higher rates than those found in areas only affected by stream erosion. However, once the sediments reach the main stream channels, the flat nature of both the cirque and trough valley floors mean that the sediments do not necessarily move through the system at the same rates as similar sediments in unglaciated terrains. In this way, the trough valleys of the Payette Lake watershed have more capacity to store sediments than valleys in unglaciated terrains.

These characteristics of surface erosion and landslide potential are reversed in the parts of the watershed affected by the ice sheet glaciation. These areas now have fairly low relief terrains, with numerous small lakes. In addition, most of the soil and weathered rock have been stripped off by the erosive action of the glacier. Therefore, these areas have less material to be eroded by natural surface erosion processes.

The youngest lithologic unit is the modern stream sediments (ms) which are located in the bottoms of all the larger streams, such as the Payette River. It is composed of sediments that were deposited by the streams within their current or recent stream channels and floodplains. These sediments can range in size from silt to boulder, but in this watershed are predominantly sand, gravel, and cobble-sized, due to the source rock for much of the sediment, the granitic rocks. These sediments are uncemented and thus highly erodible during spring runoff and other flood events. They are generally moved around and transported within the stream channels.

2.7 Geography and Dominant Landform Associations

The geology and soils within the Big Payette Lake Watershed have a significant influence on the quantity, quality and timing of runoff generated from the landscape. The landscape within the watershed is grouped according to a landtype association used by the Forest Service based upon similarities in geomorphic processes, geologic rock types, soil complexes, stream types, lakes, and potential natural vegetation. General landscape characteristics in the drainages were classified into three geomorphic groupings of landtype associations summarized by the following:

Alpine Glaciated Lands: These lands include high-elevation mountain peaks and glacial valleys shaped by the scouring action of alpine glaciers. Harsh climatic conditions, steep slopes, fragile soils and extensive areas of exposed bedrock limit productivity and management opportunities. This geomorphic group is further subdivided into smaller landtype associations based on slope gradients and other common characteristics.

- Glacial Headlands (40-80 percent slope): Slopes greater than 60 percent are associated with rock outcrop escarpments and talus slopes below narrow ridges. Mean annual precipitation, dominated by snow, averages 35 to 50 inches, of which 50-90 percent is yielded as streamflow. Surface runoff is high due to the extensive areas of exposed bedrock and shallow soils. Soils have moderate-to-moderately-high hazard ratings for surface erosion, and a moderately high risk for debris slides and avalanches in steep drainage channels.

- Glacial Scoured Uplands and Cirque Basins (10 - 40 percent slope): These are ice-scoured upland plains and cirque basins with moderate slopes. Precipitation amounts, climatic conditions, and water yields are similar to the Glacial Headlands. Some cirque basins contain small lakes and adjacent areas of wet alluvial soils. Water yield is high, resulting in both surface runoff and infiltration into shallow and moderately deep soils. Dominant soils have moderate erosion hazard ratings and mass stability hazards are generally low.

- Glacial Trough Lands (40-70 percent slope): These are U-shaped valleys and trough walls (average slopes of 30 to 60 percent) formed by glaciers. Surfaces typically contain scattered debris and deposits from glacial erosion. Mean annual precipitation averages 25 to 50 inches, of which 25-45 percent is yielded as streamflow. Steeper valley side slopes (40 to 70 percent slope) are moderately dissected by parallel drainages that are subject to high surface runoff. Soils have moderate erosion hazard ratings, and there is a moderately low risk for debris slides and avalanches on these lands.

Periglacial Uplands and Mountain Slopes: These are gentle-to-moderately-steep slopes found between the strongly glaciated lands and lower-elevation fluvial lands. This geomorphic group has been formed by glaciation but surfaces have not been scoured by major ice currents. Slopes are relatively stable and contain rolling uplands and smooth mountain slopes averaging 15 to 40 percent. Mean annual precipitation averages 25 to 45 inches, of which 30-80 percent is yielded as streamflow. Water yield is high, with most water returned to streams by subsurface flow. Soils have moderate erosion hazard ratings, and the risk for debris slides and avalanches is moderately low.

Depositional Lands: This geomorphic group is created by depositional processes originating from glacial, fluvial, or glacio-fluvial activity. These lands generally occupy gentle slope gradients in lowland positions with regard to surrounding landscapes, and nearly all are in close proximity to streams and water. These relatively stable lands contain two landtype associations:

- Moraines and Outwash Plains: These low, hilly landforms (0 to 20 percent slopes) comprise the valley bottoms and glacial trough floors where glacial deposits have accumulated on gentle slope gradients of 0 to 20 percent. Mean annual precipitation averages 25 to 50 inches based on elevation, of which less than 30 percent is yielded as streamflow. These lands provide effective buffering and storage capacity for water supply to perennial streams. The upper reaches of streams are stony and resistant to damage from high runoff, but the middle and lower reaches are more prone to damage from peak flows. Subalpine vegetation communities include stands of Engelmann spruce, subalpine fir, and lodgepole pine. Riparian community types are commonly found near alluvial lands and in small depression areas with high water tables. The inherent erosion hazard is moderately low to moderate, and there is low risk for mass movements.

- Alluvial Lands: These nearly level to gently sloping landforms (0 to 15 percent slope gradients) include valley bottomlands, floodplains, stream terraces, and alluvial fans along major drainageways and wet meadow basins. Mean annual precipitation averages 15 to 40 inches based on elevation, of which less than 30 percent is yielded as streamflow. Riparian community types are associated with high water tables and wet soils, whereas drier low-elevation sites commonly have shrub/grass communities. Their lowland positions are commonly associated with poorly drained soils, high water tables, and periodic flooding. The inherent erosion hazard is moderately low, and there is low risk for mass movements.

2.8 Vegetation Cover

Vegetation within the Payette Lake drainage basin is largely dominated by two major vegetation associations; Subalpine Fir and Grand Fir. These associations are the result of complex interactions between soil, climate, elevation and aspect that promote and delineate a specific vegetation composition. The Subalpine Fir Habitat Type is common in central Idaho at cool, moist high elevations on glaciated, periglacial and depositional landforms. Within the Subalpine Fir series, three principle stands of tree cover are prevalent and include lodgepole pine, Engelmann spruce and subalpine fir; whitebark pine, Douglas-fir and western larch can occur to a lesser extent. The understory can include huckleberry, mountain maple, spirea and beargrass. Due to adequate moisture, stand-replacing fires infrequently burn in these forests and trees are typically large. In many cases wind and insects cause more disturbance than fire. About 95% of National Forest lands and 70% of state lands within the landscape contain this vegetation series. Prior to the 1994 fire, most of the land area within this vegetation type was in a late successional stage, which is characteristic for the long intervals between fire frequencies in this series.

The Grand Fir Habitat series is found in areas between the drier Douglas-fir zone and the cooler subalpine fir zone on glaciated, depositional and fluvial landforms. Most of this series occurs in the southern portion of the Big Payette Lake drainage within the State Lands management area and along the extensive southern aspect of Twentymile Creek. Ponderosa Pine, Douglas-fir, Lodgepole Pine, Engelmann spruce, Western Larch, and Aspen may be present depending on the successional stage. Understory species include Pinegrass, Spirea, Huckleberry, Beargrass and Mountain maple. Pre-fire assessments of growth stage suggest this series was also dominated by mature/overmature populations. A more detailed review of the vegetation types and fire series is described in the Blackwell Fire Assessment (USFS, 1995).

2.9 Management History

Timber management history within the watershed began 1914 to 1922 when a portable saw mill was established in Squaw Meadows (Upper North Fork Payette River) to manufacture railroad ties (USDA, 1966). Other incursions for timber harvest were not renewed until the later half of the century. Timber harvesting began in Fisher Creek sometime after 1947, Twentymile Creek beginning in 1968, Brush Creek in 1955, Pearl Creek in 1966, and Deep Creek in 1984 (USDA,1995a).

More recent timber management history within the Big Payette Lake drainage basin was assembled from historical aerial photography dating back to the early 1950's (see Management History Appendix Figures and Table 2-3). Effects of timber management prior to this period, although important, were not well documented. Moreover, due to recovery and regrowth, management activities preceding this period were not expected to be a dominant feature within the landscape and thus, less likely to be a source of surface erosion. A variety of harvest methods were employed throughout the past fifty year period. Early practices included liberal use of tractor clear cutting with skid trails. More recent methods have included use of helicopter, skyline and less frequent use of skid trails and clearcutting. The acres harvested increased substantially in the 1990's due to salvage sales of insect damaged trees (Table 2-3). Since its initial passage by the State Legislature in 1974, the Idaho Forest Practices Act has been instrumental in helping to reduce sediment inputs from timber harvest in the watershed. Insect infestation started in the late 1970's. At this time, the

Department of Lands and U.S. Forest Service entomologists predicted most spruce trees over 12 inches DBH (diameter at breast height) would be killed by the insects (Spruce Bark Beetle)

Table 2-3. Sale acres of timber harvest by decade.

Subwatershed	Watershed Acres	1950's	1960's	1970's	1980's	1990's	Total
Box Creek	5,318	0	0	0	0	725	725
Brush Creek	5,434	171	9	0	23	461	664
Copet Creek	1,838	0	0	0	0	25	25
Cougar Creek	2,404	0	0	5	0	1	6
Dead Horse	3,084	0	0	0	232	373	605
Deep Creek	2,832	0	0	0	35	0	35
Fall Creek	4,282	0	0	0	263	44	307
Fisher Creek	11,485	512	148	925	231	852	2,668
Lemah Creek	3,262	0	0	0	0	585	585
Middle Upper NF	3,566	0	0	0	118	661	779
No Name Creek	872	0	0	0	0	4	4
Payette Lake	15,535	0	0	398	163	5	565
Pearl Creek	3,269	0	364	41	61	142	608
Sylvan Creek	1,359	0	0	94	279	60	432
Twah	4,628	0	0	0	5	1,355	1,360
Twentymile	10,232	0	284	165	335	196	980
Upper NF Payette	11,223	0	614	780	834	257	2,485
Upper Payette	3,944	0	63	387	138	237	826
Wagon Bay	1,391	0	0	94	6	0	100
Total	95,958	683	1,482	2,889	2,722	5,983	13,759

Grazing by sheep has also been supported within the rangelands and on lower gradient slopes in the watershed. Prior to the establishment of the Idaho National Forest (now the Payette National Forest) in 1908, livestock grazing was unregulated. Large bands of sheep were trailed into the area during this period, though the exact number of animals is unknown. The earliest grazing permit in the landscape was given in 1912 on the Pearl Creek and Twentymile allotments, and the first permitted use on State Lands occurred in the 1930's. Between 1912 and 1918, approximately 30,100 head of sheep were permitted to graze in the landscape. The Forest Service began monitoring and managing range conditions in the 1920's. Since that time, reductions in numbers, consolidations of allotments, and increased management have combined to improve range conditions. Currently, there are 4,600 head of sheep permitted in the landscape on both National Forest and State Lands.

Mining within the watershed has been limited. The sewer district had a sand pit and the county operated a sand and gravel pit for road improvements. The Warren Wagon road was initially built in the 1860's to access mines on the Salmon River drainage just north of the Upper Payette River drainage divide.

2.10 Fires

Forest records indicate that frequent fires have burned in Big Payette Lake drainage (History of

Payette National Forest 1966). In 1910 and 1930 there were several large fires (Rothery 1940). An insect epidemic that peaked in 1930 (spruce budworm, spruce beetle, and lodgepole pine mountain pine beetle) probably provided the fuels for the 1930 fires. The fires of 1994 were preceded by a Forest-wide spruce beetle epidemic that killed thousands of trees from 1985-1989. About 27 million board feet of this spruce mortality was salvage logged from 1,600 acres. Before effective fire suppression began in the 1940's, fires created large patches of young trees and left small patches of mature trees unburned. Human activity such as logging and fire suppression may currently be influencing vegetative patterns.

Although the Forest Service concluded that the wildfires in 1994 were within the historic range of variation for the subalpine fir habitat type prevalent in the region, these fires affected the sizes of vegetative patches, the composition and structure of stands, and the future potential of both fire hazard and insect disturbance. Over one-half (52%) of the landscape acres (including state and private land) within the Big Payette Lake drainage basin were burned [19,544 ha (48,273 ac.)]. Natural fire breaks and different burn intensities, however, created a mosaic of islands of unburned vegetation patches from 50 to 700 acres in size. Re-sprouting forbs and grasses were already observed by the fall of 1994, and much of the herbaceous layer had recovered by spring of 1995.

Tree mortality by fire was estimated and separated into three classes (Figure 2-6), depending on the number of dead trees at the time surveys were conducted, plus those projected to die within the next five years. High mortality designations represent areas where the expected number of trees killed by fire ranged from 70-100% mortality [11,753 ha (29,029 ac.)]; moderate varied from 30-70% mortality [5,181 ha (12,797 ac.)]; and low designations were those of less than 30% [2,602 ha (6,426 ac.)]. Patches of green trees exist within both the high and moderate mortality areas. Large patches of high and moderate mortality areas were created, while the low mortality burns were smaller in size. The extremely large amount of high mortality in the northern portion of the landscape was a result of a "blow-up" where the Blackwell and Corral Fires merged within the Upper Payette Lake basin due to heavy fuels of dead trees.

Intensity (heat generated by the fire) can affect both the structure and composition of vegetation by eliminating seed sources and by increasing competition for space and nutrients by more opportunistic species. In the subalpine series, the acres of mature/overmature trees has been dramatically reduced from about 80% to 45%. Conversely, the number of seedling, sapling and pole class trees is expected to increase from 5% to around 40%. Spruce/fir stands at the higher elevations could take as long as one hundred years to establish trees. A large portion of the high and moderate intensity burn acres are expected to reseed back to lodgepole pine due to reduced numbers of spruce and subalpine fir seed trees.

Figure 2-6. Fire related tree mortality in the Payette Lake watershed.

The grand fir series is not expected to experience significant change in structure and composition due to lower tree mortality. The mature/overmature age class has been reduced by about 10%; the immature class reduced by 5%; the seedling, sapling, pole age trees will increase by 5%.
Pioneer species, such as Ponderosa Pine, Western Larch, Douglas Fir, and Lodgepole Pine, will slowly seed in the high mortality areas and the larger openings within the moderately burned areas.

Additional damage by fire and insects may further alter the balance in forest health and cycling of nutrients. Dead snags and fallen timber has created increased amounts of standing and ground fuel loads. Risk of rapid rates of fire spread in previously burned areas will likely be minimal in the near future due to the removal of fine fuels, which are low in areas that experienced high and moderate severity ground fires. A potential for fire exists in areas of spruce and fir where low mortality, accumulation of fine fuels and snags exist. The remaining green stands of mature/overmature spruce and fir are also vulnerable to ignition. Increased insect activity can be expected within the burn area for the next 2 to 5 years. Fire-stressed trees are frequently attacked by insects and provide suitable habitat for insect brood survival.

2.11 Fisheries and Wildlife

2.11.1 Lake Fishery

Payette Lake has a long history of providing important fishery benefits. The earliest records documented a subsistence fishery on both big(sockeye salmon) and small(kokanee) redfish in 1894. Evermann, 1896, reported 25,000 sockeye salmon being captured at Lardo, Idaho and another 75,000 Payette Lake-bound sockeye were harvested at the mouth of Gold Fork. Early settlers salted these fish for year long consumption. The fish from Payette Lake played an important role in settling the McCall/Cascade area.

The sockeye salmon run was blocked by the construction of Black Canyon Dam in the 1920's, but the fresh water kokanee population persisted, providing much of the fishing opportunity to the present. The Idaho Department of Fish and Game has intermittently stocked kokanee but most of the kokanee result from natural spawning on the lake’s shoreline and in the North Fork Payette River above the lake. The IDFG introduced lake trout (mackinaw) in the late 1950's and cutthroat trout in 1988. These three fish species require cold, clean, clear water with high dissolved oxygen content. The cold infertile water of Payette Lake favors kokanee, lake trout and cutthroat over other species, that is why these fish were chosen to be the base for fishing in the lake. In fact, the number of fish caught would probably improve if Payette Lake had more nutrients, but the fish community would have to change. Rainbow trout, yellow perch, brook trout, suckers and squawfish would displace the colder water species. Importantly, the water clarity and color would also change as the nutrients stimulate algae growth. The IDFG senses that this is not what is desired of Payette Lake and the existing and future fisheries management planning accommodates the high value of nonfishing recreation while preserving fishing opportunities on coldwater fish species.

2.11.2 Watershed Fishery

The watershed to Payette Lake includes some very interesting and valuable fisheries. The N.F.Payette River not only provides clean water to Payette Lake, but it also provides the gravel needed for kokanee, rainbow and cutthroat spawning and incubation. The N.F.Payette River also supports rearing populations of rainbow and cutthroat trout. Adult rainbows ascend the river for spawning and sporadically during the summer to take advantage of aquatic insect hatches. Plants of hatchery rainbow trout support a popular trout fishery throughout the summer.

Fishing, camping, hiking, ORV use, canoeing and swimming are common activities for recreationists using the N.F.Payette River above Payette Lake. Planting fish improves fishing success and stimulates angler use of the watershed. Recreationists can negatively effect water quality through inappropriate activities. The impacts might include littering, improper human waste disposal, trampling streambanks and spilling household or automotive materials. These impacts are lessened by programs that educated recreationists that their activities can damage the resources that they are there to enjoy. Signs, brochures, campground programs, and personal contacts by natural resource workers are effective methods to reduce impacts from recreational use of the watershed.

Streamflow

In many ways, the flows in the N.F.Payette River effect the health of the fish populations and the quality of water in Payette Lake. Idaho Code 42-1501 declares minimum flow to be a beneficial use for the protection of fish and wildlife habitat, aquatic life, recreation, aesthetic beauty, transportation and navigation values, and water quality. IDFG personnel measured stream flows and other habitat parameters on transects within three river reaches representative of the river's habitat types. Instream Flow Incremental Methodology and Physical Habitat Simulation System were used to quantify the amount of potential fish habitat available for each life history stage of salmonids that occur in the upper N. F. Payette River (Trihey and Wegner, 1981). This method is designed to demonstrate the impact of incremental changes in stream flow on fish habitat (Fig. 4-32). It will be used to identify and pursue streamflows that will continue to support the beneficial uses. Other analyses can compare flows and the other uses.

The tributaries of the N.F. Payette River support naturally reproducing populations of rainbow, cutthroat and brook trout. A myriad of alpine lakes dot the watershed. Blackwell Lake and Brush Lake are managed for trophy fishing experiences using a 20-inch minimum size limit to allow the fish to attain larger sizes. Alpine lakes provide excellent fishing and have the highest "approval" rating among anglers for any fishing opportunity in the state (Reid, IDFG,1989). Pearl Lake, Box Lake and Twenty-mile Lakes are also very popular.

Upper Payette Lake and Granite Lake are manmade reservoirs covering natural lakes. Both contain complex fish communities of non-game and gamefish species. Both are liberally augmented with hatchery rainbow trout. Both lakes have recently received introductions of splake, a brook trout X lake trout hybrid.

Current Program and Future Plans

The current fishery program in Payette Lake is based on naturally produced kokanee, natural and hatchery-enhanced lake trout, introduced and hatchery-augmented cutthroat, and natural and stocked rainbow trout.

Kokanee are, and will continue to be, the major species supporting sport fishing on Payette Lake. They not only provide 73.1% of the total harvest, they also provide the prey base for the lake trout. The IDFG annually monitors the kokanee population using mid-water trawling techniques and by counting the number of adult fish in the spawning run. Mid-water trawling techniques are described in detail in Grunder (1990) and Bowles et al. (1986,1987). In general the mid-water trawl is a long funnel shaped net with a ten foot square mouth. This net is pulled through the water at various depths. The number of kokanee caught in the net is directly proportional to the total number of fish in the lake. The number of kokanee caught in the trawl is then expanded to give an estimate of the total kokanee population in the lake.

The kokanee spawning run is enumerated by walking the entire stretch of the N.F. Payette River that is utilized by spawning fish and counting all live fish. This count is made every three to four days until the number of fish counted begins to decrease. The peak count is then multiplied by a correction factor of 1.73 (Frost 1994).

Since 1992 kokanee population estimates have increased. From 1988 to 1996 the age 1+ population estimate has increased from <2000 to 132,000 fish (Figure 2.3).

There has also been a dramatic increase in the number of spawning kokanee in the N.F. Payette River. Between 1988 and 1996, we counted 14,500 to 60,707 adult kokanee (Figure 2.4). These values should produce good fishing for kokanee and an adequate prey base for the lake trout. Angling success is not as high as is desired, but the trend appears upward in 1995 and 1996.

Lake trout provide a trophy component to the Payette Lake fishery. Lake trout fishing on Payette Lake is excellent when compared to other lakes nationwide. In the 1988 samples, more than ½ of the fish exceeded 15 pounds. This species was introduced in 1955, intermittent hatchery plants continued until 1985. Fishing pressure on lake trout has been relatively low, until recent years. This allowed a large, "old growth" population to establish in the lake. Beginning in the mid-1990's, angler interest and participation increased. Signs of over harvest of large fish (>30") became apparent when we compared 1988 data to 1994-1995 data. Public opinion favored maintaining/restoring the large fish to the population. A trophy regulation was implemented in January 1996, requiring release of all lake trout under 36" and allowing only 1 fish per day. Population sampling also showed very few juvenile lake trout to be present, suggesting limited reproduction or poor early survival. 1000 fin-clipped, 9-inch lake trout will be stocked in the spring of 1997. These fish will be tracked for several years to determine the need for future stocking.

Westslope cutthroat trout were introduced in 1988. Initially they were scatter planted around the perimeter of the lake. Additionally, fry/fingerlings were stocked in many of the N.F. Payette River tributaries, and stocked 9-10" yearlings in the N.F. Payette River between Payette Lake and Upper Payette Lake.

In 1991, a net pen rearing operation was begun in the lake near Sports Marina. This is a community project with the Reed Gillespie Central Idaho Chapter of Trout Unlimited (TU) being the lead partner. The City of McCall owns the walkway/dock. The IDFG provides the fish, technical assistance and much of the feeding and stocking labor. The McCall Chamber of Commerce supports the program and plans to help on an as needed basis. Several other organizations helped with the construction of the facility.

Cutthroat provide a limited but increasingly important component to the fishery. Cutthroat are shoreline oriented, as opposed to the deep water habits of kokanee and lake trout, thereby giving shore-based or small boat anglers a target species suited to their fishing techniques. A return to scatter planting yearling cutthroat and conversion of the net pens to rainbow trout rearing is planned beginning in 1997.

Rainbow trout provide 15.3% of the total catch from Payette Lake. Of which, 72.5% are from natural origin and 27.5% are from hatchery stocking. Scatter planting 5,000, 9-11" rainbows occurs each year, targeting planting sites with good angler access to encourage good return-to-the-creel. Natural rainbows enter the lake from spawning and early rearing areas in the N.F. Payette River and its tributaries. Some natural rainbows contribute to angler catches in the N.F.Payette River. We are in the process of evaluating a segment of the N.F.Payette River for quality fishing management, but early indications suggest that protective regulations would not affect a significant response in the population. Quality management would likely displace traditional bait anglers.

2.11.3 Wildlife In The Watershed and Lake

The Payette Lake watershed contains a variety of wildlife habitats, and therefore, supports a variety of wildlife species. The watershed lies in Game Management Unit 24 which is an important hunting unit. It has general archery and rifle hunts for both elk and deer, as well as a popular controlled muzzleloader elk hunt. Black bear, mountain lions and snowshoe hares can also be taken during open seasons. Fox and other furbearers (including beaver, mink, marten, and muskrat) are available to trappers. River otter and fisher live in the watershed, but are protected from hunting or trapping. Predatory mammals include the coyote, skunk, and weasel. Many nongame mammals inhabit the N.F. Payette River drainage, these include pine squirrels, flying squirrels, ground squirrels, chipmunks, pika, hoary marmots, and various mice, voles and wood rats.

Several migratory waterfowl nest in or migrate through the watershed. Major nesters are Canada geese, mallard ducks, wood ducks, mergansers, green-wing and cinnamon teal. Snow geese and trumpeter swans are regular visitors.
Many raptors use the watershed. Bald eagles nest in the vicinity and regularly hunt the lake and heavily utilize the kokanee during their spawning run. The same is true for osprey. Red-tailed, Swainson’s, Ferruginous, and rough-legged hawks are common. Peregrine falcon are occasionally reported. Kestrel, Sharp-shinned hawks, and Goshawks are relatively common. Great horned, great gray, boreal, saw wet, and screech owls inhabit the watershed.

Shorebirds and other water-oriented birds frequent the area. These include sandhill cranes, great blue herons, sandpipers, kingfishers, and dippers. Many neotropical birds rely on the area’s habitat for much of their life. These bird species range from hummingbirds to thrushes. Several woodpeckers benefit from the old growth forest in the McCall area, the largest is the pileated woodpecker. Crows, ravens, vultures and magpies help to clean the area of carrion. Blue grouse, ruffed grouse and spruce grouse support popular hunting seasons.

Mammals that use Payette Lake directly include river otters, mink, muskrats and beavers. The latter two species can, at times, become bothersome to humans when they burrow into Styrofoam dock logs or chew down ornamental trees. The IDFG offers advice to property owners on how to reduce or prevent damage.

As mentioned earlier, bald eagles and osprey depend on the lake's fish population for important food sources. Western grebe and Canada geese use the lake during the parts of the year when the lake is ice-free. As with the beaver, Canada geese are viewed by landowners and visitors either as a wonderful wildlife amenity or a destructive nuisance. The IDFG has monitored the goose population since 1994 and found a stable population of 225-250 geese. The goal is to maintain the population at about this level. If the population increases dramatically, then a trapping and relocation program will be initiated. The IDFG offers technical advice to help reduce "goose problems" on docks and lawns.

Phosphorus loading from waterfowl was estimated for the Cascade Reservoir Water Quality Management Plan (1991). From that evaluation, the Payette Lake goose population is estimated to contribute from 65.57 to 72.85 kilograms of phosphorus per year.

Most of the wildlife species mentioned in the previous section also frequent the shoreline of Payette Lake.

Chapter III

3.0 Methods and Materials

3.1 Lake Monitoring

3.1.1 Hydrologic Budget

The budgets accounted for the mass of water entering and leaving the lake via pathways such as streamflow, precipitation, evaporation, and change in lake storage. Such data were important components of the nutrient load/lake response model and were also used to compute nutrient budgets for the lake. Hydrologic budgets were computed with the following equation (quantities in cubic hectometers):

$$R = GTI + UTI + DSR + P - E - SWGO - MW - CS, \quad (1)$$

where

R is the residual;
GTI is gaged tributary flow;
UTI is ungaged tributary flow;
DSR is direct surface runoff;
P is precipitation to the lake surface;
E is evaporation from the lake surface;
SWGO is gaged surface-water outflow;
MW is municipal water withdrawal;
CS is change in lake storage.

Gaged surface-water inflows were measured at the USGS gaging station 13238322, North Fork Payette River below Fisher Creek, and at DEQ gaging stations at Dead Horse Creek and Fall Creek (Fig. 3-2). Gaged surface-water outflow was measured at the USGS gaging station 13239000, North Fork Payette River at McCall (Fig. 3-2). Discharge at the two USGS gaging stations was determined from continuous monitoring of stage (water-surface elevation) and periodic measurements of streamflow using methods described in Buchanan and Somers (1968, 1969), Carter and Davidian (1968), Kennedy (1983, 1984), and Riggs (1968). Discharge was determined by DEQ at its two gaging stations by relating periodic streamflow measurements to a stage-discharge curve.

Ungaged tributary inflows were estimated by DEQ by multiplying drainage-basin area by a unit-runoff coefficient determined at a nearby gaged surface-water inflow station, either Dead Horse or Fall Creek. Unit-runoff coefficients for these two creeks were determined by dividing annual discharge, in cubic hectometers, by drainage-basin area, in square kilometers (Table 3-1).

Direct surface runoff was estimated by DEQ using methods described in Schueler (1987), who estimated runoff by relating precipitation, infiltration, percent of impervious surfaces and soil moisture storage.

Precipitation to the lake surface was determined by multiplying lake surface area by the precipitation recorded during water years 1995 (0.83 m) and 1996 (0.73 m) at the National Weather Service station in McCall. Evaporation from the lake surface was estimated by multiplying lake-surface area by an annual evaporation rate of 0.76 m. The evaporation rate was derived from a map of annual free-water-surface evaporation in Idaho (Myron Molnau and K.C.S. Kpordze, University of Idaho, written commun., 1992). The change in lake storage was determined with a combination of lake stage data collected at USGS station 13238500, Payette Lake at McCall, and area and volume curves (Fig. 3-1) generated by this study. An evaluation of ground-water flux for Payette Lake was beyond the scope of this study.

Figure 3-1. Relation of depth to lake surface area and volume for Payette Lake.

Figure 3-2. Location of U.S. Geological Survey Discharge Monitoring Stations.

The residual for the hydrologic budget was computed as the difference between inflow and outflow minus change in lake storage. The residual included the errors associated with all budget components and unmeasured components such as ground-water flux and bank-storage flux.

The error associated with the hydrologic budget was comp uted with methods described by Winter (1981) and Brown (1987). The error associated with each budget component was computed with the following equation (Brown, 1987):

$$E = [(P^2)\ (C^2)]^{0.5}, (2)$$

where

E is total standard error associated with budget component C;

P is percent error used to determine budget component C; and C is value of budget component.

Percent error for each budget component was adapted from Winter (1981). Assignment of percent error to each budget component was as follows: gaged surface-water inflow and outflow and change in lake storage, 7.5 percent; precipitation, 15 percent; other components, 25 percent. The propagation of error for the hydrologic budget was computed with the following equation (Brown, 1987):

$$OE = [(E_1)^2 + E_2)^2 + ...+ (E_n)^2]^{0.5}, (3)$$

where

OE is overall standard error associated with hydrologic budget, in cubic hectometers; and
En is total standard error associated with each budget component.

3.1.2 Nutrient Budgets

The budgets were calculated by multiplying the hydrologic quantities in equation 1 by their associated nutrient concentrations.

The nutrient loads associated by the lake's primary inlet and outlet tributaries (USGS gaging stations 13238322 and 13239000) were determined with nutrient concentration data collected concurrent with streamflow measurements. Nutrient samples were collected over a wide range of discharges using standardized USGS cross-sectional, depth-integrating methods (Edwards and Glysson, 1988). The samples were analyzed for total concentrations of phosphorus, orthophosphorus, organic plus ammonia nitrogen, nitrite plus nitrate, and ammonia at the USGS National Water Quality Laboratory using low-level detection limit methods described by Fishman and Friedman (1989) and quality assurance/quality control procedures as described by Pritt and Raese (1995). Approximately ten percent of the nutrient samples were submitted as duplicates or blanks for quality assurance purposes as described by Friedman and Erdmann (1982).
Nutrient loads from ungaged surface-water inflows were estimated by multiplying drainage area, in square kilometers, by a nutrient-export coefficient, in kilograms per square kilometer. The nutrient-export coefficients were derived from nutrient load data collected by DEQ's watershed-monitoring program. A coefficient is computed by dividing the annual nutrient load, in kilograms, by the drainage basin area, in square kilometers.

Nonpoint-source nutrient loads from residential and commercial areas were estimated as described in the Stormwater Monitoring of Developed Areas (Section 4.3). The annual nutrient load was calculated with equations that combine precipitation, percent impervious area, drainage area, and national, flow-weighted concentrations of total phosphorus or total nitrogen.

Atmospheric input of nutrients to the lake's surface was estimated with data from the National Atmospheric Deposition Program's monitoring station at Smiths Ferry. The annual areal deposition rates, in kilograms per square kilometer, were multiplied by lake surface area, in square kilometers, to determine the annual load to Payette Lake. The nutrient load associated with the annual change in lake storage was determined by multiplying that volume, in cubic hectometers, by the mean annual concentration of nutrients, in micrograms per liter, in the epilimnion of limnetic station 1.

The residual for each nutrient budget was computed as the difference between the inflow and outflow of nutrients minus the nutrient load associated with the change in lake storage. The residual contains the errors associated with all budget components and unmeasured components such as ground-water flux.

Errors associated with each component of a nutrient budget were computed using errors in the hydrologic budget and errors in the collection and analysis of nutrient concentration data. Assignment of percent error to each concentration in a nutrient budget was as follows: gaged inflows and outflow and lake storage change, 15 percent; ungaged inflows and precipitation, 30 percent. Total error for each budget component was computed with the following equation (Brown, 1987):

$$E= [[(E_c)^2(Q)^2]+[(E_q)^2(C)^2]]^{0.5}, \quad (4)$$

where

E is total standard error associated with a nutrient budget component, in kilograms;
Ec is standard error associated with a nutrient concentration, in micrograms per liter;
Q is quantity of water, in cubic hectometers;
Eq is standard error associated with quantity of water, in cubic hectometers; and
C is nutrient concentration, in micrograms per liter.
Overall error for each nutrient budget was computed with the following equation (Brown, 1987):

$$OE= [(E_1)^2+(E_2)^2+...+(E_n)^2]^{0.5}, \quad (5)$$

where

OE is overall standard error associated with nutrient budget, in kilograms; and
En is total standard error associated with each budget component.

3.1.3 Limnology

Data Collection and Analysis

The physical, chemical, and biological functions of a lake are important factors in determining its susceptibility to eutrophication. The nutrient load/lake response model used to assess eutrophication in Payette Lake required a large amount of limnological data in order to simulate the lake's response to changes in nutrient loadings. Collection of limnological data at the lake was conducted in both the limnetic zone and the littoral zone.

Limnetic Zone

Four limnetic stations (Fig. 3-3) were sampled from October 1994 through September 1996. Each station represented an important limnetic zone. Station 1 monitored the large volume of water contained in the lake's southwest basin and was nearest to the lake's outlet. Station 2 monitored the small basin that connected the southwest and northern basins. Station 3 monitored the northern basin which was the deepest and was nearest the lake's primary tributary. Station 4 monitored the southeastern basin which was the shallowest and most hydrologically isolated from the primary tributary.

Sampling at the four limnetic stations typically occurred tri-weekly during May through October; one winter trip occurred in February, 1996 when the lake was ice-covered. A profile of photosynthetically-active radiation (PAR) was made with a spherical quantum sensor and planar deck-cell sensor in order to determine the euphotic-zone depth and compute an extinction coefficient. The euphotic zone is defined as that part of the water column in which in situ PAR is equal to or greater than 1 percent of the PAR incident upon the lake surface. Water-column transparency was then measured with a 20-cm-diameter secchi disc for later correlation with the PAR data. A full-depth profile of water temperature, specific conductance, pH, and dissolved-oxygen concentration and percent saturation was then made with a multi-parameter water-quality profiling instrument (Hydrolab Surveyor II).

A nonmetallic water-sampling bottle was used to obtain three samples: euphotic-zone composite, mid-depth, and 1 m above the lake bottom. Each water sample was analyzed for concentrations of total phosphorus and ammonia plus organic nitrogen and dissolved ammonia, nitrite plus nitrate and orthophosphorus. The euphotic-zone composite was also used for chlorophyll-a and phytoplankton analyses. The chlorophyll-a sample was obtained by filtering 500 ml of sample water through a pre-rinsed glass-fiber filter (Whatman GF/F) which was then immediately frozen until analysis. The phytoplankton sample was preserved with Lugol's solution. Nutrient samples were analyzed at the USGS National Water Quality Laboratory using low-level detection limit methods as described by Fishman and Friedman (1989) and quality assurance/quality control procedures as described by Pritt and Raese (1995). Approximately ten percent of the nutrient samples were submitted as duplicates or blanks for quality assurance purposes as described by Friedman and Erdmann (1982). Chlorophyll-a was analyzed according to Britton and Greeson (1989) using high performance liquid chromatography. Aquatic Analysts of Portland, Oregon evaluated the phytoplankton samples for taxonomic composition, density, biomass, and diversity indices.

During July, 1996 the surficial lakebed sediments at the four limnetic stations were sampled using a stainless-steel Ponar dredge. Each sample was analyzed for total phosphorus and nitrogen using methods described by Fishman and Friedman (1989).

Littoral Zone

Nutrient and chlorophyll samples were taken from the 1-m depth at 25 littoral stations (Fig. 3-3) during August-September, 1995 to aid in selection of stations to monitor periphyton production. Sampling protocol paralleled that used for limnetic sampling. During July-August, 1996, 20 of the 25 littoral stations were equipped with artificial substrates to monitor periphyton production in relation to nearshore influences. Artificial substrates were chosen, instead of natural substrates, to reduce the number of environmental variables used for the statistical evaluation. The substrates were placed on July 23-24, were incubated in situ for about 30 days, and then were retrieved on August 20-21.

Each artificial substrate consisted on a 5-cm-diameter unglazed ceramic ball affixed with adhesive to a 0.5-m-long rigid plastic shaft. At each station, three substrates were held vertically by a concrete-filled, plastic bucket. The bucket was placed on the lakebed such that the ceramic balls were about 2 m beneath the lake surface and about 0.5 m above the lakebed. This design and placement reduced the potential losses of periphyton due to benthic-invertebrate grazing and wave-induced sloughing. The amount of PAR received by each station during the incubation was computed so periphyton growth, quantified as chlorophyll-a, could be normalized to PAR. A LiCor solar monitor (model LI-1776) located on the southeast shore of Payette Lake recorded the hourly input of PAR. The amount of shading by the horizon and nearby structures and vegetation was quantified at each station using a solar pathfinder instrument. This allowed adjustment of the incubation PAR data to account for differences in incident PAR at each station. Finally, the PAR received during incubation at each station's substrates was computed with the following equation:

$PAR_z = PAR_i(e^{-nz})PS$, (6),

where

PAR_z is PAR input to artificial substrate during incubation, in Einsteins per square meter;
PAR_i is PAR input to lake surface during incubation, in Einsteins per square meter;
e is base of natural logarithms, unitless;
n is extinction coefficient of nearest littoral station, per meter;
z is depth of artificial substrate, in meters; and
PS is decimal percent of station shaded.

Immediately following retrieval, the periphyton attached to a ceramic ball was brushed gently into a 500-ml plastic jar containing 200 ml of lake water. The periphyton-lake water sample was homogenized in a blender and then three subsamples were withdrawn for filtration. The filters (Whitman GO/F glass-fiber) were frozen immediately. The chlorophyll-a analyses were performed by the author using a Turner Designs fluorometer (model 10-005R) and the methods described by Koenings and others (1987). Two replicate analyses were run on the supernatant derived from an acetone extraction of each chlorophyll-a-bearing filter. The amount of chlorophyll-a associated with the periphyton on each ceramic ball was computed with the following equation:

$$B_{chl} = [(C)(V_e)(V_t/V_f)(CF)] / A, \quad (7)$$

where

B_{chl} is periphyton biomass, as chlorophyll-a , on artificial substrate, in milligrams per square meter;
C is concentration of chlorophyll-a in extract, in micrograms per liter;
V_e is volume of extract, in liters;
V_t is volume of periphyton-lake water sample, in liters;
V_f is volume of periphyton-lake water sample filtered, in liters;
CF is factor to convert micrograms to milligrams; and
A is area of artificial substrate, in square meters.

During July, 1996, the 20 littoral stations equipped with artificial substrates were surveyed for occurrence and taxonomic composition of aquatic macrophytes. The taxonomic work was performed on-site by a botanist with the U.S. Bureau of Land Management.

Figure 3-3. Locations of limnetic and littoral sampling stations.

3.1.4 Nutrient Load/Lake Response Model

Model Description: The empirical nutrient load/lake response model (Walker, 1996) applied to Payette Lake provided a mathematical method for simulating the lake's limnological responses to alterations in water and nutrient loads delivered to the lake from various sources. The model combined data on the lake's morphometrics, hydrologic and nutrient budgets, and limnological characteristics in order to simulate the following eutrophication-related variables: concentrations of total phosphorus, total nitrogen, and chlorophyll-a; secchi-disc transparency, and hypolimnetic dissolved-oxygen deficit.

Three programs, FLUX, PROFILE, and BATHTUB, compose the model. The FLUX program quantifies tributary loads of water and nutrients using a variety of calculation methods. The PROFILE program generates statistical summaries of water-quality conditions in the water body within a temporal and spatial context. The BATHTUB program applies nutrient-balance and eutrophication-response models within a spatially segmented hydraulic framework that accounts for advection, diffusion, and sedimentation. BATHTUB is a highly evolved version of empirical lake-eutrophication models, and incorporates additional variables to account for important process such a nonlinear nutrient-sedimentation kinetics, inflow nutrient partitioning, seasonal and spatial variations, and algal growth limitation by factors such as phosphorus, nitrogen, light, and flushing rate. If error estimates are provided for input variables, BATHTUB can express output variables in probabilistic terms. An important feature of BATHTUB is the ability for modeling linked segments of the lake to account for spatial variations in water quality.

Table 3-1. Characteristics of the four segments of Payette Lake modeled by BATHTUB.

[km^2, square kilometer, cubic kilometers, m, meters]

Seg				
Characteristics and units	1	2	3	4
Surface area, km^2	6.51	1.69	1.37	10.9
Volume, km^3	.279	.035	.038	.402
Mean depth, m	42.9	20.7	27.7	36.9
maximum depth, m	92.7	37.2	55.5	70.1
Segment weight[1]	.32	.08	.07	.53
Important tributary Inflow source	North Fork Payette River	None	None	None
Outflow routed to segment number	3	1	4	Outlet
Limnetic station For segment	3	4	2	1

[1] Based on surface area of segment divided by surface area of lake.

Segment boundaries can be selected on the basis of factors such as lake morphometry, important sources of water and nutrients, and lake hydrodynamics.

Payette Lake was divided into four segments (Fig. 3-3); each segment's characteristics are listed in Table 3-1. Segment 1 is the deep, northeastern basin; it covers 6.5 km2 and contains 0.28 km3. This segment receives the lake's primary inflow from the North Fork Payette River. Segment 2 is the southeastern basin which covers 1.7 km2 and contains 0.04 km3. This segment is the most hydrologically isolated from the primary inflow and is furthest from the lake's outflow. Segment 3 is the smallest basin and connects the northeastern and southwestern basins. This segment covers 1.4 km2 and contains 0.04 km3. Segment 4 is the southwestern basin and contains the lake's outlet into the North Fork Payette River. This segment has the largest area and volume, 10.9 km2 and 0.4 km3.

Water-quality characteristics for each segment were input to BATHTUB. The characteristics were computed with PROFILE using data from the four limnetic stations. Excepting the metalimnetic and hypolimnetic dissolved-oxygen deficits, the characteristics represented mean annual values for the euphotic zone for water years 1995 and 1996. The euphotic zone was the primary focus for modeling because most of the empirical relations used by BATHTUB were derived from studies of euphotic zones.

The hydrologic and nutrient budgets were the source of water and nutrient loads input to BATHTUB. Each segment received water and nutrient loads from the subbasins draining into it. If a subbasin contributed to more than one segment its water and nutrient load was apportioned between the segments.

3.2 Watershed Monitoring and Assessment

There are no permitted point source discharges of pollutants directly entering streams or lakes within the Big Payette Lake Watershed. Consequently, watershed monitoring was limited to evaluation of non-point source runoff associated with the local land uses (Figure 2-2). Sub-watersheds above Big Payette Lake were assessed to determine relative importance of the drainage areas, landscape type, management history and fisheries habitat quality as these factors influence the incremental and aggregate quantity and quality of flow in the North Fork Payette River. Other diffuse land use impacts were also evaluated in and around the recreation and urbanized areas of the watershed adjacent to Big Payette Lake.

3.2.1 Rationale for Selection of Sub-watershed Monitoring Sites

Prior to initiating the study, existing data collected by DEQ, Idaho Fish and Game and the Payette National Forest were reviewed by the Payette Lake Technical Advisory Working Committee. Sub-watersheds for monitoring were prioritized based on factors such as intensity of past management activity, anticipated future uses, fire history and general conditions of stream habitat quality. Historic changes in stream channel alteration were additionally considered as an important reference concerning the long term stability of sub-watershed stream conditions. These factors provided some relative estimate of how the potential cumulative stability (or instability) of the local watersheds may influence biotic and abiotic processes of the local streams.

Figure 3-4 identifies the priority sub-watersheds, streams and sample site locations selected for non-point source monitoring above Big Payette Lake. A total of 8 sub-watersheds were selected that cover a range of relative impacts based on intensity of previous logging activity, percent of equivalent clear-cut, recreational use and recent fire damage (Table 3-2). An additional monitoring site (sample site 4; Table 3-2) was selected at the outflow of Upper Payette Lake to ascertain whether this lake effectively reduces export of nutrients and sediment from the upstream watersheds. Water quality and flow samples were also monitored at the USGS gauging station on the N.F. Payette River below the confluence of Fisher Creek. Although this site was principally used to estimate the N.F. Payette River bulk nutrient loads and water volume to Big Payette Lake, nutrient loads from unmonitored sub-watersheds such as Brush Creek and adjoining lands along the river mainstem were estimated by difference.

3.2.2 Sub-watershed Water Quality and Stream Flow Monitoring

Quantity and quality of runoff reflecting non-point source land uses was monitored at roughly 2 week intervals during spring snow-melt and approximately monthly during the remainder of the year. This information was used to identify the relative rank and importance of the sub-watersheds relative to the cumulative contribution of flows and nutrients to the North Fork Payette River.

Samples for nutrients and solids were collected by two methods; either as 1) flow weighted collection of samples using automated ISCO water sampling devices or 2) as channel cross-composite, depth integrated grab samples using a DH-48 sampler and plastic churn splitter to composite grab samples. Samples for nutrient analysis and solids (sediment) analysis were stored in plastic cubitainers on ice and returned to the Idaho State laboratory for analysis within 24 hours.

Table 3-3 lists the parameters analyzed in water samples and analytical methods. Total phosphorus and nitrogen species were analyzed from unfiltered samples. Dissolved nutrients (dissolved ortho-phosphate) are determined by filtering samples through a 0.45 um filter. Disposable filters will be used for filtering samples in the field. A separate new filter was used for each sample site. Physicochemical parameters were measured in-situ using a Model H-20 Hydrolab. Probes were submerged in the center of the stream channel and allowed to equilibrate for 15 minutes prior to recording results. A manual of field protocols was developed and followed in the collection and handling of samples (Worth, 1995).

Figure 3-4. Watershed flow and water quality sample site locations.

Table 3-2. Watershed Non-Point Source - Priority Stream Sites and Impact Characteristics.

Site #	Watershed Name	Acres	Type of Impact
1	NF Payette River above Upper Payette Lake	11,223	- Timber harvest - Burn impact NE of lake, 80% of watershed burned
2	Cougar Creek	2,404	- No harvest - 73% of watershed burned
3	Twentymile Creek	10,232	- Minor timber harvest - 82% of watershed burned
4	NF Payette River Outflow Upper Payette Lake		- Lake retention
5	Deep Creek	2,827	- No harvest - 30% burned
6	Pearl Creek	3,271	- Timber harvest - 95% of watershed burned
7	NF Payette River (USGS Gauge Site)	12,942	- Includes upstream inputs
8	Fisher Creek	11,519	- Timber harvest - 20% burned
9	Dead Horse Creek	3,086	- Timber harvest - Un-burned
10	Fall Creek	4,235	- Timber harvest - 50% burned

Automated sampling sites (ISCO) were programmed to composite discrete collections of water samples according to measured quantities of stream volume (see calibration of flows below). Samples were removed at two week intervals and analyzed for total phosphorus, total nitrogen and sediments following the same methods outlined in Table 3-3.

Suspended sediment concentrations in runoff was determined as the difference in weight of aliquots of unfiltered and filtered (0.45 um) stream samples after evaporation (105^{o}C) to dryness.

Stream Flow Monitoring

Instantaneous stream flows (cfs) were measured during each water quality sampling event. Flows were measured through a known cross-section area of a stream channel using Marsh/McBirney digital flow meters. For water depths of less than 2 feet, estimates of water velocity were made using the six tenths estimate (0.6) of the average stream depth from water surface. At water depths greater than 4 feet, estimates of water velocity were made using the 2 point method (velocity is the average of measurements taken at 0.2 and 0.8 of the depth from water surface). Under very high flow conditions when stream wading was not possible, a bridge board was used to obtain estimates of flow velocity.

Continuous surface water flows were additionally monitored at Upper Payette Lake Inflow (N.F. Payette River), Cougar Creek, Twentymile Creek, Fall Creek and Dead Horse Creek by installing ISCO flow meters (model 4230-bubbler) and recording devices in open stream channels. Computed channel flows were corrected to channel stage height using direct open channel calibration of flows obtained from routine flow measurements using Marsh/McBirney flow velocity meters. A stage calibration was calculated for each automated site and used to correct estimated flows between measured sampling events.

Monitoring Stormwater Runoff into Big Payette Lake

Stormwater inflows from urban runoff within the city of McCall were monitored using the ISCO automated samplers and through grab samples during individual storm events. Figure 3-5 identifies the major storm sewers draining to Big Payette Lake and monitoring sites. Sites were selected based on accessibility for sample collection and representation of the surrounding land use intensity and type (Table 3-4).

Automated samplers (ISCO) were installed in two stormwater collection systems located in the downtown core area (Art Roberts Park and Public Boat Marina, Figure 3-5). Flow weighted samples were composited at these sites based on storm runoff volume.

Routine stormwater analysis included measures of nutrient concentrations (total and dissolved) and solids. Analytical procedures for grab samples were identical to those outlined for stream monitoring in Table 3-3. Automated composite samples were only analyzed for total constituents. Bacteria contamination (fecal coliform and fecal streptococcus) in stormwater runoff were measured from grab samples collected during individual storm events. Samples were collected from culvert discharge in plastic 500 ml bottles fixed with sodium thiosulfate. All samples were stored on ice and transported to the Idaho State Lab (Boise) within 24 hours after collection.

Table 3-3. Water Quality Parameters Monitored.

Parameters	STORET#	MDL[1]-Units	Methods
NO_2+NO_3 as N	00631	0.005 mg/L	EPA Method 353.2 Methods
NH_4 as N, Total	00610	0.005 mg/L	EPA Method 350.1
TKN	00625	0.05 mg/L	EPA Method 351.2
Tot. Phosphorus	00665	0.005 mg/L	EPA Method 365.4 (Semi automated block digester)
Ortho-Phos.	00671	0.001 mg/L	EPA 365.2
Suspended Sediment	80154	<2 mg/L	EPA 160.2
Total Solids			
Chloride	00940	<0.9 mg/L	EPA Method 325.3
Flow	00060	.01 cfs	Electronic measurement for instantaneous flow measurement
Temperature	00010	.01 ^{o}C	Point and continuous
Oxygen, Diss.	00300	.01 mg/L	DO meter
Specific Conductivity	00095	.001 umhos	Conductivity meter
pH	00403	.01 SU	pH meter

[1] = Minimum Detection Limits

Bacterial Monitoring Associated with Recreation Use

Bacteria samples were collected from selected streams and/or beach areas to measure total and fecal coliform contamination associated with concentrated recreational use areas (Figure 3-5). Samples sites were located upstream and downstream of concentrated use areas along active use areas on the N.F. Payette River between the National Forest Boundary and Big Payette Lake. Sites included an undesignated campground at the forest boundary, the Fisher Creek campground and Indian Campground. Samples for surface water contamination along beaches were collected at the water surface within 1.0 meters of the beach, upstream and downstream of the beach use areas. These sites included the North Beach, Lucks Point, Firemans Cove, the boat docks at Ponderosa State Park and a high use area between Deadhorse Creek and the North Beach. All sites were sampled before and after major holidays during the summer recreation season (July 4 and Labor Day) when density of recreational use was expected to be greatest. Methods of collection were identical to those described above.

Table 3-4. Stormwater Monitoring Sites and Drainage Basin Characteristics.

Basin No.	**Size (ha)**	**General Characteristics**	**Monitoring Site Description**
1	200	Located north of downtown McCall and includes entrance to Ponderosa State Park. Approximately 50% of basin lies within McCall city limits. Drainage gradient is to the lake. The drainage conveyance consists of open ditches and overland flow (down gradient contour discharge).	Not monitored.
2	253	Located north of downtown McCall and borders the eastern shore of Big Payette Lake southwest basin. Major feature includes City golf course (western end of basin). Approximately 35% of basin in city limits. Approximately 60% of basin is woodland with very low residential density. Drainage gradient is to the lake. Drainage conveyance is through a prominent open ditch with numerous smaller feeder ditches. Land surface cover predominately open spaces and small percentage impervious cover.	• Open ditch at intersection of Agate St and Davis Ave. Discharge to lake approximately 1,000 ft west.
3	69	Located just north of downtown McCall and borders the eastern shore of Big Payette Lake southwest basin. Significant growth areas include the Old Mill site (residential/multi-unit and single family) and railroad right-of-way (commercial). Land surface includes impervious and vegetated coverings. Drainage gradient is to the lake. Drainage conveyance includes mostly shallow open ditches.	• Subsurface drainage pipe (4") discharging to lake at Mill Park Development.
4	105	Drainage basin located partially within the downtown McCall and borders the eastern shore of Big Payette lake southwest basin. Major features include the Marina (west side of basin) and railroad right-of-way. Drainage	• Concrete collection box next to Marina; discharge outfall at lake shoreline approximately 30 ft west of collection box.

		gradient is to the lake. Drainage conveyance includes numerous open ditches and enclosed CMP/concrete pipe as water is routed through the more developed areas along the west side of the basin (downtown area). High flows are common during spring snowmelt. Land surface cover consists of woodland on the east side of the basin and increasing impervious cover to the west near the lake.	

Figure 3-5. Site location map for stormwater runoff monitoring and recreation survey bacteria monitoring.

Table 3-4 continued. Stormwater Monitoring Sites and Drainage Basin Characteristics.

Basin No.	**Size hectares**	**General Characteristics**	**Monitoring Site Description**
5	56	Basin discharges to N.F. Payette River	Not monitored.
6	116	Basin discharges to N.F. Payette	Not monitored.
7	81	Drainage basin is located partially within the McCall downtown area and borders the south shoreline of Big Payette Lake southwest basin. Downtown core is located on the est side of the basin. Drainage gradient is fragmented with runoff flowing to the lake and the N.F. Payette River. Major features include significant drainage of State Highway 55 fronting the lake and high density commercial development in the downtown core. Drainage conveyance includes numerous open ditches which route water through a maze of piped storm drains in the downtown area and smaller piped collections systems to the west. Land surface cover varies from a high percentage of impervious cover in the downtown to low density residential to the west.	• Legacy Park discharge at concrete pipe below an just east of the Restaurant complex. • Concrete collection box and skimmer at Art Roberts Park. Discharge to lake Approximately 300 ft to the north. • Concrete collection box at Paul's Grocery Store. Discharge to lake approximately 300 ft north. • Concrete pipe at end of driveway north of Mission St-Hwy 55 intersection. Culvert discharge at lake shoreline on west side of condo bldg. • Concrete collection box on north side Hwy. 55 and State St intersection. Discharge to lake approximately 300 ft north.
8	93	Located on the west side of Big Payette Lake southwest basin. Major features are the Warren Wagon Road drainage, and the North Shore Lodge Resort. The northern portion of this basin is mostly sparse cabins and woodland. Commercial zoning abuts the city limits to the south with a large percentage of impervious surface. Drainage gradient is mostly to the lake. Drainage conveyance is minimal ditching and mostly overland flow (down gradient discharge). Some storm drain piping exists in the	Not monitored.

		southern portion of the basin discharging to N.F. Payette River.	
9	220	Basin discharges to N.F. Payette	Not monitored.
10	96	Basin discharges to N.F. Payette	Not monitored.
11	261	Basin discharges to N.F. Payette	Not monitored.
12	1608	Basin discharges to N.F. Payette	Not monitored.
13	583	Basin discharges to N.F. Payette	Not monitored.

(1 hectare = 2.47 acres)

Quality Assurance/Quality Control (QA/QC): Water Quality Samples

All grab samples collected for water quality analysis were fixed in the field at the time of collection by advanced addition of the appropriate preservative to each sample bottle. For automated sample collections, samples were removed from the storage container at two week intervals. All samples were stored on ice and transported to the Idaho state lab for analysis.

Addition of spikes and sample results from specified stations were used for assessment of field and laboratory techniques. Duplicate samples were collected and used to determine media variability. Overall precision of the sampling and analytical methods was evaluated by analyzing duplicate samples collected at the same time and location. Duplicate samples were collected on every sampling date in which stream grab samples were collected. Average relative range and average coefficient variation were within acceptable margins of error.

Two types of spiked samples were used to determine laboratory accuracy and precision and potential degradation of samples stored on-site between intervals of sample retrieval. One set of samples was spiked at the beginning of each two week interval of automated sample collection. These spikes remained inside the automated sampler and were removed with the following batch of samples submitted for analysis. Analysis of these spikes provided an estimate of the change in recovery due to on-site holding conditions. A second set of containers were spiked at the time of sample retrieval and submitted for analysis with remaining samples. These results were used to determine percent recovery and average percent recovery.

Blank samples were used to determine laboratory equipment accuracy and precision and to assess sample handling errors and biases. Blank samples were submitted with each sample batch and treated as samples collected from the field, duplicating handling, storage, and transportation methods.

Physical-chemical parameters were measured in-situ using a Hydrolab Model-20 electronic meter for determination of dissolved oxygen, pH, conductivity and temperature. Various probes were maintained as recommended by the manufacture and calibrated according to specifications prior to each day of sample collection. Calibration logs were also maintained to record errors and trends in equipment operation.

3.3 Stream Habitat Quality

3.3.1 Purpose and Objectives

This study evaluates the stream habitat conditions in the Payette Lake Watershed (PLWS) for the technical report from which the Payette Lake management plan will be developed. Data from 1993-1996 was analyzed to determine the quality of stream habitat and ability to support aquatic biota.

Objectives for this analysis were to:

1. Compile existing data on the PLWS from federal and state agencies;
2. Characterize and compare stream channel habitat and water quality conditions (excluding nutrients) in subwatersheds;
3. Determine the macroinvertebrate species composition and abundance of the PLWS and subwatersheds;
4. Relate current stream habitat conditions to adjacent land use, and natural events;
5. Develop recommendations for continued stream habitat monitoring in the PLWS.

3.3.2 Data Acquisition

Conditions related to stream habitat quality, stability and the functional support of key biological species were evaluated using four different protocols but with somewhat comparable measures of overall habitat complexity, hydrologic function and biological sensitivity. Field investigations were initiated at different but overlapping time periods resulting from the individual management needs by the U.S. Forest Service, Idaho Division of Environmental Quality, Idaho Department of Fish and Game, and the Idaho Department of Lands. The four protocols used were R1-R4 Riparian Assessment Protocol, the Beneficial Use Reconnaissance Protocol (BURP), Stream Reach Inventory and Channel Stability Evaluation, and the Cumulative Watershed Effects protocol. (Site locations are identified in Figure 3-6 and Table 3-5).

Table 3-5. Beneficial Use Reconnaissance Program Stream Habitat Quality Monitoring Sites.

Watershed/Stream	Year	Site Latitude-Longitude	Stream Length	Method	Channel Type
Cougar Ck	94	44^{0}08'22"-116^{0}01'44"	Lower	BURP	B
	95	Unknown	Upper	BURP	A
20Mile Ck	94	45^{0}08'00"-115^{0}58'10"	Middle	BURP	C
	94	45^{0}08'03"-115^{0}58'49"	Lower	BURP	C
	95	45^{0}07'23"-115^{0}57'20"	Upper	BURP	C
	95	45^{0}08'00"-115^{0}58'10"	Middle	BURP	C
	95	45^{0}08'03"-115^{0}58'49"	Lower	BURP	C
Upper NF	94	45^{0}09'06"-116^{0}00'13"		BURP	B
Payette R	94	45^{0}08'26"-116^{0}00'50"		BURP	A
	94	45^{0}06'45"-116^{0}01'53"		BURP	C
Deep Ck	95	45^{0}05'61"-116^{0}02'10"	Upper	BURP	C
	95	45^{0}05'59"-116^{0}02'21"	Lower	BURP	A
Pearl Ck	95	45^{0}05'06"-116^{0}00'51"	Upper	BURP	?
	95	45^{0}05'58"-116^{0}01'54"	Lower	BURP	A
Box Ck	94	45^{0}02'02"-116^{0}03'03"	Middle	BURP	B
	94	45^{0}02'09"-116^{0}02'43"	Lower	BURP	C
	95	45^{0}02'13"-116^{0}01'57"	Upper	BURP	B
	95	45^{0}02'02"-116^{0}03'03"	Middle	BURP	B
	95	45^{0}02'07"-116^{0}02'44"	Lower	BURP	B
Brush Ck	94	45^{0}03'52"-116^{0}02'32"	Upper	BURP	A
	95	45^{0}03'55"-116^{0}01'30"	Lower	BURP	A
Deadhorse	94	45^{0}00'09"-116^{0}05'52"	Upper	BURP	B
	95	44^{0}58'50"-116^{0}04'32"	Lower	BURP	A
Fall Ck	94	44^{0}55'00"-116^{0}00'30"	Middle	BURP	B
	94	44^{0}57'05"-116^{0}03'15"	Lower	BURP	B
	95	44^{0}57'10"-116^{0}02'03"	Upper	BURP	B
	95	44^{0}55'00"-116^{0}00'30"	Middle	BURP	B
	95	44^{0}57'17"-116^{0}03'13"	Lower	BURP	B/C
Trail Ck	95	45^{0}10'36"-115^{0}59'13"	Upper	BURP	B
Fisher Ck	93	45^{0}02'22"-116^{0}03'35"	Lower	BURP	No Rosgen
	93	45^{0}04'33"-116^{0}05'56"	Upper	BURP	No Rosgen
	95	45^{0}02'18"-116^{0}03'31"	Lower	BURP	B
	95	45^{0}04'53"-116^{0}05'57"	Upper	BURP	C
Landing Ck	94	45^{0}00'42"-116^{0}05'25"		BURP	C
	95	44^{0}58'06"-116^{0}05'39"		BURP	C
	95	45^{0}00'39"-116^{0}05'27"	Upper	BURP	B

Figure 3-6. Stream habitat monitoring sites.

3.3.3 Stream Habitat Assessment Methods

1. Payette National Forest Region 1 / Region 4 (Northern Region/Intermountain Region) Fish Habitat Inventory (1995, Overton et al.).

This stream inventory procedure was initially developed in 1990 by the Forest Service's Intermountain and Northern Regions and the Intermountain Research Station. It is designed to describe and quantify fish and fish habitat characteristics for a given area by determining salmonid fish species composition, distribution and relative abundance; describing and quantifying fish habitat structure; and linking fish species and their life stages to habitat structure. The inventory is conducted at base flow usually by a two-person crew comprised of a "recorder" who records the data and an "observer" who classifies the habitat types and measures the variables. Prior to field work, extensive information is collected from maps and references and recorded on a "Header Form". Included in this information is reach type, reach boundaries and descriptions, gradient, elevations, Rosgen channel type, Ecoregion classifications, geology , and stream identity codes. The field data collected is extensive and includes *in part*: habitat type (run, glide, riffles and pools) ; habitat unit average width, length, and depth (including maximum); number and depth of pocket pools; pool crest depth, percent surface fines, substrate composition (Wolman Pebble Count Procedure), bank length, bank stability, bank undercut, quantities of large woody debris, and temperature. Fish population data is obtained by snorkeling counts of the total number of fish within given habitat units. Commonly a 20 percent sampling frequency is used for pool and riffle habitats. Training and quality control are also emphasized in the R1/R4 methodology. Payette National Forest R1/R4 data from 5 Payette Lake Watershed streams are analyzed in this report.

2. Idaho Division of Environmental Quality Beneficial Use Reconnaissance Project (BURP) (1996, IDEQ).

The BURP protocol is a modification of the Environmental Protection Agency Rapid Bioassessment Protocol used to evaluate stream conditions, stability and beneficial use support status (Robinson and Minshall, 1992). A combination of metrics were used to provide quantitative and qualitative measures of stream conditions and associated biological communities.

BURP monitoring sites are located in each of the priority streams upstream of the water quality monitoring stations (Figure 3-6). Several streams were sampled in summer 1994 just prior to closure of the Payette National Forest due to fires. Selected portions of each stream reach are classified according to the Rosgen stream classification system (Rosgen, 1993). Table 3-6 lists the various metrics that are obtained from each sample site. Monitoring is conducted during low flow conditions (September) when streams can be readily observed by wading. Low flow conditions also reflect the period in which sediment deposition from erosion, stream temperatures and other surrogate measures of environmental stressors are greatest.

Table 3-6. Metrics used for Beneficial Use Attainability Survey.

Parameter	**Method/ Definition**	**Level of Intensity**

Parameter	Method/ Definition	Level of Intensity
Flow	Harrelson et al. 1994	one measurement per site; set interval method
Width/Depth	Bauer and Burton 1993. pg. 86	measure wetted and bankfull conditions at 3 riffles; record X-sectional depth a minimum of 10 times
Shade	Bauer and Burton 1993. pg. 68	measure with a densiometer at three riffles; use habitat types and lengths to weight calculations for stream reach shade calculations
Bank Stability	Bauer and Burton 1993. pg. 98	longitudinal (total stream reach length) for both stream banks
Substrate	Wolman 1954	at three riffles; a minimum of 50 counts per riffle; set interval method
Habitat Types	Meehan 1991	longitudinal; classify as pool, glide, run, riffle
Pool Complexity	Bauer and Burton 1993. pg. 119	measurements taken in a minimum of 3 pools, length, max width, max depth and depth at pool tailout
Large Organic Debris	Platts et al. 1987. pg. 83	LOD > 10 cm diameter and >1 m in length; within bankfull zone of influence (applicable only in forested situations)
Stream Channel Classification	Rosgen 1994	to letter classification only (A,B,C, etc.)
Habitat Assessment	Hayslip 1993	follow habitat assessment protocol
Temperature	Franson 1992	instantaneous temperature measurements
Photopoints		photographs upstream and downstream at lower end of each reach; record directions in which photographs are taken
GPS	Trimble 1995	collect uncorrected (raw) data
Macroinvertebrates	Clark and Maret 1993	Hess sampler, w/500 µm mesh at three riffles (n=3); samples preserved and stored separately in the field; lab personnel composite the three samples, count and identify the first 500 individuals; Surber or kick net samplers used if conditions do not permit use of a Hess sampler

Parameter	Method/ Definition	Level of Intensity
Fish	Modified from Chandler et al. 1993	collect fish in the study reach or an equivalent length of stream which includes all habitat types encountered in the study reach; collect, count, and voucher specimens (6 individuals if possible) for each species; measure total length of all salmonids

The BURP methodology involves collecting data on stream habitat parameters in relatively short reaches, commonly 100 meters, or 20 X stream width. These reaches are chosen to be representative of the entire stream segment being assessed. For this reason, the determination of habitat quality and comparisons of biotic data between study streams and reference conditions is greatly affected by site selections and whether the survey site accurately represents the conditions within the entire stream. Consequently, sample reaches should be both comparable between streams and representative of the entire stream segment being assessed.

Multiple measures are taken of most core parameters which include: flow, width / depth, canopy closure (shade), bank stability, substrate composition, habitat types, pool complexity (determined by evaluating 5 separate variables), large organic debris, stream channel classification, habitat assessment (determined by rating 12 criteria), and temperature. In addition, Macroinvertebrates are collected at each site, and fish are sampled by electroshocking. Crews receive training in field techniques and are supervised to ensure quality control. The habitat assessment and pool quality criteria are included in the *Stream Habitat and Parameter Interpretation, Standards and References* section of this report. BURP data from 11 Payette Lake Watershed streams (21 sites) is analyzed in this report.

3. Stream Reach Inventory and Channel Stability Evaluation. A Watershed Management Procedure (1978, Pfankuch).

This procedure was developed to measure and evaluate the resistive capacity of mountain stream channels to the detachment of bed and bank materials and to provide information about the capacity of streams to adjust and recover from changes in flow and increases in sediment production. The inventory utilizes maps, aerial photos, and field professional observations and measurements. The condition of the upper stream banks, lower stream banks, and channel bottom is evaluated by rating a total of 15 parameters including: slope, mass wasting potential, large woody debris, bank vegetation, channel capacity, bank obstructions and rock content, bank cutting and deposition, rock angularity, substrate brightness, particle embeddedness, scouring and deposition, and presence of aquatic vegetation. This methodology is commonly used by hydrologists and was utilized by the Payette National Forest to evaluate streams in the Payette Lake Watershed. See field inventory sheet included in *Stream Habitat and Parameter Interpretation, Standards and References* section of this report for parameter evaluation criteria.

4. Forest Practices Cumulative Watershed Effects Process for Idaho. (1995, Idaho Department of Lands).

This methodology combines field measurements with professional judgement to examine watershed processes in order to: 1) determine the hazards inherent in the watershed from erosion, increased water temperature, or nutrient accumulation; 2) evaluate the current stream condition; and 3) evaluate the current watershed condition. For each condition analyzed, rating criteria are provided. The Box Creek Subwatershed was analyzed using this process and results are summarized in the Stream Habitat Quality Appendix Tables; Box Creek Data Summary.

3.3.4 Stream Habitat Parameters-- Description and Limitations

Selection of monitoring parameters is based on designated uses, management activities and cost (MacDonald et al. 1991). Habitats for aquatic species are products of geology and soils, topography, vegetation, climate, and hydrology of a watershed (Meehan 1991). Meehan (1991) states that for the most part, these watershed characteristics remain fairly constant, and so does the productivity of the aquatic habitats. Any changes in these conditions can bring about changes in habitats that may greatly affect aquatic populations. Such changes may be caused by human activities such as logging, road construction, livestock grazing, and mining, or by natural events such as floods, mass soil movements, wind, and fire.

Stream parameters reviewed below are those used in this report to formulate conclusions regarding ecosystem functioning in the Payette Lake Watershed. Data was collected using different methodologies by the agencies.

Large Woody Debris (LWD)

a. Description of Data: The amount of large woody debris in stream channels is evaluated in both the BURP and R1/R4 methodologies. If both methodologies are reported for a given stream, the R1/R4 values are used for analysis as they represent a greater percent of the stream. In the BURP method, all LWD greater than 10 cm. in diameter and 1 meter in length is counted within each stream reach (IDEQ 1996). Diameters and lengths are not recorded, however, and the wood count is not delineated into numbers of pieces as single, aggregates, and root wads, making the BURP LOD count not comparable to Overton's (1995) natural conditions database. The R1/R4 methodology (Overton 1995) counts all LWD within bankfull width, measuring or estimating diameters and lengths, broken into three categories: 1) Single piece - must be 3 meters in length or two-thirds the wetted stream width (whichever is smaller) and 0.1 m in diameter one-third of the way up from the base. Smaller pieces are easily flushed through the system and are not retained. 2) Aggregate - a group of two or more pieces. The total number of pieces is estimated. For comparison to Overton's natural condition streams, aggregates count as one piece. 3) Root wads **-** attached to logs less than 3 meters in length. Volume of LWD was calculated for streams to facilitate comparison to INFISH standards. Aggregate volume was included in overall volume, calculated as 0.1 m x 1 m.

b. Limitations: Difficulties are encountered when trying to quantify and count large woody debris due to subjectivity and the visibility of pieces buried in aggregates, submerged in substrate and hidden by vegetation. Overton (1995) states that there is a high range of natural variability and sampling error appears to be high.

Width/Depth Ratio:

a. Description of Data: The R1/R4 methodology calculates a width to depth ratio for each habitat unit based on the mean wetted width and depth. The data summary tables for each subwatershed list the mean width and mean depth for the total habitat units in the reach. The mean width/depth shown in the table is the mean of all the width to depth ratios. The BURP data summaries also include the wetted width to depth ratio, and bankfull width and depth (width and depth at maximum flow), are provided as well.

b. Limitations: Definitions of channel width and depth varies in our data base, with the R1/R4 method using the wetted channel, and BURP using bankfull. Use of geomorphic indicators such as bankfull tend to be subjective and major runoff events can alter the channel cross-section making identification of bankfull features questionable. In addition one stream of uniform depth and width may have insignificant amounts of fish rearing habitat, yet another with the same average width to depth ratio may have shallow riffles interspersed with deep pools and overhanging banks which may provide abundant rearing habitat (Beschta and Platts 1986).

Pools

a. Description of Data: The R1 R4 methodology uses main channel pools to determine pool frequency**,** excluding pocket pools and side channel pools. Step pool complexes are counted as one pool. Inventories are conducted at base flows to maintain consistency of measurements, as changes in flow affect all pool measurements except residual depth (Overton et al. 1995). In the BURP methodology pool complexity is evaluated. Residual depth, pool length, substrate**,** overhead cover, submerged cover, and bank cover are measured. See Stream Habitat Quality Interpretation Standards and References Appendix Tables; Pool Quality Index, for ratings of these parameters. Due to the limited sampling area of the BURP methodology, the number of pools per 1.6 kilometer (one mile) was not calculated.

b. Limitations: The change from pools to runs or glides is one point on a continuum leaving the dimensions of a pool a matter of professional judgement. In larger streams with deeper pools, direct measurements are difficult and estimates may be necessary. Pool depth, pool area, and pool volume are all flow dependent, thus comparisons between surveys should consider the discharge at the time of data collection. In the PLWS study, all streams were analyzed with the R1/ R4 and BURP methodologies at base flow conditions to maintain consistency of measurements.

Pool/Riffle Ratio

a. Description of Data: This ratio was calculated by dividing the length of pool habitats by the

length of riffle habitats in both the BURP and R1/R4 methodologies. Interpretations of this ratio were made from the R1/R4 data when available because these surveys covered a larger percentage of the stream. In the Stream Habitat Quality Appendix Tables; Data Summary, the BURP pool / riffle ratios were calculated for the reach length surveyed ,and in addition, rated as part of the Habitat Quality Assessment Summary Appendix Tables, ranging from optimal to poor.
b. Limitations: The common interpretation is that a ratio of 1 is optimal. Platts (1974) found the highest salmonid fish standing crops in the South Fork Salmon River drainage were in stream reaches with a pool-riffle ratio of 0.4 - 1. However, streams with high pool-riffle ratios have been shown to be high producers of salmonids (Platts et al. 1983). In some high gradient streams, riffles and pools may be difficult to discern, and are replaced by cascades and pocket waters (IDEQ 1996). MacDonald et al. (1991) state that habitat unit surveys may be relatively insensitive to land use practices. A small amount of sediment may significantly alter the bed material or residual pool volume, but not alter the size of or ratio among different habitat units.

Substrate Composition

a. Description of Data: The R1/R4 Fish habitat Inventory technique and the BURP methodology both utilize the Wolman Pebble Count procedure to determine substrate composition, however, the techniques categorize the particle size classes somewhat differently. For the analysis in this report, " fine sediment" refers to particle sizes less than 6 mm. If both methodologies are reported for a given stream, the R1/R4 values for mean percent substrate composition is used for analysis, as it represents a greater percentage of the stream. The BURP data for this parameter represents one Wolman Pebble Count in the reach, while the R1/R4 data averages multiple counts representing a 20 percent sampling of pools and 10 percent sampling of low gradient riffles. In addition, the percent surface fines (< 6 mm) was visually estimated in the R1/R4 methodology in pool tails and low gradient riffles, and beginning in 1995, a 49-Intersection Grid technique was used by the Payette National Forest to assess some habitat units for fine sediment (6 mm). Bottom substrate (percent fines <6.35 mm) is also evaluated by ocular estimation in the BURP Habitat Assessment Summary. The dominant particle size determined by the Wolman Pebble Count is represented in bold and referred to as the "D50" in the Habitat Quality Appendix Summary Data Tables. The "D50" particle size occurs in the size class where 50 percent of the substrate particles have a diameter less than the D50 diameter. A decrease in the D50 size is generally interpreted as an adverse effect

b. Limitations: While the Wolman Pebble Count is useful for characterizing the substrate overall, it is not the preferred technique for fine sediment analysis, due to individual sampling biases. In this analysis, data from all the sampling techniques utilized (including ocular estimates and the 49-intersection grid technique)are evaluated to draw conclusions.

Bank Stability

a. Description of Data: In the R1/R4 methodology, stable banks (vegetated and unvegetated) are estimated as a percentage of the total bank length (left and right banks) for each habitat type at the steepest portion of the bank between bankfull and the existing water level. According to Overton et al. (1995) stable streambanks show no evidence of active erosion, breakdown, tension cracking, or shearing. Undercut banks are considered stable until tension fractures show on the ground surface at back of the undercut. The BURP methodology follows the approach of Platts et al. (1983) including measuring and proportioning banks into four stability classes: mostly covered and stable (non erosional), mostly covered and unstable (vulnerable), mostly uncovered and stable (vulnerable), and mostly uncovered and unstable (erosional). The streambank is envisioned as that part of the channel which would be most susceptible to erosion during high water; therefore it represents the steeper-sloped sides of the stream channel. Banks are considered unstable if they show indications of breakdown, slumping or false bank, fracture, and steepness over 80 degrees with erosion. See Section III B, Streambank Stability for definitions and discussion of protocol.

b. Limitations: Some limitations related to assessing the degree of bank stability include: the lack of accuracy and precision involved in visual estimates, the inability to identify specific causes of instability, varying sensitivity of stream reaches, and the difficulty of separating natural and management impacts. According to Platts, (1981) grazing has the most direct and obvious impact on bank stability, and this may mask other impacts (MacDonald et al. 1991). Discharge and sediment yield tend to be controlled by upslope processes, so the linkage to bank stability is not immediately obvious, however, bank stability may be most useful as a quick indicator of shift in the equilibrium of the stream system (MacDonald et al. 1991).

Temperature

a. Description of Data: Stream temperatures in the PLWS were analyzed using thermograph records from the Payette National Forest, Idaho Department of Fish and Game, and Idaho Division of Environmental Quality. Bimonthly temperatures (IDEQ) were evaluated if thermograph records were unavailable. Temperatures in this database include 1993, 1994, 1995, and 1996 data. In general, temperatures from 1994 are highest due to low flows and drought conditions. Temperatures were evaluated in terms of total number of days exceeding 13°C and 15°C, and the number of days exceeding these temperatures during the approximate fall spawning interval of August 20 - September 20. Temperatures in this range exceed INFISH (1995), IDEQ (1996), and biological standards (Bjornn and Reiser 1991) discussed in Section III B. No temperature data was available for Brush Creek, Dead Horse Creek, and Landing Creek.

b. Limitations: Thermographs provide a continuous record of temperature variability, and are a useful approach for assessing thermal suitability of streams for aquatic species. According to MacDonald et al. (1991), the additive nature of temperature increases and the likely importance of sublethal effects suggest that monitoring is needed when 1) the potential exists for large changes of water temperature due to management activities, 2) water temperatures are already in the upper range of acceptable temperatures, and 3) there is potential for significant temperature increases due to the additive effects of smaller increases. Temperature effects also need to be distinguished from open canopy effects including: increased light, increased nutrients, greater primary productivity, and amounts of large woody debris (MacDonald et al. 1991).

Dissolved Oxygen (DO)

a. Description of Data: Dissolved oxygen levels (mg/L) in the PLWS streams were obtained bimonthly by IDEQ at designated water quality sites. Records (2/15/95- 7/30/96) were available for the following streams: North Fork Payette River, Fisher Creek, Pearl Creek, Deep Creek, Twentymile Creek, and Cougar Creek.

b. Limitations: Fish can modify spawning site conditions in the redd building process, and monitoring sites should be carefully selected to represent the actual DO levels eggs will experience (Chapman 1988).

3.3.5 Aquatic Organisms

Macroinvertebrates

a. Description of Data: Macroinvertebrates are collected as part of the BURP methods from three separate riffles per site and combined as one sample, using a modified Hess stream bottom sampler with 0.5 mm mesh. The first 500 individuals are counted and identified to species. Seven metrics are calculated for the IDEQ (1996) Macroinvertebrate Biotic Index (MBI) including: percent EPT, Hilsenhoff Biotic Index (HBI), percent scrapers, percent dominance, EPT Index, Taxa Richness, and the Shannon-Weiner Diversity Index. Each metric measures a different component of community structure and a different range of sensitivity to pollution stress. The IDEQ MBI is calculated based on these metric values compared to the Northern Rockies Ecoregion reference standards representing the best conditions for this region (DEQ, 1996). The Northern Rockies Ecoregion individual metric values are presented in the Section III A, data tables for comparison with the PLWS stream values and the MBI value is given for each site. The IDEQ MBI is used to determine the level of macroinvertebrate assemblage impairment. See Stream Habitat Quality Appendix Table; Parameter Interpretation Standards and References, for interpretations of this value.

The macroinvertebrate data was also evaluated using Plafkin's (1989) Rapid Bioassessment Protocols approach for the seven metrics listed above. According to Plafkin (1989) metrics based on standard taxa richness and EPT indices (% EPT, EPT index, and taxa richness), differences of 10-20% are considered nominal, thus a value within 80% of the reference condition would be considered non-impaired for that metric. For this analysis, the best condition value obtained for the metrics within the PLWS, as well as the Northern Rockies Ecoregion values are used as references for comparison. Northern Rockies Ecoregion values are generally considered to be high (pers. comm. F. Rabe) and should not be weighted as heavily as the regional reference. Box Creek (Sites 1 and 3) had the highest PLWS values for these metrics are used for the PLWS regional reference. Percent dominance is evaluated based on percent contribution, not percent comparability to a reference site, with < 20 % dominance considered optimal (Plafkin 1989). The HBI score is evaluated as a ratio of the reference site to study site x 100, with greater than 85% considered optimal (Plafkin 1989). Shannon's H' Diversity Index and percent scrapers rate as optimal if values are within 80% of the reference site value. Section III B describes the significance and interpretation of the metrics.

All sites evaluated in the PLWS fall within 1st through 3rd order streams, with the exception of two 4th order sites on the North Fork Payette River. First through third order streams as viewed in the river continuum concept (Vannote et al.1980) are heavily canopied, light-limited heterotrophic systems with rocky substrates. Dominant macroinvertebrate species in lower order streams include shredders and collectors, with a smaller percentage of grazers and predators (Ward 1992).

b. Limitations: Disadvantages of monitoring macroinvertebrates include a relatively high degree of variability within or between sites, local or regional variations in the sensitivity of given organisms to stress, and the need for specialized taxonomic expertise (MacDonald et al. 1991). Sampling should be replicated at sites and stratified by habitat type due to variability with depth, current speed, and substrate character. The BURP macroinvertebrate samples were obtained at base flows (late July-August), however, flows differed between years which could contribute to variability, and samples were combined at sites, thus they are not replicates. Sampling variability may also result from the sampling device operations, physical features of the habitat, laboratory sorting procedures, and biological features of the study population (Platts et al. 1983).

Fish

a. Description of Data: The status of the fish population in the PLWS was determined by Idaho Division of Environmental Quality electrofishing catch per unit effort records, and snorkeling surveys conducted by Idaho Department of Fish and Game, and the Payette National Forest. The BURP electrofishing technique consists of one upstream pass without block nets, identifying and measuring all fish. In streams of a given size and with the same sampling method and efficiency of effort, poorer sites are expected to yield fewer individuals than sites of higher quality (Karr et. al.1986). Snorkeling surveys conducted for the Payette National Forest by L& H Aquatic Research (Twentymile Creek, NF Payette River, and Trail Creek) consisted of a 20% sampling frequency of slow habitat types and a 10% sampling of fast water units. Fish were identified by species, number and size class.

b. Limitations: Sampling of fish populations must be done accurately because freshwater fish have wide fluctuations in year-class strength, and sampling techniques have different advantages and disadvantages. Snorkeling is useful in streams with low conductivity, however more secretive fish may avoid detection. In general, snorkeling allows a true estimate of fish populations only for certain species under favorable conditions (Platts et al. 1983). Electrofishing may be affected by stream conductivity, temperature, depth, and clarity of water.

3.3.6 References for Stream Habitat Analysis

Standards were compiled from the literature and state and federal agencies to provide a basis from which to interpret the available stream data. In many cases more than one standard is presented for a parameter. The resources used as references for standard conditions are detailed below.

Overton, C.K., et al. 1995. User's guide to fish habitat: descriptions that represent natural conditions in the Salmon River Basin, Idaho, USDA Forest Service General Technical Report INT-GTR-322. Ogden, Utah, U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 142 p.

Overton (1995) describes the physical features of stream channels that represent natural conditions for fish habitat within the Salmon River Basin in Idaho. "Natural conditions" refers to the structure and patterns of streams that have not been substantially influenced by human disturbances. Data for this guide was collected at four scales, including watershed, channel reach type, habitat type, and habitat type attribute. Streams were evaluated at base flow conditions using the R1/R4 Fish and Fish Habitat Standard Inventory Procedure. Summary statistics were calculated for bank stability, bank undercut, width-to-depth ratio, width-to-maximum-depth ratio, surface fines, water temperature, large woody debris frequency, and pool frequency. Large woody debris and pool frequency are summarized by stream size classes. This guide was used as a reference for comparison with five Payette Lake Subwatershed streams inventoried with the R1/R4 technique. The comparisons were made with relatively un-impacted streams with similar geology (plutonic), Rosgen channel types (A, B, or C), and widths.

USDA Forest Service. 1995. Inland native fish strategy environmental assessment. Interim strategies for managing fish-producing watersheds in eastern Oregon and Washington, Idaho, Western Montana, and portions of Nevada.

This strategy provides interim direction for National Forests and US Fish and Wildlife Service agencies to protect habitat and populations of resident native fish outside of anadromous fish habitat in eastern Oregon, eastern Washington, Idaho, western Montana, and portions of Nevada. Riparian management objectives, standards and guidelines, and monitoring guidelines are presented. The riparian management objectives are described as good indicators of ecosystem health and delineate the desired conditions for fish habitat by habitat feature and interim objectives. Desired conditions are described for pool frequency, water temperature, large woody debris, bank stability, lower bank angle, and width/depth ratio; and were listed for reference to Payette Lake Watershed streams when applicable.

Bjornn, T.C. and Reiser, D.W. 1991. Habitat requirements of salmonids in streams. Influences of forest and rangeland management on salmonid fishes and their habitats. W. Meehan editor. American Fisheries Society Special Publication 19:83-138.

Bjornn and Reiser present optimum and limiting values for the range of habitat conditions for each life stage for various species of fish. Ranges of temperatures, water velocities, depths, cover, and substrates preferred by salmonids, trout, and char are presented. This source was used to provide a basis for comparison for temperature, dissolved oxygen, and substrate quality for meeting life history requirements of resident fish species in the Payette Lake Watershed.

MacDonald, L.H.; Smart, A.W.; Wissmar, R.C. 1991. Monitoring guidelines to evaluate the effects of forestry activities on streams in the Pacific Northwest and Alaska. EPA 910/9-91-001.

Seattle, Washington: U.S. Environmental Protection Agency and University of Washington. 166 p.

This document provides information for designing water quality monitoring projects and selecting monitoring parameters. Part I discusses the regulatory mechanisms for nonpoint source pollution and defines seven types of monitoring. Part II is a technical review of the six categories of parameters: physical and chemical constituents, flow, sediment, channel characteristics, riparian, and aquatic organisms. Each parameter is discussed in seven sub-sections: definition, relation to designated uses, response to management activities, measurement concepts, standards, current uses, and assessment. This reference was useful for evaluating some of the monitoring techniques used in the Payette Lake Watershed, and for providing standards for some parameters in the Payette Lake Watershed Data Base.

Idaho Division of Environmental Quality. 1996. Water body assessment guidance. A stream to standards process. Prepared for State of Idaho, Watershed Monitoring and Analysis Bureau. 109 p.

This document presents guidelines for assessing data collected by the Beneficial Use Reconnaissance Project (BURP), and other sources. BURP objectives are to determine beneficial use attainability, and beneficial use status for streams in Idaho. Aquatic life beneficial use is the most sensitive of all the beneficial uses a water body can have. This guide is based on interpretation of *Idaho's Water Quality Standards and Wastewater Treatment Requirements*, and includes cold water biota general criteria for stream parameters. This reference presented State of Idaho standards for dissolved oxygen, temperature, and macroinvertebrate community structure for comparison with Payette Lake Watershed data.

Plafkin, J.L.; Barbour, M.T.; Porter, K.D.; Gross, S.K.; Hughs, R.M. 1989. Rapid bioassessment protocols for use in streams and rivers. Benthic macroinvertebrates and fish. U.S. Environmental Protection Agency, EPA/444/4-89-001.

The purpose of this document was to provide states with a practical technical reference for conducting cost-effective biological assessments of lotic systems. Three macroinvertebrate and two fish protocols are presented which advocate an integrated assessment, comparing habitat and biological measures with defined reference conditions. This reference was useful for interpreting the macroinvertebrate data collected in BURP.

Platts, W.S.; Megahan, W.F. Minshall, G.W. 1983. Methods for evaluating stream, riparian, and biotic conditions. Gen. Tech. Rep. INT-138. Ogden, Utah: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 70 p.

This report discusses some of the environmental parameters that best measure and describe conditions existing in aquatic ecosystems. Standard techniques are presented for measuring the aquatic, riparian, and biotic attributes; and the precision and accuracy of these measurements is discussed. This reference was useful for assessing the macroinvertebrate community structure on the Payette Lake Watershed as well as for providing a basis to evaluate and interpret stream habitat parameters including pool quality, pool / riffle ratios, and bank stability.

3.3.7 Stream-bed Sediment Nutrient Enrichment Monitoring

Stream channels can store significant amounts of fine sediments depending on the channel morphology, roughness and slope. Fine sediments, in addition to impacting fish habitat, have a strong affinity for nutrients, particularly phosphorus, and may accumulate additional nutrients through other bio-geochemical processes and effect the bioavailability of sediment bound nutrients (Taylor and Kumishi, 1971; Bostrom, et al, 1988). The nutrient status of fine sediments stored in streams was determined for each priority sub-watershed. Samples were collected in conjunction with the BURP stream assessments. Due to presence of gravels or very coarse sands, core samples were not obtained from all sites.

Submerged soils in streams were collected with a PVC core driven into the substrate to a depth of approximately 150 mm. Samples were collected from the center of the stream channel and at the wetted edge depending on the substrate conditions. The intact soil core was placed into a single plastic bag and labeled. If distinct soil horizons were present, each horizon was measured for depth of horizon, separated into an individual bag and labeled accordingly.

Analysis of soils from stream beds included estimates of the percent sand, silt and clay present in each core using the hydrometer method. This analysis was contracted to the University of Idaho analytical services laboratory. Other soil characteristics analyzed included the following:

> <u>Bulk density</u> - Dry bulk density were be computed from percent dry weights of the soil sub-sample, wet weight and volume of the original core. Percent dry weights and water content were calculated from soil wet and dry weights. Bulk densities are expressed as g dry weight/cm^3 of soil for each core volume.
>
> <u>Soil pH</u> - Soil pH was measured using a 10 g wet weight of soil sub-sample mixed with 20 ml deionized water. This soil/water mixture was allowed to settle and pH obtained from the liquid after 10 minutes

Table 3-7. Lists the chemical constituents analyzed from each stream-bed core. Estimates of labile and non-labile fractions of phosphorus were determined by a modification as described.
Table 3-7. Soil Chemistry Analysis Methods

Parameter	Sample Source	Method
Extractable Inorganic N	Wet/Dry Soil	Known sample extracted with 1M KCL solution (1:100 soil to extractant on a soil dry basis), shaken for 1 hour, centrifuged for 15 minutes at 5,000 rpm and then filtered (0.45 um pore membrane filter). Filtered extract analyzed for ammonium -N using an automated salicylate nitroprusside method 351.2 (EPA, 1983).
HCL Extractable P	Dry Soil	5.0 g of dry soil extracted with 25 ml of 1M HCL for

		three hours, filtered (0.45 um pore membrane filter) and analyzed for SRP using method 365.1 (EPA, 1983) and total P using block digestion and automated ascorbic acid method 365.4 (EPA, 1983). HCL-P_i represents the Ca bound P fraction.
HCL Extractable Cations	Dry Soil	1M HCL extract prepared as in HCL extractable P and analyzed for Ca, Mg, Fe, and A1 using inductively coupled argon plasma (ICAP) spectrometry method 200.7 (EPA, 1983).
Bicarbonate Extractable P	Wet/Dry Soil	1 g dry weight equivalent of wet soil extracted with 25 ml of 0.5M $NaHCO_3$ solution (pH=8.5), shaken for 30 minutes, soil suspension filtered (0.45 um pore membrane filter) and analyzed for soluble reactive P (SRP) and total P. A sub-sample of the extract (10 ml) is digested using a potassium persulfate digestion method 4500-P (APHA), 1989). Digested volume is analyzed using automated ascorbic acid method 365.1 (EPA, 1983). P fractions will be reported as P^i (inorganic P or soluble reactive P) and P_0 (organic P).
Total P	Dry Soil	1.0 g dried weight combusted at 550^0 C for 4 hours in a muffle furnace. Ash residue dissolved in 20 ml of 6M HCL, then heated to evaporate to dryness. Residue redissolved in 2.25 ml 6M HCL, heated again and filtered (Whitman #42 filter) and brought to 50 ml volume and analyzed for total P using automated ascorbic acid method 365.4 (EPA, 1983).
Total N	Dry Soil	Finely ground (100 mesh) samples analyzed for total N and C using a Leco CHN 600 Combustion Autoanalyzer.

3.3.8 Channel Geometry Monitoring and Bank Stability

Changes in channel cross-section profile were measured annually to determine inter-annual differences in accretion and deposition processes. These measures provided an estimate of the amount of stream bank material eroded or re-deposited from upstream erosion. A cross-section profile of each stream channel and floodplain was determined for representative channel types monitored under the BURP protocols. In most cases, at least two channel sites were measured for each stream reach. Channel types were classified using the Rosgen Stream Classification system.

Complete protocols for the channel measurements are listed in Worth (1995). Briefly, transects crossing perpendicular to the channel were established at roughly 10, 20, 50, 70, 80, 100 meters downstream from a selected stream section. Channel cross sections were measured for the wetted width (WW) of the stream channel at equally spaced intervals by dividing the WW by 14 (at least 14 measurements were obtained). The bank full width was also measured together with measures of bank angle for both banks (angle in degrees deviation from horizontal) and the length and angle of bank undercut.

Bank stability was additionally measured throughout the entire reach of stream segment monitored. A minimum 100 m length of channel including both banks was documented by visual observations. Stability was estimated based on the linear meters of stream bank characterized according to the following criteria:

Covered & Stable (non-erosional) - more than 50% of bank surfaces are covered by vegetation in rigorous condition or covered by armored materials (large rocks). Stream banks appear stable and no evidence of cutting, breakdown, shearing or slumping.

Covered & Unstable (vulnerable) - over 50% of bank surfaces are covered by vegetation in rigorous condition or covered by armored materials (large rocks). Streambanks appear unstable with evidence of breakdown, cracking, sloughing, cutting or slumping. Recent evidence of erosion is typified by vertical or near vertical banks with little or no regrowth.

Uncovered & Stable (vulnerable) - less than 50% of streambank surfaces are covered with vegetation in vigorous condition or covered by armored materials. Stream banks appear stable and no evidence of cutting, breakdown, shearing or slumping. Banks may be bare but they appear to be holding together and are not vertical.

Uncovered & Unstable (eroding) - less than 50% of banks are covered by vegetation in vigorous condition or by armored materials. Streambanks appear unstable with evidence of breakdown, cracking, sloughing, cutting or slumping. Recent evidence of erosion is typified by vertical or near vertical banks with little or no regrowth.

3.4 Assessment of Watershed Sediment Contributions

The volume of sediment reaching aquatic systems as a result of soil creep, mass wasting, fire, roads, and harvest activities was calculated for the Payette Lake watershed. Calculations were based on observations made during field visits on October 11-16, 1996; aerial photographs of the watershed; Geographic Information System (GIS) databases of streams, roads, and past harvest; and watershed information supplied by the US Forest Service.

3.4.1 Background Sediment Yield

The major processes moving sediment downslope and into streams in the undisturbed portions of the Payette Lake basin include soil creep, mass wasting, and surface erosion on burned, unvegetated hillsides. Soil creep is the slow downslope movement of soil resulting from gravitational forces and during discussions between DEQ, the Payette National Forest and the consultants was believed to include soil movement resulting from biological activities such as animal burrowing and soil attached to roots of fallen trees. Mass wasting was observed to be an important delivery process in the steep valley sidewalls in portions of the glaciated uplands in the watershed. A large fire (Corral-Blackwell fire), covering half of the watershed occurred in 1994. Fires can remove vegetation protecting the soil and result in increased surface erosion and mass wasting.

Soil Creep

The sediment yield from soil creep was estimated using the following formula:

> Annual Sediment Yield from Soil Creep = Length of Stream Channel * 2 banks* Average Soil Depth * Average Creep Rate

The length of channel was obtained from the GIS stream database. An average soil depth of 2 feet and an average creep rate of 0.06 inches/yr (1.5 mm/year) was used (Washington Forest Practices Board 1994). Stream channel length was multiplied by 2 to account for creep from both sides of the stream. The calculated soil creep was multiplied by 1.4 to account for the bulk density of soil/rock along stream banks and convert the volumetric creep estimate to tons. The bulk density value chosen is an average of lower density, thinner upper soil horizons and the higher density, thicker lower soil horizons.

In order to provide an alternate estimate of background sediment production, rates measured in undisturbed drainages of similar geology were used. A value of 25 tons/sq. mi/yr was multiplied by the area of each subbasin (Walt Megahan, pers. comm. 1997). This estimate, however, may be biased due to inclusion of multiple sediment sources (surface erosion, channel erosion, and mass wasting) in a single collective estimate. Mass wasting contributions in this study are calculated as a separate addition to the total sediment sources. Thus, estimation of background erosion contributions using the undisturbed erosion coefficient may slightly overestimate natural background sediment totals when tabulated with mass wasting contributions.

Mass Wasting

In consultation with DEQ personnel, Forest Service employees, Idaho Department of Lands representatives and other individuals knowledgeable about mass wasting processes in central Idaho, the analysts agreed to use a modified form of the mass wasting analysis procedures outlined in the Washington State Watershed Analysis methodology, version 3.0 (Washington Forest Practices Board, 1994). This methodology uses the underlying characteristics of the watershed to determine landscape areas that have produced landslides in the past and that have the potential to produce landslides in the future. It is a qualitative approach, which emphasizes analyzing the actual landslide history of the watershed in combination with the underlying general characteristics of the landscape (i.e., its slope, aspect, lithologic types and landscape evolution).

The method assumes that slopes and rock types that have failed in the past are more likely to fail again in the future. It uses three kinds of information: an analysis of historical aerial photographs to create a landslide inventory, research into the nature and susceptibility of the lithologies underlying the located landslides, and a geomorphic analysis of the characteristics of the watershed's slopes that have produced landslides in the past. All of this information allows the analyst to create a rating system that is used to delineate areas in the watershed that are more likely to produce landslides in the future. In addition, the inventory includes information about whether or not a particular landslide delivered sediment to a stream or body of water, and about the quantity of material that it may have removed and transported to the stream. Because it is a qualitative analysis, this approach does not attempt to predict a reliability level for the hazard rating system it develops. Instead, the analyst defines the confidence level for the various kinds of information that he/she develops and uses in the analysis.

Three methods were used to analyze the mass wasting in the Payette Lake watershed: aerial photo analysis, field investigations, and watershed slope analysis. Five sets of aerial photographs, taken in 1946, 1969, 1976, 1987, and 1995, were examined to track the history of the mass wasting features in the watershed. The 1946 set of photographs are black and white and did not provide full coverage of the entire watershed. Therefore, the landslides in areas that were not covered by the 1946 photos may have been present in 1946, but they were actually inventoried off of the 1969 photos. The mass failures first recognized in the 1949 or 1969 photos could have occurred any time before the photos were taken Therefore, they may be either "ancient" in the sense of having occurred and reactivated within the recent geological past, or "historical", having occurred within more recent time preceding 1946. It is not possible to interpret from photos the exact age of a particular landslide, other than by noting its presence or absence in a particular photo set.

Field identification and verification of the mapped mass failures was undertaken from October 9-16, 1996. The work included checking and investigating active and recent landslides identified from aerial photo analysis, and identifying landslides and mass failures that were not visible on the aerial photographs.

The analysis of the watershed slopes was undertaken with the aid of a slope map generated by the GIS analyst, an analysis of the slope aspect from the topographic maps, and identification of specific landforms from the aerial photographs. These three types analysis were then compared with each other and combined with the landslide inventory map and lithologic map to find areas that are more susceptible to mass wasting.

While the GIS slope map is used as the basis for some of the landslide hazard mapping in the watershed, it should be noted that the slope map has some limitations. The density of the data points used to create the map means that small areas of high slope located within larger areas of lower slope may not be shown. Instead, they are generalized into the lower slope categories. The glacial nature of this watershed means that it contains a larger number of these high slope "pockets" than the more typical fluvially dissected terrain. This fact is important, because these pocket areas are more susceptible to mass wasting. Thus, it appears that some debris slides formed within lower slope terrain, when in fact they are probably located within one of these high slope pockets that does not show up in the mapping of the lower slope terrain. Managers working in these areas should note the locations of these landslides and take the same sorts of precautions as suggested for the mapped high landslide hazard areas.

Fire

The Corral-Blackwell fires burned over half of the Payette Lake watershed during the summer of

1994. Based on observations made during field work in the watershed, the following assumptions were made to calculate the input of sediment from the 1994 fires:

(1) Any sediment eroded from burned areas did not reach streams unless the riparian vegetation was burned (defined as moderate or high intensity burn on USFS stream surveys or showing up as brown or black vegetation in the 1995 color aerial photographs of the basin).

(2) In areas where riparian vegetation was burned, the hillside area that could contribute eroded sediment to that stream segment was delineated based on USGS topographic maps. Burn intensity was determined from USFS burn intensity maps for each area.

(3) Fire erosion rates for low or moderate intensity fires as defined in the BOISED sediment erosion/delivery model were used (Table 3-8).

Table 3-8. Basic fire erosion rates (in tons/square mile/year). Adapted from Reinig et al. (1991).

Year Since Fire	Low Intensity Burn	Moderate Intensity Burn
1 (1995)	110	275
2 (1996)	24	60
3 (1997)	5	13
4 (1998)	1	3

Total estimated sediment input from the 4 years following the Corral-Blackwell fires was thus calculated as:

Sediment Input from Fire (tons) = Basic Fire Erosion Rate X Geologic Erosion Factor X Area Contributing to Stream Reach

Geologic Erosion Factor = Factor for each landtype (Reinig et al. 1991)

3.4.2 Sediment Input from Land Management Activities

Roads

Erosion from roads in the basin was estimated using road erosion rates from the BOISED manual (Reinig et al. 1991) applied to road segments that contribute to streams in the basin. Approximately 80 percent of the total miles of open forest roads in the basin were surveyed during October, 1996. Information on the road tread, cutslope, fillslope, ditch, and delivery of road runoff to a stream were recorded for each road segment that delivered to a stream. Each of these delivering segments was also marked on a map. After returning from the road survey, these delivering segments were transferred to a base map for entry into the GIS system. Delivering segments were also delineated on the map for non-surveyed roads in the basin at locations where these roads crossed streams. Average tread width, surfacing, cutslope and fillslope cover, and delivery rates were assigned to non-inventoried roads based on observations of the roads in the basin.

Roads within the town of McCall were not included in the survey. Erosion from these roads is accounted for in stormwater runoff measurements made by Idaho Division of Environmental Quality.

Road erosion rates were calculated as follows. Factors used are defined below and in Tables 3-9 through 3-11.

Average Sediment Input from Roads (tons/yr) = Basic Road Erosion Rate X Geologic Erosion Factor X Road Gradient Factor X Mitigation Factor X Delivery Factor X Road Prism Width X Segment Length

Geologic Erosion Factor = Erosion factor for each landtype (varies from 0.5 to 1.3 depending on landtype/soil erodability)
Road Prism Width = average total width of cutslope, ditch, tread, and fillslope
Segment Length = length of road that delivers sediment to a stream
Delivery Factor = percent of road drainage that reaches creek (estimated in field)

Table 3-9. Basic Road Erosion Rate.

Road Use	Traffic Type	Erosion Rate* (tons/sq mi/yr)
Heavy	Main haul road or highway	7,000
Moderate	Secondary road	6,000
Light	Less than 5 vehicles/day	5,000
None	Closed to traffic	1,250

* Erosion rates for existing roads were used to calculate long-term average annual road erosion rates for comparison with other sediment sources. A newly constructed or heavily reconstructed road will have a much (2-5 times) higher erosion rate for the first 3-4 years following construction (Megahan, 1974).

Table 3-10. Road Gradient Factor

Road Slope	Factor
0-5%	0.5

Table 3-11. Mitigation Factor

Tread Composition	Factor
[illegible]	0.05
[illegible]	0.2
[illegible]	1.0

In addition to estimates of surface erosion from the road prism, sections of road with rills or gullies that delivered to streams were also noted. The dimensions of the gullies (average width, depth, and length) were estimated in the field so a volume of eroded sediment could be calculated.

An alternate estimate of road surface erosion rates was calculated using procedures and empirical relationships from the Washington Department of Natural Resources Watershed Analysis Manual (Washington Forest Practices Board 1994). This method uses erosion rates and mitigation factors compiled from road research throughout the Pacific Northwest. While the erosion rates are derived from areas farther away from Payette Lake than the BOISED method rates, the Washington method has the advantage of applying much more site-specific information from the road survey to calculations of erosion from that particular road segment. Thus, while the BOISED method may more closely represent total volumes of sediment coming from road segments in the basin, the Washington method allows road managers to determine more accurately which road segments and which road prism components are supplying the most sediment to streams in the basin.

The average annual volume of sediment delivered to a stream system at each stream crossing was calculated based on the following formulas:

> Total Sediment Delivered from each Road Segment (in tons/year) = Tread + Cutslope + Fillslope + Gully Erosion
>
> > Tread = Basic Erosion Rate x Tread Surfacing Factor x Traffic Factor x Segment Length x Road Width x Delivery Factor
> >
> > Cutslope = Basic Erosion Rate x Cutslope Cover Factor x Segment Length x Cutslope Height x Delivery Factor
> >
> > Fillslope = Basic Erosion Rate x Fillslope Cover Factor x Fillslope Segment Length x Fillslope Height x Delivery Factor

Values for each factor in the equations were obtained from information collected during the road inventory. These values were linked to lookup tables to calculate total sediment delivered from each road segment (based on WDNR 1994). Tables 3-12 through 3-15 show the values that were used. Parent material for each road segment was assigned based on observations of the road cut.

Table 3-12. Basic Soil Erosion Rate.

Parent Material	Basic Erosion Rates (tons/acre/year)
alluvium	30
sandy till	30
silty till	60
granite	30
gneiss	30

Table 3-13. Road Tread Surfacing Factor.

Surface Type	Surface Factor
Asphalt	0.05
Gravel	0.2
Native	1.0

Table 3-14. Traffic Factor

Road Use	Traffic Factor
Heavy	5
Moderate	
Light	
None	.

Table 3-15. Cutslope and fillslope cover

Percent Vegetation or Rock	Cover Factor
	0.1023
	0.1500
	0.2003
	0.2540
	0.3116
	0.3742
	0.4433
	0.5222
	0.6155
	0.7700
	1.0000

The delivery of sediment from each of the road prism components was determined based on the road drainage configuration (Table 3-16) and the delivery of road runoff as noted in the field for each segments (directly to a stream channel - 100 percent delivery; within 200 feet of a stream - 10 percent delivery; or to the forest floor - no delivery).

Table 3-16. Road Component Delivery.

Ler			
Road Drainage	Tread	Cutslope	Fillslope
Insloped	All	All	Length noted in field
Outsloped	Equal to length of fillslope	Equal to length of fillslope	Length noted in field
Crowned	Half width for total length	All	Length noted in field

Timber Harvest

An evaluation of the potential for surface erosion from harvest practices in the basin was made based on observations from aerial photographs and field checking of individual harvest units for erosion. Maps of past harvest were obtained from the GIS database. Selected recent harvest units were observed during the field visit to determine if erosion was occurring and reaching waterways. The type of erosion (sheet erosion, gullying, rilling) was noted in each unit as well as whether the eroded sediment was delivered to a stream or body of water.

Observations on the ground and on aerial photographs showed that minimal sediment from timber harvesting or skid trails in recently harvested units was reaching creeks. Stream buffers and erosion control measures on skid trails (e.g. water bars) were effective at protecting waterways. The only potential for sediment to reach creeks was if skid trails or ground disturbance occurred close to creeks. The following equation was used to estimate sediment reaching waterways from timber harvest activities:

Sediment Input from Harvest (tons) = Basic Harvest Erosion Rate X Stream Length within Harvest Units X 2 banks X 50 feet on each bank

Basic harvest erosion rates were taken from the BOISED manual, and vary by type of harvest (clearcut, partial cut) and tree skidding method (tractor, skyline, cable, helicopter). The rates also decline each year following harvest as vegetation regrows in harvested areas and erosion decreases (Table 3-17). Stream lengths within harvest units were obtained from the GIS database. The assumption that sediment produced from 50 feet on each side of the creek reached the creek is a maximum assumption. The little research measuring surface erosion transport distances in harvest units that has been performed suggests 30 foot buffers are effective at trapping sediment (Walt Megahan, pers. comm.,1997). Field observations in the Payette Lake watershed indicated eroded sediment movement varied with small-scale topography, vegetation, and obstructions within each unit.

Total sediment input from harvest was divided by the period of harvest records (1950-1995) to yield an average annual sediment input (tons/yr) from harvest in the basin for comparison with other sediment sources.

Table 3-17. Basic Harvest Erosion Rate by Year after Harvest (tons/sq. mile/year) from Reinig et al. 1991.

Harvest	Type/Method	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
clearcut	tractor	340	180	140	90	40	20
clearcut	helicopter	65	34	27	17	8	4
clearcut	skyline	112	59	46	30	13	7
partial cut	tractor	241	128	99	64	28	14
partial cut	helicopter	48	25	20	13	6	3
partial cut	cable	146	77	60	39	17	9

3.4.3 Relative Phosphorus Loading from Surface Erosion and Mass Wasting Sources

Phosphorus is an important nutrient that is often associated with eroded sediments and can contribute to eutrophication in lakes. The amount of phosphorus contributed from eroded sediments depends upon the phosphorus content of the particular sediment source, and the availability of that phosphorus to algae and other microorganisms (bioavailable phosphorus). Actual phosphorus loading from different sediment sources is a very complex issue since phosphorus levels vary considerably both within a soil profile and between different soil types in a watershed. Some limited data on relative phosphorus levels in soils have been collected in the Gold Fork River watershed, south of the Payette Lake basin (Fisher et al. 1997). The Gold Fork data indicate that bioavailable phosphorus from the A soil horizons (surface soil layer; rich in organic matter) averaged 5 times higher that from C soil horizons (lower, parent material layers). Bioavailable phosphorus is generally associated with and transported by clay-sized sediments from eroded soil. Clay content of granitic soils averages 5 percent; clay content of road fills is typically 3 percent (Walt Megahan, pers. comm. 1997).

In order to provide an estimate of the relative amount of phosphorus (relative phosphorus loading - RPL) from different sediment sources in the Payette Lake watershed, the following relationships were used (Walt Megahan, pers. comm. 1997). It should be noted that these estimates do not provide actual phosphorus levels, but only relative loading levels to help compare the effect of different sources.

Soil Creep/Background Sediment RPL:

RPL = 0.05 x sediment input x 2.0

where:

0.05 = percent clay in creep material

2.0 = P concentration factor equal to the weighted average P factor assuming a 0.5 foot thick A horizon (P factor 5.0) and a 1.5 foot thick C horizon (P factor 1.0) for creep material.

Mass Wasting RPL:

RPL = 0.05 x sediment input x 1.33

where:

0.05 = percent clay in landslide material

1.33 = P concentration factor equal to the weighted average P factor assuming a 0.5 foot thick A horizon (P factor 5.0) and a 5.5 foot thick C horizon (P factor 1.0) on landslide areas.

Road Erosion RPL:

RPL = 0.03 x sediment input x 1.0

where:

0.03 = percent clay in road fills

1.0 = P concentration factor equal to C horizon P factor.

Harvest Unit RPL:

RPL = 0.05 x sediment input x 5.0

where:

0.05 = percent clay in A soil horizon

5.0 = P concentration factor equal to the A horizon P factor.

Burned Areas RPL:

RPL = 0.05 x sediment input x 5.0

where:

0.05 = percent clay in A soil horizon

5.0 = P concentration factor equal to the A horizon P factor.

3.5 Boating Recreation/Creel Survey Techniques

The IDFG, jointly funded by DEQ, conducted a creel census and boating recreation survey from July 1995 through June 1996. The survey was structured to sample eight weekday and weekend days in consecutive four week periods. Days were split into two equal time periods between sunrise and sunset. We made three angler/boat counts per day during the selected count period at three hour intervals. The survey days and count periods were randomly selected using the IDFG standard creel survey computer program (McArthur, et. al. 1993). This program was used to summarize data and generate total angler participation estimates.

Kokanee are, and will continue to be, the major species supporting sport fishing on Payette Lake. They not only provide 73.1% of the total harvest, they also provide the prey base for the lake trout. The IDFG annually monitors the kokanee population in Big Payette Lake using mid-water trawling techniques and by counting the number of adult fish in the spawning run. Mid-water trawling techniques are described in detail in Grunder (1990) and Bowles et al. (1986,1987). In general the mid-water trawl is a long funnel shaped net with a ten foot square mouth. This net is pulled through the water at various depths which contain kokanee. The number of kokanee caught in the net is directly proportional to the total number of fish in the lake. The number of kokanee caught in the trawl is then expanded to give an estimate of the total kokanee population size in the lake.

The N.F. Payette River provides important spawning habitat for kokanee. Each year, spawning begins in late September and extends through October. The kokanee spawning run is enumerated by walking the entire stretch of the N.F.Payette River that is utilized by spawning fish and counting all live fish. This count is made every three to four days until the number of fish counted begins to decrease. The peak count is then multiplied by a correction factor of 1.73 (Frost 1994).

3.6 Assessment of Sediment Accumulation Rates

A paleolimnologic analysis of a lake within it's watershed uses lake sediment stratigraphies to reconstruct a historical pattern. This method is analogous to the use of tree rings to assess atmospheric and/or disturbance conditions affecting the region surrounding a particular forest stand. A historical pattern is derived from both techniques through careful sample collection and subsequent physical, chemical and biological analyses of extracted segments.

A paleolimnologic study of Payette and Upper Payette Lakes was devised in order to contribute to the understanding of the natural and human events which occurred within the catchment over the last 140-180 years.
The purposes of this study were to:

1.) Establish a quantitative record of sediment inputs to Payette and Upper Payette Lake from approximately 1840 through to the present day;

2.) Correlate changes in sedimentation records to known catchment events of both natural and human origin. Also note significant watershed events that fail to produce a response in lake sedimentation rates; and

3.) Assess the potential for a degradation in water quality that may result from particle-bound nutrients moving into the lake(s).

The results from this study, taken in concert with other research projects conducted by the Idaho Division of Environmental Quality (IDEQ) within the Payette Lake catchment, will provide a basis for acceptable water quality criteria within Big Payette Lake and Upper Payette Lakes.

3.6.1 Sampling

A lake sediment stratigraphy is sampled by collecting a lake sediment core. The coring device used to retrieve material from Big Payette Lake and Upper Payette Lakes uses a sphincter-like aperture mounted at the end of a plexiglass tube to seal a sediment core in place. The 'sphincter corer' (designed and constructed by Gubala and Eilers) weighs approximately 200 lbs and is deployed by means of a custom crane and boom rigging from a standard 17' powerboat. The corer is lowered gently into the sediment, where the sphincter is then tripped and sealed. A 1-1.5 m long, 10 cm diameter tube of sediment is then captured within a plexiglass tube and raised to the surface. Upon retrieval, the sediment core is then subsectioned horizontally at 1.0 cm intervals starting from the sediment-water interface and working downward. This process is facilitated through the use of a vertical extrusion device, which pushes the sediment up from the bottom in a calibrated manner, to be sliced and packaged at the top.

Approximately 75 cc of wet sediment material is recovered for each centimeter of depth within a 10 cm diameter sediment core. Given an average % water content for lake sediments, 75 cc of material translates to 6-10 grams dry weight of useable material per centimeter slice. This relatively large mass of material derived from the 'sphincter corer' permits multiple sets of analyses on the same sediment intervals, increasing statistical power and reducing sampling costs.

3.6.2 Sample Site Selection

The accuracy of a paleolimnologic reconstruction depends upon the 'representativeness' of the sediment cores retrieved from the target lake. There are two distinct and important components of the term 'accuracy' mentioned here. First (I) is the accuracy of the historical reconstruction, relating to the timing and *relative* response of a lake to a single or series of watershed events. The second (II) component of paleolimnologic accuracy relates to the *absolute* response of a lake to the same events.

To obtain high degree of Type I accuracy, a paleolimnologist must locate a sampling site with sufficiently high and integrative sedimentary region to insure the highest possible degree of temporal resolution within the recovered core. This is accomplished by retrieving a sediment core from a deep, stable basin within a lake, taking advantage of higher than average whole lake accumulation rates. In this manner, small scale changes in sedimentation patterns will be amplified to detectable levels upon analysis.

Type II accuracy is obtained through collection of multiple cores, recovered from a variety of sedimentary environments within a lake. Unique sedimentary environments are typically defined by a combination of lake hydraulics and depth. Sediment accumulation rates derived from a sufficiently diverse sample of sedimentary environments then yield an accurate whole lake response to catchment events and/or disturbances. Obtaining a high degree of Type II accuracy can be a time consuming and costly affair as multiple cores are required to achieve statistical significance.

In an effort to balance the data quality objectives against the budgetary constraints of the IDEQ, this study sought to optimize for Type I accuracy. As such, preferentially high sedimentation rate regions within Big Payette Lake and Upper Payette Lakes were sought for sample collection. Based upon existing basin morphometry, two sample sites were selected from within Big Payette Lake: the deepest section of the northwest (NW) arm and a similar trough in the southeast (SE) region (Figure 3-3). Since bathymetric data did not exist for Upper Payette Lake, a cursory hydroacoustic survey revealed an appropriate stable basin for coring to the northern section of the lake at a maximum depth of 28 m.

The three cores collected from the two lakes likely represented an accurate reconstruction of each of the basin histories. Since the sample sites were selected to optimize for temporal resolution, the absolute rates of sediment accumulation, presented in the results, will overestimate the absolute rates of accumulation in each system. The degree of overestimation is likely limited to a factor of two, since the morphometries of the two lakes suggest a small to medium potential for 'sediment focusing.' (The highest degree of 'sediment focusing' is noted in conically shaped lake basins and has been noted as no greater than a factor of two times the average whole-lake accumulation rates).

3.6.3 Stratigraphic Dating and Sediment Accumulation Rates

A history of the sediment accumulation rates are the primary response factor(s) sought from this sediment coring project. To determine the rates of accumulation, specific dates must be assigned to each sediment interval sliced from the core. This process is accomplished through the analysis of a naturally occurring radioisotope, 210Pb. 210Pb, a particle derived from the decay of naturally occurring radon gas, is continuously deposited upon the lake and it's watershed. A continuous source of this material is also deposited into the lake sediments, both directly and through the movement of soils and sediments into the lake from the watershed. With a half life of 22.6 years, 210Pb decays quickly upon burial within the sediments. Comparison of the residual 210Pb found buried in the sediment with the amount deposited at the surface yields a relative age of deposition of the down-core layers. Based upon current analytical techniques, 210Pb can be measured to as low as 0.1 disintegrations per minute (dpm). Given a typical rate of supply of 210Pb to a North American watershed, the 0.1 dpm analytical limit is sufficient to detect the material in the sediment for approximately 7-8 half lives (160-180 years). To refine this radiometric dating process a model known as the 'Constant Rate of Supply' (CARS) is applied to the results from the sediment sequences of each core (Appleby and Oldfield, 1978).

Once a sediment core has been retrieved and subsectioned, 210Pb is systematically determined in each interval, starting from the surface and working down through the core (or backwards in time). These analyses are halted once a steady background of 210Pb has been established to the extent of the analytical limits. The CARS model is applied and dates or 'time before present' is determined for each discrete interval. Combining this dating curve with determination of cumulative dry mass in each interval and core then yields the desired results of sediment accumulation rates versus time before present over the last 160-180 years.

3.6.4 Dating Confidence

The confidence intervals of 210Pb dates and subsequent sediment accumulation rates assigned to each sediment interval become larger as one moves backwards in time. This is due to the fixed analytical limit for measuring 210Pb (0.1 dpm) relative to the decreasing amount of material to be measured at depth in a core. Correctly propagating error through the cumulative calculations also broaden the confidence intervals significantly beyond the 100 year before present period. But while the confidence intervals for down-core intervals may appear large, additional confidence in the data is obtained through the time series provided by continuous record in the core. Interpretation of each dating and sediment accumulation rate curve must acknowledge these potential limitations as well as the advantages of a robust, explicit and continuous historical reconstruction.

3.6.5 Nutrient Content Analysis

In addition to ^{210}Pb analysis, selective core segments were analyzed for total phosphorus, total nitrogen, total carbon, iron, and particle size. This analysis was performed by the University of Idaho soils laboratory. This analysis was performed to ascertain historical differences in the nutrient content of accumulated sediments which may further indicate whether changes in the sedimentation processes are related to internal verses external sources.

3.7 Minimum Stream Flows

The Lake Reservoir Company holds 3,000 acre feet of storage in Upper Payette Lake for use downriver near the town of Payette. This Irrigation storage is typically released from Upper Payette Lake in late summer so that the company could meet other requirements for irrigation, Payette Lake levels and stream flows below Lardo dam.. The minimum stream flow study was prompted by a concern that the needs of fisheries resources in the river below Upper Payette Lake have not regularly been met under past management of releases, and the needed resource flows have not been quantified. Figure 4-31 a. on page 191 shows river discharge at the USGS gauge downstream from Fisher Creek for the period of record. The gauging station began operating October 1, 1994.

3.7.1 Field Studies

Four reaches were identified in the North Fork of the Payette River from Upper Payette Lake Dam to slack water above Payette Lake based on gradient and frequencies of four habitat types (pools, riffles, runs, and pocket water): I -- Upper Payette Lake Dam to Pearl Creek, II -- Pearl Creek to Brush Creek, III -- Brush Creek to Fisher Creek, and IV -- Fisher Creek to Box Creek (Figure 3-7). In July, 1996 one study site was established in each reach. Each study site consisted of two or three transects. The downriver transect at each site was selected just above a hydraulic control that influenced water velocities and depths of the entire site. Streambed elevations were measured along each transect to 0.01 feet relative to a benchmark established at each site. Water surface elevation was measured for each transect on three occasions, at relative high, intermediate, and low discharges. Water velocities were measured at the downriver transect of each site on all three occasions. Velocities were measured at all other transects at the intermediate discharge only. Water surface elevation and velocities were measured on July 8 - 9, July 18 - 19, and August 7; at discharges of 310 cfs, 135 cfs, and 27 cfs, respectively (as measured by the USGS Gauge below Fisher Creek).

Summer water temperatures were monitored with a Hobo electronic temperature recorder (model HTI -5 to +35°C) placed in the river at the USGS gauging station downriver from Fisher Creek.

Fish density and length information was collected at each site by snorkeling on July 24. Five snorkelers moved abreast upstream from the downriver to the upriver transect, recording species, number and length of all salmonids seen. Discharge at the USGS gauge was 111 cfs.

Frequency of pools, riffles, runs, and pocket water was determined by a “50 pace survey” on July 18

- 19, at a discharge of 135 cfs. To conduct the survey a person, taking uniform steps, walks down the river, and stops at every 50th pace, recording the habitat type at that specific location.

Figure 3-7 Minimum Stream Flow Assessment Sites. Study sites are marked (X).

3.7.2 IFIM Simulations

The computer-based Riverine Habitat Simulation (RHABSIM) program, developed by Thomas R. Payne (Payne and Associates 1995), was used to model the relationship between discharge and available fish habitat. This program is a modification of the Physical Habitat Simulation (PHABSIM) program, a part of the Instream Flow Incremental Methodology (IFIM) developed by the Midcontinent Ecological Science Center, U.S. Geological Survey, Fort Collins, Colorado. This group was formerly known as the Instream Flow Group and was under the administration of the U.S. Fish and Wildlife Service. The reader should consult Instream Flow papers No. 11 (Milhous et al. 1984) and No. 26 (Milhous et al. 1989) for a more in-depth discussion of the methodologies of the programs. Suitability curves were used from Cochnauer and Elms-Cockrum (1986) for rainbow trout, and Foster and Bennett's (1995) habitat suitability curves for spawning kokanee to quantify available fish habitat for a given discharge.

Chapter IV

4.0 Watershed Assessment - Results and Analysis/Quantity and Quality of Watershed Runoff

4.1 Watershed Water Budgets

4.1.1 Precipitation and Snow Pack Conditions

Rainfall and snow pack conditions were obtained from the U.S. Natural Resources Conservation Service (NRCS) Snotel Data Site at Secesh Summit (elevation 1,978 meters) located on the northern edge of the North Fork Payette River basin boundary. Monthly precipitation and the snow water equivalent (SWE) of the snowpack for water years 1994-1996 are presented in Figure 4-1 and 4-2. The SWE recorded at this site provides an estimate of the quantity of water contained in the snowpack that would be available for runoff. Water volume stored as snowpack is generally greatest in April and May at the onset of snowmelt and reflects the accumulated storage of precipitation deposited as snow during the earlier months. A comparison of the SWE with the historical trend (1961 - 1990; Figure 4-2) shows that water content of the snowpack exceeded historical averages by 15% (38.0 inches or 965 mm) and 9% (36.1 inches or 917 mm), respectively, at the onset of the snowmelt season in May of 1995 and 1996.

Rain on snow events can potentially generate episodic peak flows in runoff that exceed normal rates of snowmelt. Precipitation amounts were below normal in May (2.1 inches or 53 mm) and above normal (5.0 inches or 127 mm) in June 1995 (Figure 4-1). These conditions were reversed during the following snowmelt season with above normal precipitation in May (7.2 inches or 183 mm) and well below normal in June (1.1 inches or 30 mm). Total annual precipitation at the Secesh Summit for both water years was 1,514 mm (59.6 inches) and 1,661 mm (65.4 inches) in 1995 and 1996, respectively. These totals exceeded the annual average (1961-1990) of 1,298 mm (51.1 inches).

Local precipitation information near Big Payette Lake was obtained from the McCall Airport (elevation 5,030 feet) climate monitoring site (Figure 4-3). Total precipitation in calendar year 1995 was 824 mm (32.5 inches) and 665 mm (26.2 inches) in calendar year 1996. Daily precipitation amounts follow a distinct seasonal pattern with lower rainfall amounts occurring during the warmer summer months and increasing in the fall and winter with passage of cold fronts. These weather fronts can generate significant runoff to Big Payette Lake as rain on snow events. These events are most likely to occur in February or March when air temperatures begin fluctuating above freezing.

Figure 4-1. & Figure 4-2

Figure 4-3. McCall rainfall amounts.

4.1.2

Tributary Stream Flows and Water Budgets

Upper Payette Lake Tributaries: Hydrographs based on field flow measurements and continuous water level recorders are presented in Figures 4-4. The daily hydrograph at the N.F. Payette River above Upper Payette Lake represents the typical pattern in runoff observed in the Upper Payette Lake drainage basin. Selection of a suitable site for monitoring stream flow was limited due to backwater affects from the Upper Payette Lake and the braided stream conditions that were present upstream. Consequently, stream flows were measured from a bridge spanning a well defined channel near the stream confluence with Upper Payette Lake. The close proximity of this site to the lake and lack of slope influenced recorder sensitivity during the period July through September when the lake was normally full (5555.3 ft. msl). Effects on the discharge estimates during the remainder of the year were minimal due to regulation of water levels within the lake. Water levels are typically reduced by 0.9 m (3.0 ft) in the fall to create additional storage space for the following year snowmelt.

Peak flows in WY 1995 were observed in late May coinciding with the rise in air temperatures as recorded at the NRCS Secesh Snotel Data Site (Figure 4-4). Runoff volume declined through the remaining snowmelt period and reached a seasonal low in late September. The following year hydrograph was similar but with peak flows occurring approximately two weeks later (June) due to cooler spring temperatures.

Highest tributary stream flows were recorded from the North Fork Payette River above Upper Payette Lake. Flow estimates from this site for WY 1995 ranged from 0.8 - 522 cfs. Higher peak flows were recorded during the second week of June in WY 1996 which exceeded 810 cfs, but fewer days of high flow rates were observed in WY 1996 as compared to WY 1995.

Continuous flow measurements on Twentymile Creek were maintained for only a short period before the gauge site was damaged during the first year peak flow event. Field measurements of flow rates were obtained throughout the study whenever stream conditions permitted. Peak flows were difficult to measure due to changes in channel routing under high flow conditions. Two distinct channels are present near the confluence of this stream with Upper Payette Lake. At flow volumes below 50 cfs, runoff is typically confined to the mainstem channel (north branch). As flows increase and reach bank full stage, additional water spills into a second channel (south branch) which continues to the lake. This south channel appears to have been formed in recent years during peak runoff events and currently has a bottom channel elevation higher than the river mainstem. The substrate in this south channel is sandy in texture and appears to be eroding downward and laterally.

The hydrograph pattern in runoff for Cougar Creek was similar to that of the North Fork Payette River flowing into Upper Payette Lake. Stream flow volumes ranged from 0.2 - 109.7 cfs in WY 1995 and from 0.1 - 131.6 cfs in WY 1996. As with the North Fork Payette river inflow, an accelerated runoff event was recorded during the second week of June and produced the highest peak flows for the water year.

Comparison of synoptic field flow measurements taken throughout the two water years confirm there is a high degree of similarity in the temporal runoff characteristics between streams draining into Upper Payette Lake (Table 4-1). Highest correlations were observed among flow measurements between the North Fork Payette River above Upper Payette Lake and other streams.

Figure 4-4. Daily Hydrographs representing a) gauged seasonal runoff from tributary streams; b) synoptic field flow measurements in the Upper Payette Lake drainage basin, and; c) average daily air temperature (degrees Celsius) at Secesh Summit Snotel Site. Trend line estimated for missing data by interpolation.

Table 4-1. Correlation matrix of synoptic stream flow measurements obtained during water years 1995 and 1996.

Uppe		Low				
	UPL-In	Cougar	20Mile	Deep	Pearl	Fisher
Cougar	.97					
20Mile	.95	.96				
Deep	.81	.84	.85			
Pearl	.90	.83	.83	.43		
Fisher	.97	.96	.95	.70	.73	
UPL-Out	.95	.95	.95	.87	.71	.96

Upper Payette Lake Water Budget: Total inflow to Upper Payette Lake was estimated by combining runoff from the gaged and ungaged inflows (Table 4-2). Ungaged inflows to Upper Payette Lake include runoff from Camp Creek on the west side of the lake and Outlet Creek on the east side. Total water yield from these sources was estimated by computing the water yield coefficient (m^3/hectare) for Cougar Creek and applying this yield to the drainage area of the ungaged streams. Both ungaged streams are lower yield perennial streams (compared to other inflows) but drain different land types. The Camp Creek drainage is similar to Cougar Creek and characterized by a glaciated valley with steep walls and subject to short-term, intense runoff. Culverts placed in the campground road crossing this stream adjacent to Upper Payette Lake were washed-out during the 1994 snowmelt season. Outlet Creek drains a smaller basin composed of moraines and glacial outwash with low slope gradients. Accordingly, the yield coefficient for Outlet Creek was reduced by fifty percent to reflect these differences in land type and drainage conditions.

Estimated water yields from monitored streams for the Upper Payette Lake subbasins ranged from 10,500 - 15,700 m^3/ha (Table 4-2). Despite the significant loss of vegetation cover associated with wildfires in these watersheds, the estimated water yields fell within the range of estimates for unburned watersheds (see Table 4-4 and Table 4-5). Estimates of pre-burn water yield characteristics are not available. Reduction of vegetation cover by wildfires can result in increased snow depths and affect melt rates (McNabb and Swanson, 1990). Other studies on the changes in hydrology related to wildfires have reported increased water yields, higher peak flows, increased overland flow and stream baseflow (Tiedemann et al., 1979). Initial increases in the annual yield range from approximately 762 - 5,077 m^3/ha (3-20 acre-inches/acre) have been reported in the northwest (Beschta, 1990). A post fire assessment of these watersheds conducted by the forest service rated these streams as having a moderate to high risk potential for change in flow or stream channel characteristics following the fire (Payette National Forest, 1995).

Table 4-2. Monthly cumulative (cf) estimates for streams flowing into Upper Payette Lake. Streams designated as UPLIN = North Fork Payette River into Upper Payette Lake, 20Mile=Twentymile Creek, COUGAR = Cougar Creek. Cumulative flows for Camp Creek are based on water yield of Cougar Creek. Cumulative flows for Outlet Creek are based on Cougar Creek water yield at 50%.

WY95	UPLIN	20MILE	COUGAR	CAMP	OUTLET	Total
OCT	90	68	17	14	3	192
NOV	157	118	33	27	6	341
DEC	132	100	28	23	5	287
JAN	173	264	48	39	8	533
FEB	539	1,064	225	185	37	2,049
MAR	1,058	1,107	391	321	64	2,942
APR	3,520	2,167	971	797	159	7,614
MAY	9,734	6,486	2,071	1,699	340	20,329
JUN	4,686	3,480	909	746	149	9,970
JUL	1,636	2,002	483	397	79	4,598
AUG	776	698	132	108	22	1,736
SEP	471	379	30	25	5	910
Total	22,973	17,933	5,339	4,380	876	51,501
(m3/ha)	12,377	10,597	13,429	13,429	6,714	11,698
(Acre-Ft/Acre)	4.1	3.5	4.4	4.4	2.2	3.8
WY96						
OCT	444	388	73	60	12	976
NOV	1.008	965	126	104	21	2.223
DEC	2.655	2.670	595	488	98	6.505
JAN	2.158	2.335	466	382	76	5.417
FEB	1.785	2.006	419	343	69	4.621
MAR	632	756	159	131	26	1.704
APR	2.632	2.230	571	468	94	5.994
MAY	8.450	4.983	1.476	1.211	242	16.361
JUN	7.835	7.063	1.606	1.318	264	18.085
JUL	1.152	1.388	314	257	52	3.162
AUG	172	181	41	34	7	434
SEP	289	306	24	20	4	642
Total	29,210	25,269	5,868	4,814	963	66,124
(m3/ha)	15,737	14,933	14,759	14,759	7,379	15,020
(Acre-Ft/Acre)	5.2	4.9	4.8	4.8	2.4	4.9

Figure 4.5. Comparison of total monthly inflow and outflow water volume for Upper Payette Lake.

Table 4-3. Radial gate openings and discharge volumes.

Discharge Over Spillway	
Gates Closed (Feet of Head)	cfs
1	206
2	580
3	1,070

This is where chapters 4-8 would go.

Chapter IV

4.0 Watershed Assessment - Results and Analysis/Quantity and Quality of Watershed Runoff

4.1 Watershed Water Budgets

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Highest tributary stream flows were recorded from the North Fork Payette River above Upper Payette Lake. Flow estimates from this site for WY 1995 ranged from 0.8 - 522 cfs. Higher peak flows were recorded during the second week of June in WY 1996 which exceeded 810 cfs, but fewer days of high flow rates were observed in WY 1996 as compared to WY 1995.

Continuous flow measurements on Twentymile Creek were maintained for only a short period before the gauge site was damaged during the first year peak flow event. Field measurements of flow rates were obtained throughout the study whenever stream conditions permitted. Peak flows were difficult to measure due to changes in channel routing under high flow conditions. Two distinct channels are present near the confluence of this stream with Upper Payette Lake. At flow volumes below 50 cfs, runoff is typically confined to the mainstem channel (north branch). As flows increase and reach bank full stage, additional water spills into a second channel (south branch) which continues to the lake. This south channel appears to have been formed in recent years during peak runoff events and currently has a bottom channel elevation higher than the river mainstem. The substrate in this south channel is sandy in texture and appears to be eroding downward and laterally.

The hydrograph pattern in runoff for Cougar Creek was similar to that of the North Fork Payette River flowing into Upper Payette Lake. Stream flow volumes ranged from 0.2 - 109.7 cfs in WY 1995 and from 0.1 - 131.6 cfs in WY 1996. As with the North Fork Payette river inflow, an accelerated runoff event was recorded during the second week of June and produced the highest peak flows for the water year.

Comparison of synoptic field flow measurements taken throughout the two water years confirm there is a high degree of similarity in the temporal runoff characteristics between streams draining into Upper Payette Lake (Table 4-1). Highest correlations were observed among flow measurements between the North Fork Payette River above Upper Payette Lake and other streams.

Figure 4-4. Daily Hydrographs representing a) gauged seasonal runoff from tributary streams; b) synoptic field flow measurements in the Upper Payette Lake drainage basin, and; c) average daily air temperature (degrees Celsius) at Secesh Summit Snotel Site. Trend line estimated for missing data by interpolation.

Table 4-1. Correlation matrix of synoptic stream flow measurements obtained during water years 1995 and 1996.

Uppe		Lowe				
	UPL-In	Cougar	20Mile	Deep	Pearl	Fisher
Cougar	.97					
20Mile	.95	.96				
Deep	.81	.84	.85			
Pearl	.90	.83	.83	.43		
Fisher	.97	.96	.95	.70	.73	
UPL-Out	.95	.95	.95	.87	.71	.96

Upper Payette Lake Water Budget: Total inflow to Upper Payette Lake was estimated by combining runoff from the gaged and ungaged inflows (Table 4-2). Ungaged inflows to Upper Payette Lake include runoff from Camp Creek on the west side of the lake and Outlet Creek on the east side. Total water yield from these sources was estimated by computing the water yield coefficient (m^3/hectare) for Cougar Creek and applying this yield to the drainage area of the ungaged streams. Both ungaged streams are lower yield perennial streams (compared to other inflows) but drain different land types. The Camp Creek drainage is similar to Cougar Creek and characterized by a glaciated valley with steep walls and subject to short-term, intense runoff. Culverts placed in the campground road crossing this stream adjacent to Upper Payette Lake were washed-out during the 1994 snowmelt season. Outlet Creek drains a smaller basin composed of moraines and glacial outwash with low slope gradients. Accordingly, the yield coefficient for Outlet Creek was reduced by fifty percent to reflect these differences in land type and drainage conditions.

Estimated water yields from monitored streams for the Upper Payette Lake subbasins ranged from 10,500 - 15,700 m^3/ha (Table 4-2). Despite the significant loss of vegetation cover associated with wildfires in these watersheds, the estimated water yields fell within the range of estimates for unburned watersheds (see Table 4-4 and Table 4-5). Estimates of pre-burn water yield characteristics are not available. Reduction of vegetation cover by wildfires can result in increased snow depths and affect melt rates (McNabb and Swanson, 1990). Other studies on the changes in hydrology related to wildfires have reported increased water yields, higher peak flows, increased overland flow and stream baseflow (Tiedemann et al., 1979). Initial increases in the annual yield range from approximately 762 - 5,077 m^3/ha (3-20 acre-inches/acre) have been reported in the northwest (Beschta, 1990). A post fire assessment of these watersheds conducted by the forest service rated these streams as having a moderate to high risk potential for change in flow or stream channel characteristics following the fire (Payette National Forest, 1995).

Table 4-2. Monthly cumulative (cf) estimates for streams flowing into Upper Payette Lake. Streams designated as UPLIN = North Fork Payette River into Upper Payette Lake, 20Mile=Twentymile Creek, COUGAR = Cougar Creek. Cumulative flows for Camp Creek are based on water yield of Cougar Creek. Cumulative flows for Outlet Creek are based on Cougar Creek water yield at 50%.

WY95	UPLIN	20MILE	COUGAR	CAMP	OUTLET	Total
OCT	90	68	17	14	3	192
NOV	157	118	33	27	6	341
DEC	132	100	28	23	5	287
JAN	173	264	48	39	8	533
FEB	539	1,064	225	185	37	2,049
MAR	1,058	1,107	391	321	64	2,942
APR	3,520	2,167	971	797	159	7,614
MAY	9,734	6,486	2,071	1,699	340	20,329
JUN	4,686	3,480	909	746	149	9,970
JUL	1,636	2,002	483	397	79	4,598
AUG	776	698	132	108	22	1,736
SEP	471	379	30	25	5	910
Total	22,973	17,933	5,339	4,380	876	51,501
(m3/ha)	12,377	10,597	13,429	13,429	6,714	11,698
(Acre-Ft/Acre)	4.1	3.5	4.4	4.4	2.2	3.8
WY96						
OCT	444	388	73	60	12	976
NOV	1.008	965	126	104	21	2.223
DEC	2.655	2.670	595	488	98	6.505
JAN	2.158	2.335	466	382	76	5.417
FEB	1.785	2.006	419	343	69	4.621
MAR	632	756	159	131	26	1.704
APR	2.632	2.230	571	468	94	5.994
MAY	8.450	4.983	1.476	1.211	242	16.361
JUN	7.835	7.063	1.606	1.318	264	18.085
JUL	1.152	1.388	314	257	52	3.162
AUG	172	181	41	34	7	434
SEP	289	306	24	20	4	642
Total	29,210	25,269	5,868	4,814	963	66,124
(m3/ha)	15,737	14,933	14,759	14,759	7,379	15,020
(Acre-Ft/Acre)	5.2	4.9	4.8	4.8	2.4	4.9

Figure 4.5. Comparison of total monthly inflow and outflow water volume for Upper Payette Lake.

Table 4-3. Radial gate openings and discharge volumes.

Discharge Over Spillway

Gates Closed (Feet of Head)	cfs
1	206
2	580
3	1,070

Table 5-1. Hydrologic budget associated with each budget component, Payette 1995-1996.

	1995		1996	
	Volume hm^3	Percent of Total	Volume hm^3	Percent of Total
Gag ed Infl ows **Infl ow** **Infl ow**				
North Fork Payette River	304	70.7	399	74.7
Fall Creek	17.3	4.0	15.3	3.6
Deadhorse Creek	11.7	2.7	11.4	2.6
[1] **Ungaged Tributaries**	90	20.8	101	23.6
[2] **Direct Surface Runoff** Developed and Undeveloped Lake Perimeter	2.9	0.7	2.7	0.6
Precipitation	4.7	1.1	4.1	0.9
Outf low **Outf low**				
North Fork Payette River	408	96.2	528	97.1
Evaporation	4.3	1.0	4.2	1.0
Municipal withdrawal	11.4	2.7	11.4	2.7
Summary				
Total Inflow	430		534	
Total Outflow	424		544	

	1995	1996
Change in Lake Storage	30	-87
[3] Residual	-24	77

[1] Includes runoff contributions from watersheds below USGS gage 13238322 and other tributaries draining directly to the lake.
[2] Runoff = Area *rainfall*runoff coefficient. Runoff coefficients based on land types and values as presented in Tables 5-4 through 5-13 and 5-4 through 5-14.
[3] (Total inflow-total outflow)-change in lake storage.

Table 5-2. Annual coefficients for unit runoff and nutrient export for three gaged inflow stations and one gaged outflow station, Payette Lake, 1995-1996. [km^2, square kilometer; kh^3/km^2, cubic hectometer per square kilometer; kg/km^2, kilogram per square kilometer; TP, total phosphorus; TN, total nitrogen].

Station Name (Figure 3-2)	Drainage area (km^2)	Unit-runoff coefficient (hm^3/km^2)		Nutr (kg/			
				TP		TN	
		1995	1996	1995	1996	1995	1996
North Fork Payette River below Fisher Creek	221	1.38	1.81	12.0	16.5	725	951
Dead Horse Creek	12.8	0.93	0.91	15.5	13.9	370	307
Fall Creek	17.3	1.00	0.88	842	46.4	1,500	797
North Fork Payette River at McCall	373	1.09	1.42	6.2	8.0	278	400

5.2 Nutrient Budgets

Substantially more total phosphorus entered Payette Lake in 1995-96 than was discharged from the lake (Table 5-3). In 1995, the largest single source load of phosphorus to the lake was Fall Creek (55.4%). This creek was heavily impacted by the 1994 fire and contained high concentrations of phosphorus in the runoff. Accordingly, computed loadings and the standard error of the estimate for this creek was extremely high (6,682-22,480 kg). Assuming the lower loading estimate better approximates the phosphorus yield, the Fall Creek contribution of phosphorus would have exceeded 36% of all inputs. More stable post fire conditions in 1996 provide a better basis for comparing relative importance of the inflows to Payette Lake. These results indicate the N.F. Payette River accounted for 46 percent of the total loading of phosphorus to the lake. Other ungaged surface-water tributaries accounted for 23.6 percent of the incoming load. These two sources together accounted for nearly 70 percent of the incoming load. Direct surface runoff around the perimeter contributed 9.5 percent of the total phosphorus load. Atmospheric deposition accounted for roughly 8 percent of the load. The City of McCall's municipal water withdrawal accounted for about 3-percent of the outflow of total phosphorus; the remainder was via the lake's outlet.

As with total phosphorus, Payette Lake received substantially more total nitrogen in 1995-96 than it discharged (Table 5-4). The North Fork Payette River inflow dominated the inflow budget in both years; the next largest contribution was from ungaged tributary inflow. Atmospheric deposition accounted for less than 3-percent of the load. About 2-percent of the outflow of total nitrogen was via municipal water withdrawal.

Table 5-3. Total phosphorus budget Payette Lake, 1995-1996.

	1995		1996	
	Load kg/yr	Percent of Total	Load kg/yr	Percent of Total
Gaged Inflows	**Inflow**		**Inflow**	
North Fork Payette River	2,660	10.1	3,640	46.3
[1] Fall Creek	14,571	55.5	803	10.2
Deadhorse Creek	198	0.8	178	2.3
[2] **Ungaged Tributaries**	7,360	28.0	1,860	23.6
[3] **Direct Surface Runoff** Developed and Undeveloped Lake Perimeter	818	3.1	725	9.2
Atmospheric Deposition	660	2.5	660	8.4
	Outflow		**Outflow**	
North Fork Payette River	2,300		2,960	97.7
Municipal withdrawal	49		69	2.9
Summary				
Total Inflow	26,267		7,866	
Total Outflow	2,349		3,029	
Change in Lake Storage	129		-531	
[4] Residual	23,789		5,368	
Percent Retention	90.6		68.2	

[1] Estimate based on two consecutive sampling periods in which extremely high concentrations of TP were measured during high flow events. Estimated TP load with standard errors ranges from 6,682 to 22,460 kg/yr.
[2] Includes runoff contributions from watersheds below USGS gage 13238322 and other tributaries draining directly to

the lake.
[3] Load=Area *Rainfall*runoff coefficient*TP concentration. Runoff coefficients based on land types and values as indicated in Tables 5-4 through 5-13 and 5-4 through 5-14. A runoff concentration of 14 mg/m3 TP was used for undeveloped lands. Mean pollutant concentrations used for developed lands as described in stormwater section (4.3.1).
[4] (Total inflow-total outflow)-change in lake storage.

Payette Lake acted as a trap (Outflow-Inflow = positive residual) for total phosphorus and total nitrogen (Tables 5-3 and 5-4). For example, the residual for total phosphorus in 1995 was 23,789 kg and 5,368 kg in 1996; thus the lake trapped roughly 90% of the inflow TP in 1995 and approximately 68% in 1996. The high trapping efficiency of the lake is due, in part, to its long residence time and the presence of a shallow morphometric constriction between the northern and southwestern basins. Model calibration indicated phosphorus sedimentation rates were particularly high resulting in rapid removal of particulate phosphorus from the water column as this material quickly settles to the lake bottom (see Model Calibration). Total nitrogen retention was also high at roughly 55 to 53% for the two water years.

Due to the long residence time, nutrient character of the source waters entering the lake are quite different compared to the outflow. The total and dissolved forms of phosphorus and nitrogen for the two North Fork Payette River stations (inflow and outflow) were concurrently measured and associated loads computed for each water year (Table 5-5). The percentage contribution of dissolved orthophosphorus to total phosphorus of the inflow averaged 22.4 percent and declined to 15.6 percent for the outflow station. Similarly, the percentage contribution of dissolved inorganic nitrogen to total nitrogen averaged 67.1 percent for the inflow station and 34 percent for the outflow station. These declines in the percentage contribution of the dissolved fractions between the inflow and outflow stations is attributable, in part, to phytoplankton and periphyton assimilation and conversion to the particulate nutrient pool of the lake (detrital algae).

Nitrogen and phosphorus was also added to Payette Lake from decomposition of kokanee salmon carcasses remaining from the autumn spawning run into the lower reach of the North Fork Payette River. About 7 kg of phosphorus and 55 kg of nitrogen were added to the lake in 1995 and 1996. These loads were not reported in the nutrient budgets (tables 5-3 and 5-4), but would have been a very small percentage addition. The loads were calculated using two data sources. Data from IDFG on numbers of spawning fish, mean biomass per fish and predation losses (P. Janssen, IDFG, written communication, 1996) were multiplied by the percentage composition of phosphorus and nitrogen in the carcasses. Phosphorus and nitrogen comprised 0.364 and 3.0 percent, respectively, of the biomass of rainbow trout *(Oncorhynchus mykiss)* as reported by Schuldt and Hershey (1995); these values were assumed to apply to kokanee salmon in the North Fork Payette River. Although this load was a small addition to Payette Lake's nutrient budget, it occurs annually and, thus, represents a long term, cumulative nutrient load.

An unquantified nutrient load to Payette Lake was from periphyton in the North Fork Payette River downstream from the USGS gaging station downstream from Fisher Creek (Figure 5-3). This lower most reach of the river supports a substantial amount of periphyton during the summer, partly because this is a quiescent reach affected by backwater from Payette Lake. Backwater conditions were produced by the damming of the lake in the early 1940's. In the autumn and winter, the periphyton become senescent and some portion, in a particulate and dissolved form, is scoured and transported into the lake with streamflow. This nutrient load was not quantifiable, but is probably not large in relation to the lake's nutrient budget. However, it represents another long term nutrient load.

Table 5-4. Total nitrogen budget Payette Lake, 1995-1996.

	1995		1996	
	Load kg/yr	Percent of Total	Load kg/yr	Percent of Total
Gaged Inflows	**Inflow**		**Inflow**	
North Fork Payette River	16,000	64.3	210,000	74.5
Fall Creek	25,960	10.4	13,782	4.9
Deadhorse Creek	4,730	1.9	3,934	1.4
[1] **Ungaged Tributaries**	48,069	19.3	44,631	15.8
[2] **Direct Surface Runoff** Developed and Undeveloped Lake Perimeter	3,532	1.4	2,965	1.1
Atmospheric Deposition	6,560	2.6	6,560	2.3
	Outflow		**Outflow**	
North Fork Payette River	104,000	98.2	149,000	98.3
Municipal withdrawal	1,890	1.8	2,530	2.4
Summary				
Total Inflow	248,851		281,872	
Total Outflow	105,890		151,530	
Change in Lake Storage	4,980		-19,300	
[3] Residual	137,981		149,642	
Percent Retention	55.4		53.1	

[1] Includes runoff contributions from watersheds below USGS gage 13238322 and other tributaries draining directly to the lake.

[2] Load=Area*Rainfall*runoff coefficient*TP concentration. Runoff coefficients based on land types and values as indicated in Tables 4-13 and 4-14. A runoff concentration of 305.7 mg/m3 TN was used for undeveloped lands. Mean pollutant concentrations used for developed lands as described in stormwater section (4.3.1).

[3] (Total inflow-total outflow)-change in lake storage.

Table 5-5. Loads of nitrogen and phosphorus for water years 1995 and 1996 at North Fork Payette River below Fisher Creek (13238322) and North Fork Payette River at McCall (13239000).

		Load (kg/yr)	
Station	Constituent	1995	1996
13238322	TP	2,660	3,640
	DOP	591	820
	TN	160,200	210,200
	TON	52,800	69,300
	DIN	107,400	141,000
	DN+N	106,200	139,400
	DAMM	1,200	1,570
13239000	TP	2,300	2,960
	DOP	356	462
	TN	103,500	148,700
	TON	66,200	101,200
	DIN	37,400	47,500
	DN+N	36,600	46,400
	DAMM	733	973

5.3 Limnology

5.3.1 Water temperature

Solar heating was sufficient to develop thermal stratification and thermoclines (decrease in water temperature with depth exceeds 1 C per meter) at the four stations in both years (Figure 5-1). Thermoclines developed during June and persisted into October. Thermocline depths ranged from about 4 m in June to about 10 m in October. Maximum water temperatures in both years were measured near the surface in late July. In 1995, the maximum was 21.1 C at station 1; in 1996, the maximum was 20.6 C at station 3. Minimum water temperatures reached 0 C immediately beneath the ice that covered the lake surface during the winter months. Hypolimnetic water temperatures ranged from about 4 C during ice cover to between 5 and 6 C near the end of thermal stratification.

5.3.2 Water-column transparency

The two measures of water-column transparency, secchi-disc transparency and euphotic-zone depth, had a strong positive correlation ($r=0.77$, $p<0.00001$, $n=71$). The smallest values for the two variables were measured during June of both years when snowmelt runoff had increased turbidity in the lake (Figure 5-2). After June, the two variables steadily increased in depth as suspended sediment settled. One exception to this trend was at station 1 during 1996 when both variables either decreased in depth or failed to deepen substantially. Among the four stations, station 1 had the highest density of phytoplankton; thus, its water-column transparency was accordingly reduced.

Median secchi-disc transparencies at the four stations during 1995 were equal to or less than those measured in 1996 (Table 5-6). Median euphotic-zone depths were equivalent between the two years, except at station 3. The euphotic zone was typically deeper than the thermocline at each of the four stations. Under that condition, the phytoplankton circulating within the epilimnion (mixed zone above the thermocline) remain exposed to amounts of PAR sufficient for photosynthetic production of carbon in excess of respiratory demands.

Table 5-6. Medians and ranges of secchi-disc transparency and euphotic-zone depth at four limnetic stations, Payette Lake, 1995-1996.

	Secchi-disc transparency (meters)		Euphotic-zone depth (meters)		
Limnetic station	Median	Range	Median	Range	No. of Samples
1995					
1	4.5	2.5-7	11	9-13	9
2	5.3	2.3-7.2	11	9-13	9
3	4.6	2.5-8	10.5	8-13	8
4	4.2	2.5-6.6	11	8-13	9
1996					
1					
2	4.5	3.5-7	11	10-13	9
3	5.5	3.1-7.6	11	9-13	9
4	5.2	3.6-7.6	11	9-13	9
	5.3	3.5-7.8	11	9-13	9

Secchi-disc transparency (meters)	Euphotic-zone depth (meters)

Figure 5-1. Lines of equal temperature, in degrees celsius, at stations 1-4 during selected months of 1995-1996.

Figure 5-2. Depths of euphotic zone and secchi-disc transparency at stations 1-4 during 1995-1996.

5.3.3 Specific conductance

Specific conductance is a measure of the ability of water to conduct electricity and is typically proportional to the water's dissolved-solids concentration. For most natural waters, the ratio of dissolved-solids concentration to specific conductance ranges from 0.55 to 0.75 (Hem, 1985).

Specific conductance in Payette Lake ranged from 17 to 35 uS/cm; most values were about 20 uS/cm (Brennan and others, 1996, 1997). These values are considered low for natural waters (Hem, 1985). The values above 30 uS/cm were measured in the lower hypolimnion at station 1 in conjunction with anoxic dissolved-oxygen concentrations. The lowest values were measured during June and represented the dilution effects of snowmelt runoff.

5.3.4 pH

The variable pH represents the negative base-10 logarithm of the hydrogen ion activity in moles per liter. In dilute solutions, the overall range in pH can be 0 to 14; values above 7 are considered basic and those below 7 are considered acidic.

The overall range of pH in the lake was 6.2 to 8.8 (Brennan and others, 1996, 1997). The general trend in pH was larger values in the euphotic zone during July (1995) or August and September (1996) and smaller values in the hypolimnion during late summer and autumn. This overall pattern in pH fits that described for many lakes. In the summer, pH in the euphotic zone increases in response to photosynthetic utilization of carbon dioxide, whereas pH in the hypolimnion decreases as carbon dioxide is added by decomposition of organic matter.

5.3.5 Dissolved oxygen

The concentration of dissolved oxygen in natural freshwater is affected by temperature, barometric pressure, production of oxygen by photosynthesis, consumption of oxygen by respiration and decomposition, and mixing of water masses. The ratio (expressed as a percent) of measured dissolved-oxygen concentrations to those that would exist under saturated conditions at the same temperature and pressure is useful for comparing dissolved oxygen when significant variations in temperature and pressure exist, such as comparisons spanning time or depth.

The overall range in dissolved-oxygen concentration over depth and time at the four stations was 0 to 11.7 mg/L in 1995 and 0 to 11.0 mg/L in 1996 (Figure 5-3). The maximum concentration for each year was measured at station 4; in mid-June of 1995 and in late July of 1996. The anoxic concentrations were measured during both years, but only in the lower hypolimnion at station 1 (See station locations in Figure 3-3 on page 39). The pattern within a year was that maximum dissolved-oxygen concentrations were measured within the epilimnion during the summer when photosynthetic production of oxygen exceeded oxygen consumption by respiration and decomposition; minimum concentrations were measured in the hypolimnion during late summer and autumn when thermal stratification had reduced mixing of the oxygenated epilimnion with the

Figure 5-3. Lines of equal dissolved oxygen concentration, in milligrams per liter, at stations 1-4 during selected months of 1995-1996.

hypolimnion. An important feature at station 1 was the lack of full re-aeration of the water column during spring circulation. In both years, dissolved-oxygen concentrations in the hypolimnion were increased to about 7.0 mg/L whereas the other three stations were re-aerated to about 10.0 mg/L.

Stations 1 and 4 had an additional period of low dissolved-oxygen concentrations in the spring, shortly after loss of the lake's ice cover (Figure 5-3). In early May, 1995, both stations had hypolimnetic dissolved-oxygen concentrations as low as 4 mg/L. In mid-April, 1996, station 1 almost developed anoxia in its lower depths. These incidences of dissolved-oxygen minima in the spring indicate that stations 1 and 4 can have a substantial hypolimnetic dissolved-oxygen deficit under winter ice cover. One set of winter samples were collected through the ice cover at stations 1 and 4 on February 21, 1996, about midway through the 4-month period of ice cover. Dissolved-oxygen concentrations in the lower hypolimnion were 6.2 and 5.8 mg/L at stations 1 and 4, respectively. As shown in Figure 6, dissolved-oxygen concentrations in the lower hypolimnion of station 1 continued to decline to 0.5 mg/L in mid-April; dissolved-oxygen concentrations at station 4 did not change much until the lose of ice cover.

The overall range in percent saturation of dissolved oxygen over depth and time at the four stations was 0 to 129 percent in 1995 and 0 to 122 percent in 1996 (Figure 5-4). The maximum percentage for each year was measured at station 4 in mid-June of 1995 and at station 1 in late July of 1996. The zero percents were measured in the lower hypolimnion of station 1 during the late summer and autumn of both years. Saturation greater than 100 percent (supersaturation) was measured in the euphotic zone of each station. During 1995, supersaturation began in May at stations 1 and 4 and in June at stations 2 and 3 and extended into October at the four stations. During 1996, the period of supersaturation at station 1 was comparable to 1995; however, the other three stations became supersaturated in June and ended supersaturation either in September (stations 2 and 3) or in August (station 4).

Depletion of dissolved oxygen within the hypolimnion of a stratified lake is an important symptom of eutrophication because it reflects the decay of organic matter produced within the euphotic zone or input to the lake by terrestrial sources. Dissolved oxygen was depleted in the hypolimnia of Payette Lake's four stations during both years; however, only station 1 developed anoxic dissolved-oxygen concentrations. Accordingly, an areal hypolimnetic oxygen depletion rate (AHOD) was calculated for station 1 for each year. AHOD, in milligrams per square meter per day, is defined as the rate of decrease of dissolved oxygen mass in the hypolimnion divided by the surface area of the hypolimnion. If AHOD is divided by the mean depth of the hypolimnion, one obtains the volumetric hypolimnetic oxygen depletion rate (VHOD), which is the rate of decrease of the volume-weighted-average dissolved-oxygen concentration in the hypolimnion. AHOD and VHOD were calculated for Payette Lake's station 1 for both years using procedures in Walker (1996). The calculated values represent the period from initial thermal stratification to the onset of anoxia in the hypolimnion. For 1995, this period was from June 12 to September 5; for 1996, it was from June 18 to September 24. The AHOD and VHOD for 1995 were 756 mg/m^2/day and 24.9 mg/m3/day, respectively. These values were somewhat smaller in 1996; AHOD was 451 mg/m2/day and VHOD was 14.8 mg/m3/day.
Hutchinson (1957) used AHOD to define limits for oligotrophic and eutrophic lakes: if AHOD is less than 250 mg/m2/day, the lake is considered oligotrophic; if AHOD is more than 550

mg/m2/day, the lake is considered eutrophic. On the basis of these limits, Payette Lake would be considered eutrophic in 1995 and bordering on eutrophic in 1996. The 1981 study of Payette Lake (Falter and Mitchell, 1981) reported an AHOD for the west basin (station 1, this study) of 300 mg/m2/day; this result places the lake slightly above the threshold for oligotrophic but well below that for eutrophic.

5.3.6 Phosphorus

Phosphorus is one of several essential nutrients in the metabolism of aquatic plants. Eutrophication research has focused heavily on phosphorus because it is the nutrient typically found to have the smallest supply-to-demand ratio for aquatic plant growth. Phosphorus concentrations for this study are reported as total phosphorus and dissolved orthophosphorus, as phosphorus. Total phosphorus represents the phosphorus in solution and contained in or attached to biotic and abiotic particulate material. Dissolved orthophosphorus is determined from the filtrate that passes through a filter with a nominal pore size of 0.45 um. The orthophosphate ion is the most important form of phosphorus because it is directly available for metabolic use by aquatic plants.

Median concentrations of total phosphorus at the four stations ranged from 4 to 6.5 ug/L in the euphotic zone and from 4 to 8.5 ug/L in the lower hypolimnion; the largest median concentrations were at station 1 in 1996 (Table 5-7). Median concentrations of total phosphorus in the euphotic zone and lower hypolimnion were slightly larger in 1996, except at station 4. The median concentrations of dissolved orthophosphorus were 0.5 ug/L in the euphotic zone at the four stations; the medians for the lower hypolimnion samples ranged from 0.5 to 1 ug/L (Table 5-7).

Total phosphorus concentrations at the four stations ranged from 0.5 to 65 ug/L during 1995 and from 0.5 to 52 ug/L during 1996, whereas dissolved orthophosphorus concentrations ranged from 0.5 to 14 ug/L during 1995 and from 0.5 to 23 ug/L during 1996 (Figure 5-5). The largest concentrations of both constituents were measured in the hypolimnion of station 1 from September through November, 1995 when near-bottom water had become anoxic. Under anoxic conditions, constituents such as phosphorus, ammonia, iron, and manganese in the lakebed sediments are solubilized and released into the hypolimnion (Stumm and Morgan, 1970).

Phytoplanktonic uptake of dissolved orthophosphorus in the euphotic zone during the summer growing season can sometimes be discerned by distinct declines in that constituent and concomitant increases in total phosphorus as the phytoplankton population converts dissolved orthophosphorus into particulate phosphorus. Such a relationship was not evident in Payette Lake, on the basis of the temporal patterns illustrated in Figure 5-5. The relationship may have been masked by the very low concentrations of dissolved orthophosphorus typically measured in Payette Lake's euphotic zones.

Figure 5-4. Lines of equal dissolved oxygen, as percent saturation, at stations 1-4 during selected months of 1995-1996.

Table 5-7. Medians of total phosphorus and dissolved orthophosphorus from the euphotic zone and lower hypolimnion at four limnetic stations, Payette Lake, 1995 - 1996.

Limnetic station	Total phosphorus (µg/L)				Dissolved orthophosphorus (µg/L)			
	Euphotic Zone		Lower Hypolimnion		Euphotic Zone		Lower Hypolimnion	
	Median	n	Median	n	Median	n	Median	n
1995								
1	4	9	5	9	0.5	9	1	9
2	4	9	4	8	.5	9	.5	8
3	4	8	4	8	.5	8	1	8
4	6	9	5	9	.5	9	.5	9
1996								
1	6.5	10	8.5	10	.5	10	.8	10
2	6	9	5	9	.5	9	.5	9
3	6	9	5	9	.5	9	.5	9
4	6	10	6	10	.5	10	.5	10

5.3.7 Nitrogen

Nitrogen, like phosphorus, is essential to the metabolism of aquatic plants. The supply-to-demand ratio for nitrogen is small and, thus, nitrogen may limit the growth of aquatic plants as phosphorus does. The nitrogen cycle in aquatic ecosystems is complex because most processes involving nitrogen are biologically mediated. In aquatic ecosystems, nitrogen commonly exist in the following forms: dissolved molecular nitrogen, nitrogen-containing organic compounds, ammonia, ammonium, nitrite, and nitrate. Nitrogen concentrations for this study were analyzed as total ammonia plus organic nitrogen (commonly called Kjeldahl nitrogen), dissolved ammonia, and dissolved nitrite plus nitrate, as nitrogen. Total ammonia plus organic nitrogen represents the ammonia (includes ammonium) and organic nitrogen compounds in solution and associated with biotic and abiotic particulate material. The dissolved concentrations represent the ammonia (includes ammonium) or nitrite plus nitrate in filtrate that passes through a 0.45-um filter. The following discussion is for total nitrogen (the sum of total ammonia plus organic nitrogen and dissolved nitrite plus nitrate) and dissolved inorganic nitrogen (the sum of dissolved ammonia and dissolved nitrite plus nitrate).

Figure 5-5. Concentrations of total phosphorus and dissolved orthophosphorus in the euphotic zone and lower hypolimnion at stations 1-4 during 1995 - 1996.

Median concentrations of total nitrogen at the four stations ranged from 158 to 272 ug/L in the euphotic zone and from 197 to 431 ug/L in the lower hypolimnion; 1996 medians were distinctly larger than those in 1995 (Table 5-8). Median concentrations of dissolved inorganic nitrogen at the four stations ranged from 28 to 170 ug/L in the euphotic zone and from 84 to 360 ug/L in the lower hypolimnion; as with total nitrogen, 1996 medians were larger than 1995 medians (table 8). The larger median concentrations of nitrogen measured in 1996 were attributable to the larger nitrogen loads delivered to the lake in 1996.

Table 5-8. Medians of total nitrogen and dissolved inorganic nitrogen from the euphotic zone and lower hypolimnion at four limnetic stations, Payette Lake, 1995-1996.

	Total nitrogen (µg/L)				Dissolved inorganic nitrogen (µg/L)			
Limnetic station	Euphotic Zone		Lower Hypolimnion		Euphotic Zone		Lower Hypolimnion	
	Median	n	Median	n	Median	n	Median	n
1995								
1	158	9	197	9	28	9	84	9
2	226	9	290	8	60	9	188	8
3	230	8	319	7	51	8	202	8
4	188	9	315	8	51	9	174	9
1996								
1	244	10	304	10	102	10	180	10
2	253	9	406	9	111	9	301	9
3	270	8	431	9	111	9	360	9
4	272	10	361	10	170	10	318	10

Total nitrogen concentrations at the four stations ranged from 86 to 493 ug/L during 1995 and from 83 to 529 ug/L during 1996 (Figure 5-6). Dissolved inorganic nitrogen concentrations at the four stations ranged from 7 to 335 ug/L during 1995 and from 13 to 397 ug/L during 1996 (Figure 5-6).

Lower-hypolimnion concentrations of total nitrogen and dissolved inorganic nitrogen were larger than those in the euphotic zone. The increased hypolimnetic concentrations of the two constituents reflect the settling and decomposition of organic matter from the euphotic zone into the hypolimnion. The increase in dissolved inorganic nitrogen concentrations is also indicative of nitrification in the hypolimnion, whereby, under aerobic conditions, organic and ammonia nitrogen is converted to nitrite and then nitrate. The large increase in ammonia in the lower hypolimnion of station 1 during September and October of 1995 (Figure 5-6) reflects the release of ammonia from lakebed sediments when the hypolimnion became anoxic.

Figure 5-6. Concentrations of total nitrogen, dissolved inorganic nitrogen, and dissolved ammonia in the euphotic zone and lower hypolimnion at stations 1-4 during 1995-1996.

5.3.8 Limiting nutrient

The limiting nutrient concept of Liebig, in concert with the stoichiometry of the photosynthesis equation, led to formulation of nitrogen-to-phosphorus ratios (N:P). These ratios have been used extensively in eutrophication studies to determine whether nitrogen or phosphorus was most likely to limit phytoplankton growth. The atomic ratio of nitrogen to phosphorus, 16N:1P, in the photosynthesis equation corresponds to a mass ratio of 7.2N:1P. Typically, N:P values are calculated using the biologically available forms of these two nutrients, dissolved inorganic nitrogen and dissolved orthophosphorus. If N:P (by weight) is less than 7.2, then nitrogen may be limiting, whereas if N:P exceeds 7.2, then phosphorus may be limiting (Ryding and Rast, 1989).

The N:P values in Table 5-9 and Figure 5-7 indicate a very strong tendency towards phosphorus limitation of phytoplankton growth in Payette Lake. The lowest ratio, 8.8, still exceeded the threshold of 7.2. The median ratios for 1996 were higher than those for 1995. This difference resulted from the higher concentrations of dissolved inorganic nitrogen measured in 1996 because dissolved orthophosphorus concentrations were nearly equal between the two years.

Table 5-9. Medians and ranges of ratios of dissolved inorganic nitrogen to dissolved orthophosphorus in samples from the euphotic zone at four limnetic stations, Payette Lake, 1995-1996.

Limnetic station	Median	Range	No. of samples
1995			
1	38	8.8-112	9
2	76	14-394	9
3	102	38-326	8
4	88	40-222	9
1996			
1	180	26-440	10
2	180	38-480	9
3	222	66-732	9
4	254	92-666	10

Figure 5-7. Dissolved inorganic nitrogen to dissolved orthophosphorus ratio at stations 1-4 during 1995-1996.

5.3.9 Chlorophyll-a

Chlorophyll-a is the primary photosynthetic pigment of phytoplankton and, as such, is used as an estimator of phytoplanktonic biomass. Median concentrations of chlorophyll-a at Payette Lake's four stations ranged from 1.6 to 2.4 ug/L during 1995 and from 0.8 to 1.3 ug/L during 1996 (Table 5-10). The 1995 median was highest at station 4, whereas the 1996 median was highest at station 1. The overall range in concentrations was from 0.2 to 5.2 ug/L with the largest concentration at station 1 in 1995 (table 10). Chlorophyll-a concentrations at the four stations had a distinct peak during June of 1995; temporal variation was more muted during 1996 (Figure 5-8).

5.3.10 Phytoplankton

Phytoplankton collected at the four stations during 1995-96 comprised five phyla (Chlorophyta, or green algae; Chrysophyta, or yellow-brown algae; Cryptophyta, or crytomonads; Cyanophyta, or blue-green algae; and Pyrrhophyta, or dinoflagellates), 44 genera, and 67 species (Table 5-11). The taxonomic composition was strongly dominated by the subphylum Bacillariophyceae, or diatoms. The Cyanophyta, represented by Anacystis marina and Chroococcus minimus, were a very minor component.

Lakewide, median density and biovolume for the 64 samples was 663 cells/ml and 384,000 um^3/ml, respectively. Among the four stations, median biovolume was highest at station 1 in both years (Table 5-10). Biovolume peaked in July of both years; only station 1 had a substantial secondary peak in the autumn of both years (Figure 5-9). Biovolume was dominated by one diatom, Tabellaria fenestrata, which, on average, contributed 52 percent of the lakewide biovolume.

Table 5-10. Medians and ranges of chlorophyll-a concentrations and phytoplankton biovolumes in samples from the euphotic zone at four limnetic stations, Payette Lake, 1995-1996.

Limnetic station	Chlorophyll-a concentration (µg/L)			Phytoplankton biovolume (μm^3/ml)		
	Median	Range	n	Median	Range	n
1995						
1	2.2	0.7-5.2	8	962,000	70,000-2,770,000	7
2	1.6	1.0-3.4	8	426,000	189,000-2,520,000	7
3	1.6	.7-5	8	420,000	97,100-2,820,000	7
4	2.4	.7-5	8	774,000	109,000-2,840,000	7
1996						
1	1.3	.5-2.1	10	556,000	313,000-1,890,000	9
2	1.0	.2-1.8	9	184,000	88,200-923,000	9
3	1.1	.3-1.5	8	189,000	81,900-1,700,000	9
4	.8	.3-1.3	10	230,000	76,600-2,340,000	9

Figure 5-8. Chlorophyll-a concentrations at stations 1-4 during 1995-1996.

Table 5-11. Phytoplankton taxa at four limnetic stations, Payette Lake, 1995-1996.

Figure 5-9. Phytoplankton biovolume at stations 1-4 during 1995-1996.

5.3.11 Trophic state

The biological productivity, or trophic state, of a lake is commonly categorized into one of three trophic states: oligotrophic, or low productivity; eutrophic, or high productivity; and mesotrophic, or moderate productivity. Numerous variables have been used as the basis for trophic-state classification; some of the most frequently encountered are total phosphorus, total nitrogen, chlorophyll-a, and secchi-disc transparency. These four variables were used by Ryding and Rast (1989) to develop an open-boundary trophic-state classification system which compensates for the overlap in classification that commonly occurs with a fixed-boundary system. Under the open-boundary system, a lake is considered correctly classified if three of the four classification variables are within two standard deviations of their geometric mean for the same trophic state.

Annual geometric means for euphotic-zone values of total phosphorus, total nitrogen, chlorophyll-a, and secchi-disc transparency were computed for Payette Lake for comparison to the open-boundary trophic-state classification system (Table 5-12). The lake was classified as oligotrophic in both years on the basis of total phosphorus, total nitrogen, and chlorophyll-a. On the basis of secchi-disc transparency, the lake was mesotrophic in both years.

Three earlier studies also classified the trophic state of Payette Lake. During the late 1970's, the lake was classified as oligotrophic on the basis of chemical and biological variables (Idaho Department of Health, 1970). The National Eutrophication Survey of 1975 classified the lake as early mesotrophic (U.S. Environmental Protection Agency, 1977). Falter (1984) used areal phosphorus loading as his basis for classifying the lake as mesotrophic in the early 1980's. These three studies indicate an increasing trend in trophic state; however, the trend may be misleading because the basis for trophic-state classification was not consistent among the three studies.

Table 5-12. Trophic state of Payette Lake during 1995-1996 based on annual geometric mean values for four limnological variables.

Limnological Variable	Sta	Ope trop O	M	E	Payet 1995	1996	1995-96
Total phosphorus (µg/L)	χ	8.0	26.7	84.4	4.5	4.9	4.7
	χ ±1 SD	4.8-13.3	14.5-49.0	48.0-189.0	2.0-6.8	0.9-8.9	1.4-8.0
Total nitrogen (µg/L)	χ	661	753	1,875	199	252	225
	χ ±1 SD	371-1,180	485-1,170	861-4,081	137-261	141-363	135-315
Chlorophyll-a (µg/L)	χ	1.7	4.7	14.3	1.9	0.9	1.3
	χ ±1 SD	0.8-3.4	3.0-7.4	6.7-31.0	0.8-3.0	0.4-1.4	0.4-2.2
Secchi-disc transparency (m)	χ	9.9	4.2	2.4	4.3	5.2	4.7
	χ ±1 SD	5.9-16.5	2.4-7.4	1.5-4.0	2.6-6.0	3.8-6.6	3.1-6.3

[1] Annual geometric mean and plus or minus one standard deviation.
[2] Modified from Ryding and Rast (1989).
[3] Annual geometric mean of euphotic-zone values.

5.3.12 Sediment nutrients

The lakebed sediments at the four stations had the following ranges for concentrations of total phosphorus and total nitrogen: 1,400 to 4,800 mg/kg and 720 to 920 mg/kg, respectively (Table 5-13). Station 1 had the highest concentration of total phosphorus, whereas station 4 had the highest for total nitrogen.

Table 5-13. Concentrations of total phosphorus and total nitrogen in lakebed sediments at four limnetic stations, Payette Lake, July 1996.

Concentrations (Mg/kg)

Limnetic station	Water depth (m)	Total phosphorus	Total nitrogen
1	68	4,800	720
2	55	1,400	910
3	90	1,900	740
4	34	1,400	920

Guidelines have been published for assessing the potential effects on benthic organisms of trace elements and nutrients in aquatic sediments (Persaud and others, 1993). The guidelines include three levels of effect: no effect, lowest effect, and severe effect. The lowest effect level signifies sediment contamination that can be tolerated by most benthic organisms whereas the severe effect level signifies polluted sediment that will significantly affect benthic organisms. For total phosphorus, the lowest and severe effect levels are 600 and 2,000 mg/kg, respectively. For total nitrogen, the lowest and severe effect levels are 550 and 4,800 mg/kg, respectively. The severe effect level for total phosphorus was clearly exceeded by station 1 and nearly met by station 3; total nitrogen concentrations at the four stations were well below the severe effect level (Table 5-13).

5.4 Littoral Zone

5.4.1 Periphyton production

Periphyton production in the littoral zone of Payette Lake was assessed to determine whether a statistical relation existed between periphyton production and various indices of nearshore development. The indices for each littoral station included housing density, percentage of lawn area, relative age of development, relative level of disturbance of natural soils and vegetation, and lake subbasin. The hypothesis was that stations with little or no disturbance of natural conditions would have low levels of periphyton production, whereas increased levels of disturbance would produce increased nutrient loads which would stimulate periphyton production.

Median periphyton production, as chlorophyll-a, at the 19 (one station was lost) littoral stations ranged from 0.38 (station 12) to 12.9 (station 22) mg/m^2, a difference of 33.9 times (Table 5-14). When normalized to PAR input, the median production ranged from 0.0007 (station 12) to 0.02 (station 22) $(mg/m^2)/E$, a difference of 28.6 times. For both comparisons, production was lowest at station 12 and highest at station 22. The nearshore development at station 12 included a very large home surrounded by an extensive lawn area. At station 22, new construction of several large homes had disturbed the majority of the soil and vegetative cover. This station is also at the former site of a lumber mill. On the basis of ranks, PAR-normalized periphyton production at stations 10, 11, and 15 was some of the lowest in the lake even though these three stations had substantial nearshore development. Conversely, stations 1, 2, and 4, all undisturbed, had some of the highest periphyton production.

Multiple linear regression (Helsel and Hirsch, 1992) was used to investigate the relation between PAR-normalized periphyton production and the five indices of nearshore development. Periphyton production was normalized with PAR to remove its influence from the predictive equation. Scatterplots and a correlation matrix indicated little, if any, relationship between PAR-normalized periphyton production and any of the indices of nearshore development. This observation was confirmed with the regression analyses. When the five indices were included in the model they explained 41-percent of the variation in the dependent variable; however the p-value for the F statistic was 0.175, indicative of no relationship. Of the five partial-regression coefficients, only relative level of disturbance was significant, with a p-value of 0.033.

Table 5-14. Periphyton production, as chlorophyll-a, at 19 littoral stations, Payette Lake, July-August 1996.

Periphyton production normalized to PAR

Littoral station	PAR input (E)[1]	Periphyton production (mg/m^2)[2]	[(mg/m^2)/E][2]	Rank[3]
1	637	1.01	0.0016	10
2	516	1.12	.0022	15
4	560	.97	.0017	12
6	546	.94	.0017	12
8	597	1.07	.0018	14
9	695	.84	.0012	7
10	559	.42	.0008	3.5
11	617	.52	.0008	3.5
12	552	.38	.0007	1
13	602	1.37	.0023	16
14	548	.66	.0012	6
15	560	.51	.0009	2
16	662	.63	.0010	5
17	653	.94	.0014	8
18	653	1.10	.0017	12

Periphyton production normalized to PAR

19	640	2.15	.0034	17
21	609	.88	.0014	9
22	647	12.9	.020	19
23	559	2.71	.0048	18

[1] Quantity of photon flux, as Einsteins (1 E = 1 mole of photons), input to periphyton during incubation period. [2] Median of three values. [3] Low production to high production.

The absence of a strong relationship between periphyton production and selected indices of nearshore development at Payette Lake was similar to results of a recent study at Priest Lake reported by Rothrock and Mosier (1996). Periphyton production, as chlorophyll-a, was measured on natural substrates at 21 nearshore locations during the summers of 1994-95 in Priest Lake, a 95-km2, oligotrophic lake in northern Idaho. Periphyton production in Priest Lake had no strong relationship with any of the following variables: site aspect, bank slope, fetch distance, developed versus undeveloped nearshore, and interstitial nutrient concentrations.

Boat Docks

The water quality impacts from the nearshore areas of Big Payette Lake also include boat docks. In discussions of the water quality impacts of boat docks, both existing and proposed, the emphasis usually centers on issues such as additional boat traffic, disturbances of soil (terrestrial and lakebed) during construction, encroachment into the nearshore zone of the lake, and dumping of trash. Another issue that has been neglected, but may be very relevant to Big Payette Lake, is the additional surface area of the piling and dock surfaces (those in contact with the lake water) that now grow periphyton. In the shallow, well lighted nearshore zone where docks are built, light conditions are optimal for periphyton growth. Docks tend to be built in developed areas where additional supplies of nutrients are available via urban runoff, lawn fertilizers, and septic system leachates. During the summer, additional growth of periphyton on docks may be regarded as a nuisance, but unless it is excessive, does not cause much concern. However, the water quality problem is more related to the demise of the periphyton during the fall and early winter when cold temperatures and reduced light levels cause it to die and slough off the docks. As the dead periphyton decomposes, either while settling through the water column or on the lakebed, it consumes oxygen and eventually releases the algal nutrients carbon, nitrogen and phosphorus. These nutrients may be incorporated into the lakebed sediments of the nearshore zone or currents may carry them to deeper areas of the lake. The hypolimnetic dissolved oxygen depletion within the southwest basin of Big Payette Lake is caused by an excessive oxygen demand which is fueled by the influx of organic matter undergoing decomposition. The influx is from various sources, both terrestrial and aquatic. The relative contribution of these sources is not quantifiable with the present data base. However, some portion of that influx is from the decay of periphyton from docks around the lake.

5.4.2 Aquatic macrophytes

Payette Lake contained nine genera of aquatic macrophytes on the basis of sampling at 19 littoral stations (Table 5-15). Isoetes lacustris and Myriophyllum spicatum var. exalbescens occurred most frequently, being found at 16 and 13 of the stations, respectively. Nitella sp. and Ranunculus aquatilis were each found at 8 of the stations. Chara sp. was found only at station 14. Diversity was highest at stations 11, 16, and 17, which had five genera, and lowest at station 15, which was devoid of aquatic macrophytes. Of particular interest was the discovery of M. spicatum var. spicatum at stations 21 and 22 which are adjacent to the city boat ramp. This plant, whose common name is Eurasian Milfoil, is considered a nuisance because it grows aggressively, can propagate via fragmentation, and is extremely difficult to eradicate. The occurrence of Eurasian Milfoil near the boat ramp suggests it was introduced to Payette Lake from a boat or boat trailer that had been used in a lake infested with the plant.

Table 5-15. Aquatic macrophyte taxa at 19 littoral stations, Payette Lake, July 1996.

Aquatic macrophyte taxa[1]	Littoral station No.
Phylum Chlorophyta	

Aquatic macrophyte taxa[1]	Littoral station No.
Family Characeae	
Chara sp.	14
Nitella sp.	1,2,4,5,11,12,16,23
Phylum Pteridophyta	
Family Isoetaceae	
Isoetes lacustris	1,2,4,5,6,8,10,11,12,13,14,16,17,19,21,23
Phylum Spermatophyta	
Class Angiospermae	
Family Haloragaceae	4,6,8,9,10,11,12,13,14,16,17,18,23
Myriophllum spicatum var. exalbescens	21,22
M.spicatum var. spicatum	
Family Hydrocharitaceae	6,11,13,16,17,18,22
Elodea canadensis	
Family Naiadaceae	4,5,11,17,23
Potamogeton robbinsii	6,11,19
P. zosteriformis	
Family Ranunculaceae	8,9,13,16,17,18,19,22
Ranunculus aquatilis	

[1] Taxonomy based on Prescott (1969) and Steward and others (1963).

An earlier survey of aquatic macrophytes at six locations in Payette Lake was conducted in July and September, 1981 by Falter and Mitchell (1981). The 1981 taxonomic composition was similar to that of the current study, but only six genera were found and P. robbinsii was the dominant genera. Eurasian Milfoil was not reported in the 1981 study.

5.5 Fire Effects on Lake Water Quality

The effects of the 1994 forest fires on Payette Lake's water quality were evaluated on the basis of a limited data base collected by DEQ at four limnetic stations during July, September, and October of 1992 and August and September of 1993 (D. Worth, Idaho Division of Environmental Quality, written commun., September, 1995). DEQ data for chlorophyll-a and dissolved oxygen were compared with data collected during similar time periods in 1995 and 1996. Hydrologically, lake outflow during the 1992 water year was 49 percent of the long-term mean; in the 1993 water year, lake outflow was 106 percent of the long-term mean. Thus, the lake's residence time in 1992 was 4.8 years, or about twice its normal value; in 1993, it was 2.2 years, or about normal. Residence times for the 1995 and 1996 water years were 1.84 and 1.42 years, respectively; thus, both years had shorter than normal residence times.

The limnological basis for the comparison of residence times is that longer residence times are expected to enhance a lake's biological production because nutrients and phytoplankton are retained longer in the lake. If one disregards the effects of the 1994 forest fires in this comparison, one would expect Payette Lake to have been most productive in 1992, the year with the longest residence time. However, post-fire chlorophyll-a concentrations were about double those measured in the two years prior to the fires, even though post-fire residence times were much less than normal. Chlorophyll-a concentrations for the 1992 samples ranged from 0.2 to 1.15 ug/L and had a median concentration of 0.71 ug/L. The 1993 chlorophyll-a concentrations ranged from 0.5 to 1.0 ug/L and had a median concentration of 0.65 ug/L. A similar period in 1995 had chlorophyll-a concentrations that ranged from 0.7 to 2.7 ug/L, with a median of 1.4 ug/L; for 1996, the range was from 0.8 to 2.1 ug/L, with a median of 1.3 ug/L.

Payette Lake received substantially larger loads of nitrogen during 1995-1996 as a result of the 1994 forest fires. Phosphorus loads also increased substantially in 1995, largely because of loads from Fall Creek. A comparison of in-lake nutrient concentrations indicated post-fire concentrations of nitrogen were much larger than pre-fire concentrations, whereas post-fire concentrations of phosphorus were smaller. During August and September of 1993, median concentrations, in micrograms per liter, of dissolved inorganic nitrogen, total phosphorus and dissolved ortho-phosphorus were 12, 10.5 and 10 in the upper water column and 122, 23 and 11 in the lower hypolimnion, respectively. For similar dates during 1995-96, median concentrations, in micrograms per liter, of dissolved inorganic nitrogen, total phosphorus and dissolved ortho-phosphorus were 50, 5 and 0.5 in the upper water column and 251, 5 and 0.5 in the lower hypolimnion, respectively. The 2 to 4 fold increase in dissolved inorganic nitrogen is reasonable in that this constituent is soluble and is not readily adsorbed to particulate material which may settle rapidly after introduction to the lake. In contrast, the absence of a large post-fire increase in phosphorus may be due to its ready adsorption to particulate material.

Dissolved-oxygen concentrations were also measured by DEQ in 1992 and 1993; however, the profiled depths were inconsistent and often did not occur in the deepest parts of the four basins. Thus, the assessment of pre- and post-fire development of the hypolimnetic dissolved-oxygen deficit in the southwest basin (limnetic station 1, this study) is incomplete. The most valid comparison is for late July, 1992 when a dissolved-oxygen concentration of 2.8 mg/L was measured at the 71-m depth in the southwest basin. Similar dates and depths in 1995 and 1996 for this location had dissolved-oxygen concentrations of 2.6 and 1.0 mg/L, respectively. On the basis of this comparison, the fire effects on the hypolimnetic dissolved-oxygen deficit were undetectable.

5.6 Nutrient Load/Lake Response Model

5.6.1 Model Description

The empirical nutrient load/lake response model (Walker, 1996) applied to Payette Lake provided a mathematical method for simulating the lake's limnological responses to alterations in hydrologic and nutrient loads delivered to the lake from various sources. The model combined data on the lake's morphometrics, hydrologic and nutrient budgets, and limnological characteristics in order to simulate the following eutrophication-related variables: concentrations of total phosphorus, total nitrogen, and chlorophyll-*a*; secchi-disc transparency; and hypolimnetic dissolved-oxygen deficit.

Three programs, FLUX, PROFILE, and BATHTUB, compose the model. The FLUX program quantifies tributary loads of water and nutrients using a variety of calculation methods. The PROFILE program generates statistical summaries of water-quality conditions in the water body within a temporal and spatial context. The BATHTUB program applies nutrient-balance and eutrophication-response models within a spatially segmented hydraulic framework that accounts for advection, diffusion, and sedimentation. BATHTUB is a highly evolved version of empirical lake-eutrophication models, and incorporates additional variables to account for important processes such as nonlinear nutrient-sedimentation kinetics, inflow nutrient partitioning, seasonal and spatial variations, and algal growth limitation by factors such as phosphorus, nitrogen, light, and flushing rate. If error estimates are provided for input variables, BATHTUB can express out-put variables in probabilistic terms. An important feature of BATHTUB is the ability for modeling linked segments of the lake to account for spatial variations in water quality. Segment boundaries can be selected on the basis of factors such as lake morphometry, important sources of water and nutrients, and lake hydrodynamics.

Payette Lake was divided into four segments (Figure 3-3 on page 39); each segment's characteristics are listed in table 5-16 on page 224. Segment 1 is the deep, northeastern basin; it covers 6.5 km^2 and contains 0.28 km^3. This segment receives the lake's primary inflow from the North Fork Payette River. Segment 2 is the southeastern basin which covers 1.7 km^2 and contains 0.04 km^3. This segment is the most hydrologically isolated from the primary inflow and is furthest from the lake's outflow. Segment 3 is the smallest basin and connects the northeastern and southwestern basins. This segment covers 1.4 km^2 and contains 0.04 km^3. Segment 4 is the southwestern basin and contains the lake's outlet into the North Fork Payette River. This segment has the largest area and volume, 10.9 km^2 and 0.4 km^3.

Water-quality characteristics for each segment were input to BATHTUB. The characteristics were computed with PROFILE using data from the four limnetic stations. Excepting the hypolimnetic dissolved-oxygen deficit, the characteristics represented mean annual values for the euphotic zone for water years 1995 and 1996. The euphotic zone was the primary focus for modeling because most of the empirical relations used by BATHTUB were derived from studies of euphotic zones.
The hydrologic and nutrient budgets (Tables 5-3 through 5-5) were the source of water and nutrient loads input to BATHTUB. Each segment received water and nutrient loads from the subwatersheds draining into it. If a subwatershed contributed to more than one segment its water and nutrient load was apportioned between the segments on the basis of drainage area.

5.6.2 Model Calibrations

Model Calibration and Verification

The model was calibrated with 1996 data using a selection of submodels discussed in the user manual (Walker, 1996, Table 4.2). The submodels for phosphorus and nitrogen sedimentation were based on second-order decay rates. The chlorophyll-*a* submodel was based on phosphorus, light, and flushing rate, whereas the secchi-disc transparency submodel was based on chlorophyll-*a* and turbidity. The dispersion submodel was numerically based per Fischer and others (1979). The submodels for calibration of nitrogen and phosphorus applied calibration factors to sedimentation rates, not concentrations. The initial calibration with submodels was adequate for most variables; however, several variables required calibration coefficients to achieve a satisfactory fit between estimated and observed conditions. The calibration coefficient for chlorophyll-*a* was 0.625, whereas it was 3.0 for the hypolimnetic dissolved-oxygen deficit.

Model calibration results for each segment and the area-weighted, lakewide mean values are summarized in table 17. Lakewide, the ratios between observed and estimated values for total phosphorus, total nitrogen, chlorophyll-*a*, and secchi-disc transparency were 1.11, 1.08, 1.01, and 1.0, respectively. In model segment 4, the ratio between the observed and estimated hypolimnetic dissolved-oxygen deficit was 1.12.

The model was verified with 1995 data and the submodels used in the calibration; the results are summarized in table 17. Lakewide, the ratios between observed and estimated values for total phosphorus, total nitrogen, chlorophyll-*a*, and secchi-disc transparency were 0.33, 0.7, 0.77, and 1.07, respectively. In model segment 4, the ratio between the observed and estimated hypolimnetic dissolved-oxygen deficit was 1.19.

The comparison of observed and estimated mean values is not the only criterion on which to judge the model's performance. The model output displays the mean value, plus or minus one standard error for each observed and estimated value. These statistical estimates are computed on the basis of errors associated with the model, as well as errors associated with each input variable. The presence or absence of overlap in the standard errors for each variable and segment is listed in table 18. For the calibration, the standard errors for all variables overlap in each segment and lakewide. For the verification, the standard errors do not overlap as follows: total phosphorus; all segments and lakewide; total nitrogen, segments 1,4, and lakewide; chlorophyll-*a*, segment 1. The lack of overlap for total phosphorus is largely attributable to the unusually large, but transient, load delivered by Fall Creek during May, 1995. When the model verification was performed with the 1995 total phosphorus load from Fall Creek adjusted to levels equivalent with those delivered by Fall Creek in 1996, then the standard errors for total phosphorus overlap in all segments.

Table 5-16. Results of model calibration with 1996 data and model verification with 1995 data, Payette Lake

[TP, total phosphorus, in micrograms per liter; TN, total nitrogen, in micrograms per liter; CHL, chlorophyll-*a*, in micrograms per liter; SD, secchi disc transparency, in meters; HODV, hypolimnetic dissolved oxygen deficit, volumetric, in micrograms per cubic meter per day]

		Calibration Mean Value			**Verification Mean Value**		
Segment (Fig.3-3)	**Variable**	**Observed**	**Estimated**	**Ratio of observed to estimated value**	**Observed**	**Estimated**	**Ratio of observed to estimated value**
1	TP	6.4	7.3	0.88	4.4	18.8	0.23
	TN	328	319	1.03	229	326	0.70
	CHL	1.0	1.3	0.79	1.9	4.0	0.47
	SD	5.4	5.2	1.04	5.2	4.1	1.28
2	TP	8.1	6.9	1.17	6.2	13.4	0.46
	TN	314	270	1.16	210	278	0.76
	CHL	0.9	1.2	0.75	2.2	2.7	0.82
	SD	4.8	4.6	1.04	4.9	4.6	1.06
3	TP	6.6	6.4	1.02	5.3	14.1	0.37
	TN	323	276	1.17	231	278	0.83
	CHL	1.1	1.1	1.00	1.8	2.9	0.63
	SD	4.8	4.8	1.00	5.2	4.6	1.14
4	TP	7.4	5.8	1.28	4.2	10.5	0.40
	TN	262	239	1.10	160	237	0.68
	CHL	1.2	1.0	1.24	2.3	2.0	1.15
	SD	4.3	4.4	0.97	4.9	5.1	0.96
	HODV	14.8	13.2	1.12	24.9	21.0	1.19
Lakewide	TP	7.1	6.4	1.11	4.5	13.7	0.33
	TN	291	270	1.08	191	272	0.70
	CHL	1.1	1.1	1.01	2.1	2.8	0.77
	SD	4.7	4.7	1.00	5.0	4.7	1.07

Table 5-17. Presence or absence of overlap in standard errors for observed and estimated values for five limnological variables for calibration and verification model runs, Payette Lake

[Lakewide, LW; Y, overlap present; N, overlap not present; —, not measured]

	Cali					**Verification**				
	Seg					**Segment No. (Fig. 3-3)**				
	1	**2**	**3**	**4**	**LW**	**1**	**2**	**3**	**4**	**LW**
Total Phosphorus	Y	Y	Y	Y	Y	N	N	N	N	N
Total Nitrogen	Y	Y	Y	Y	Y	N	Y	Y	N	N
Chlorophyll-*a*	Y	Y	Y	Y	Y	N	Y	Y	Y	Y
Secchi disc transparency	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Hypolimnetic dissolved oxygen deficit	—	—	—	Y	—	—	—	—	Y	—

5.6.3 Simulation Results

A wide variety of simulations was possible owing to the complexity of Payette Lake and its drainage basin, as well as to a diverse assortment of nutrient-load alterations that could be proposed and evaluated. Simulations of nutrient-load alterations were achieved by decreasing or increasing nutrient concentrations of the inflows to the lake. The water volume delivered by the inflow source was not altered because nutrient-management scenarios were assumed to affect concentrations, not flows. Limnological responses to the nutrient-load alterations were simulated with the 1996 data. The magnitudes of the responses were evaluated by comparison with the 1996 conditions estimated by the model. The output format of the simulations allowed evaluation of changes in the mean value of each response variable, either within a segment or on an area-weighted, lakewide basis.

Simulation 1 estimated limnological conditions prior to the 1994 forest fires. Concentrations of total phosphorus, dissolved orthophosphorus, total nitrogen, and dissolved inorganic nitrogen in tributaries affected by the 1994 fires were scaled back to pre-fire concentrations. For the North Fork Payette River inflow, pre-fire concentrations were those measured in the 1975 National Eutrophication Survey of Payette Lake (U.S. Environmental Protection Agency, 1977). For Fall Creek, and the Box/Lemah Creek watershed, nitrogen and phosphorus concentrations were set equal to those for Dead Horse Creek in 1996. On a lakewide basis, concentrations, in micrograms per liter, of total phosphorus increased from 6.4 to 6.5 and total nitrogen decreased from 270 to 127 (Table 5-18). Chlorophyll-a and secchi-disc transparency were unchanged. The hypolimnetic dissolved-oxygen deficit in model segment 4 increased about 1 percent. The largest change was in total nitrogen concentrations because the 1994 fires primary impact on Payette Lake was the large increases in nitrogen loads. Because the lake's phytoplankton production is strongly limited by phosphorus, not nitrogen, there was little reduction in chlorophyll-a concentrations and, consequently, little change in secchi-disc transparency and hypolimnetic dissolved-oxygen deficit. The large reduction in nitrogen concentrations did not shift the lake's phytoplankton production from phosphorus to nitrogen limitation.

Table 5-18. Simulation 1: Limnological response to estimated phosphorus and nitrogen loads delivered to Payette Lake prior to 1994 forest fires.

	Total phosphorus (µg/L)		Total nitrogen (µg/L)		Chlorophyll-a (µg/L)		Secchi-disc transparency (m)		Hypolimnetic dissolved-oxygen deficit [(mg/m^3)/d]	
Segment (Fig.3-3)	1996	Response	1996	Response	1996	Response	1996	Response	1996	Response
1	7.3	7.1	319	138	1.3	1.2	5.2	5.2	---	---
2	6.9	7.1	270	129	1.2	1.3	4.6	4.6	---	---
3	6.4	6.5	276	128	1.1	1.1	4.8	4.8	---	---
4	5.8	6.1	239	120	1.0	1.0	4.4	4.4	13.2	13.3
Lakewide	6.4	6.5	270	127	1.1	1.1	4.7	4.7	---	---

Simulation 2 took the opposite approach to simulation 1: the one-half of the watershed not burned in the 1994 fires was assumed to be burned with a severity similar to the 1994 fires. Total nitrogen and dissolved inorganic nitrogen concentrations were increased by a factor to 2.5 for the North Fork Payette River inflow, Fall Creek and the Box/Lemah Creek watershed. The smaller multiplier for these three tributaries was because about one-half of their watersheds were burned in the 1994 fires. Total phosphorus and dissolved orthophosphorus concentrations were increased 1.5 times on the six tributaries to simulate increased soil erosion. On a lakewide basis, concentrations, in micrograms per liter, of total phosphorus, total nitrogen, and chlorophyll-a increased from 6.4 to 8.4, 270 to 476, 1.1 to 1.5, respectively; secchi-disc transparency declined from 4.7 to 4.5 m (Table 5-19). The hypolimnetic dissolved-oxygen deficit in model segment 4 increased 19 percent. The in-lake increases in total nitrogen concentrations were the most noticeable impact; smaller increases in total phosphorus concentrations helped create increase chlorophyll-a concentrations and the hypolimnetic dissolved oxygen deficit; increased chlorophyll- a caused a decline in secchi-disc transparency.

Table 5-19. Simulation 2: Limnological response to increased phosphorus and nitrogen loads caused by forest fires in watershed areas not burned during the 1994 forest fires.

	Total phosphorus (µg/L)		Total nitrogen (µg/L)		Chlorophyll-a (µg/L)		Secchi-disc transparency (m)		Hypolimnetic dissolved-oxygen deficit [(mg/m^3)/d]	
Segment (Fig.3-3)	1996	Response	1996	Response	1996	Response	1996	Response	1996	Response
1	7.3	10.1	319	607	1.3	1.9	5.2	4.8	---	---
2	6.9	8.7	270	454	1.2	1.6	4.6	4.4	---	---
3	6.4	8.6	276	493	1.1	1.6	4.8	4.5	---	---
4	5.8	7.3	239	399	1.0	1.3	4.4	4.3	13.2	15.7
Lakewide										

Total phosphorus (µg/L)		Total nitrogen (µg/L)		Chlorophyll-a (µg/L)		Secchi-disc transparency (m)		Hypolimnetic dissolved-oxygen deficit [(mg/m^3)/d]	
6.2	8.4	270	476	1.1	1.1	4.7	4.7	---	---

Simulation 3 used the responses to simulated pre-fire nutrient concentrations (simulation 1, Table 5-18) as the basis for assessing the lake's response to 20-percent reductions in nutrient loads from developed shoreline areas. An assumption was made that substantive nutrient-management actions would not occur until after the limnological effects of the 1994 fires had been muted by natural recovery processes in the watershed and lake. Accordingly, concentrations of total phosphorus, dissolved orthophosphorus, total nitrogen, and dissolved inorganic nitrogen were reduced 20-percent for the developed shoreline areas of the southwest and southeast basins, the McCall urban area and the west shore of the peninsula. Sylvan, Dead Horse and Fall Creeks were assigned nutrient reductions of 10 percent to simulate management of their developed shoreline areas. On a lakewide basis, concentrations, in micrograms per liter, of total phosphorus, total nitrogen, and chlorophyll-a declined from 6.5 to 6.4 and 127 to 125, respectively (Table 5-20). Chlorophyll-a and secchi depth transparency were unchanged. The hypolimnetic dissolved-oxygen deficit in model segment 4 decreased about 1 percent. Small responses occurred in model segment 1, the northern basin, because it has very little developed shoreline to affect its large volume. Model segment 4, the southwest basin, also has a large volume, but has a substantial level of shoreline development. The responses of these two model segments were similar because both have large volumes in relation to the amount of nutrient loads delivered to them from developed shoreline areas.

Table 5-20. Simulation 3: Limnological response to 20-percent reduction in phosphorus and nitrogen loads from developed shoreline areas; comparison is to simulated response to pre-1994 forest fires (Simulation 1, Table 5-18).

	Total phosphorus (µg/L)		Total nitrogen (µg/L)		Chlorophyll-a (µg/L)		Secchi-disc transparency (m)		Hypolimnetic dissolved-oxygen deficit [(mg/m^3)/d]	
Segment (Fig.3-3)	Pre-fire	Response	Pre-fire	Response	Pre-fire	Response	Pre-fire	Response	Pre-fire	Response
1	7.1	7.0	138	136	1.2	1.2	5.2	5.2	---	---
2	7.1	6.9	129	127	1.3	1.2	4.6	4.6	---	---
3	6.5	6.4	128	126	1.1	1.1	4.8	4.8	---	---
4	6.1	5.9	120	118	1.0	1.0	4.4	4.4	13.3	13.2
Lakewide	6.5	6.4	127	125	1.1	1.1	4.7	4.7	---	---

Simulation 4 also used the responses from simulation 1 as the basis for assessing the lake's response to 20-percent reductions in nutrient loads from watershed areas subjected to timber harvest activities. Concentrations of total phosphorus, dissolved orthophosphorus, total nitrogen, and dissolved inorganic nitrogen were reduced 20-percent for the North Fork Payette River inflow, Box/Lemah Creek watershed, and Fall, Deadhorse, Copet, and Sylvan Creeks. On a lakewide basis, concentrations, in micrograms per liter, of total phosphorus, total nitrogen, and chlorophyll-a declined from 6.5 to 5.8, 127 to 108, and 1.1 to 1.0, respectively; secchi-disc transparency increased from 4.7 to 4.8 m (Table 5-21). The hypolimnetic dissolved-oxygen deficit in model segment 4 decreased about 8 percent. Model segment 1 had the largest percentage responses because most of the nutrient load reductions occurred in its tributary watersheds. The smallest percentage responses were in model segment 4 because its tributary watersheds were unaffected in this simulation.

Table 5-21. Simulation 4: Limnological response to 20-percent reduction in phosphorus and nitrogen loads from watershed areas subjected to timber-harvest activities; comparison is to simulated response to pre-1994 forest fires (Simulation 1, Table 5-18).

	Total phosphorus (µg/L)		Total nitrogen (µg/L)		Chlorophyll-a (µg/L)		Secchi-disc transparency (m)		Hypolimnetic dissolved-oxygen deficit [(mg/m³)/d]	
Segment (Fig.3-3)	1995	Response	1995	Response	1995	Response	1995	Response	1995	Response
1	7.1	6.1	138	115	1.2	1.0	5.2	5.4	---	---
2	7.1	6.4	129	111	1.3	1.1	4.6	4.7	---	---
3	6.5	5.7	128	109	1.1	0.9	4.8	4.9	---	---
4	6.1	5.5	120	104	1.0	0.9	4.4	4.4	13.3	12.3
Lakewide	6.5	5.8	127	108	1.1	1.0	4.7	4.8	---	---

Simulation 5 combined the nutrient load reductions applied in simulations 3 and 4. On a lakewide basis, concentrations, in micrograms per liter, of total phosphorus, total nitrogen, and chlorophyll-a declined from 6.5 to 5.7, 127 to 108, and 1.1 to 0.9, respectively; secchi-disc transparency increased from 4.7 to 4.8 m (Table 5-22). The hypolimnetic dissolved-oxygen deficit in model segment 4 decreased about 8.5 percent. Of the three nutrient-reduction simulations, this one achieved the largest responses lakewide and in each of the four model segments.

Table 5-22. Simulation 5: Limnological response to 20-percent reduction in phosphorus and nitrogen loads from developed shoreline areas and watershed areas subjected to timber-harvest activities; comparison is to simulated response to pre-1994 forest fires (Simulation 1, Table 5-18).

	Total phosphorus (µg/L)		Total nitrogen (µg/L)		Chlorophyll-a (µg/L)		Secchi-disc transparency (m)		Hypolimnetic dissolved-oxygen deficit [(mg/m^3)/d]	
Segment (Fig.3-3)	Pre-fire	Response	Pre-fire	Response	Pre-fire	Response	Pre-fire	Response	Pre-fire	Response
1	7.1	6.1	138	114	1.2	1.0	5.2	5.4	---	---
2	7.1	6.2	129	110	1.3	1.1	4.6	4.7	---	---
3	6.5	5.7	128	108	1.1	0.9	4.8	4.9	---	---
4	6.1	5.4	120	104	1.0	0.9	4.4	4.5	13.3	12.2
Lakewide	6.5	5.7	127	108	1.1	0.9	4.7	4.8	---	---

Chapter VI

Chapter 6.0 Summary, Recommendations and Standards

A quantitative and comprehensive study was conducted on the Big Payette Lake and drainage basin in water years 1995 through 1996. The purposes of this study were to determine the current status and condition of Big Payette Lake and the health of the contributing watershed, identify sources of nutrients that may contribute to eutrophication of Big Payette Lake, and provide a scientific basis for future management recommendations to protect water quality. The results of this Technical Study are intended to support and guide the development of a Lake Management Implementation Plan under development by the Big Payette Lake Water Quality Council. The Lake Management Plan will seek to enact specific best management practices, local ordinances, citizen education and other measures consistent with protection of the lake.

6.1 Summary

6.1.1 Watershed Assessment

Watershed assessments included measurement of the quantity and quality of runoff, identification of the sources and contribution of eroded sediments, the historical sediment accumulation rates within lakes, stream habitat quality within the watershed, recreational impacts, and a creel/ boating use survey. Two major wildfires burned nearly half the watershed in summer 1994 as field investigations for this study were initiated. Effects of the fire had a pronounced impact on the study results and interpretations.

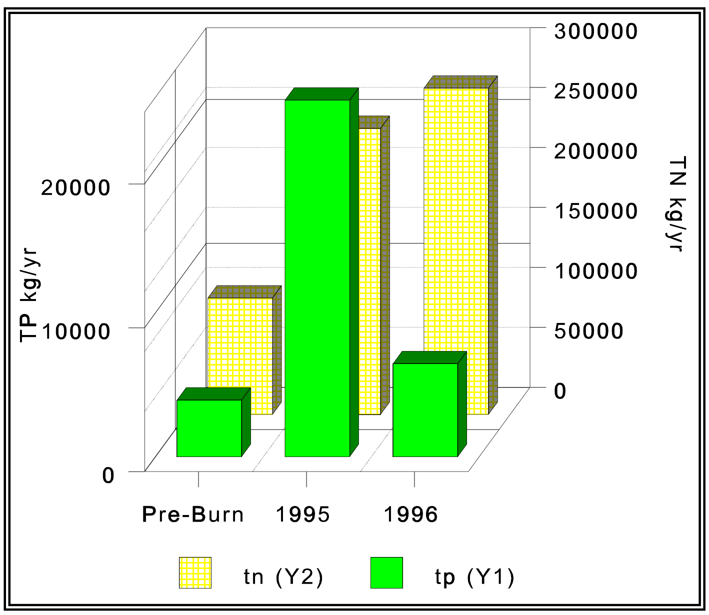
Quantity and Quality of Runoff

Subwatersheds for monitoring were prioritized based on factors such as intensity of past management activity, anticipated future uses, fire history and general conditions of stream habitat quality. Other diffuse land use impacts were also evaluated in and around the recreation and urbanized areas of the watershed adjacent to Big Payette Lake.

Climatic conditions during the study were wetter than normal and contributed to greater accumulation of snow-pack than the historical average. Runoff in 1995 was approximately 126% of normal and runoff in 1996 was 166%.

Wildfires in 1994 burned roughly 50% of the watershed as field studies were initiated. As a result, significant changes in the export of nitrogen and to a lessor extent phosphorus and sediment were noted in the streamflow of burned watersheds compared to unburned conditions (Figure 6-1). Phosphorus concentrations in streamflow were highest during the first year snowmelt and declined to near background levels the following year. Fall Creek, a burned watershed, contained the highest phosphorus concentrations in streamflow among all monitored watersheds; concentrations ranged from 1,000 to 2,600 mg/m^3 during snowmelt in 1995. Nitrogen concentrations from burned watersheds, particularly nitrate-nitrogen, were 2 to 3 times greater than unburned watersheds and remained well above background throughout the two year study. A comparison of the water yield among burned and unburned watersheds showed no appreciable difference in the volume of water discharged per unit of watershed area.

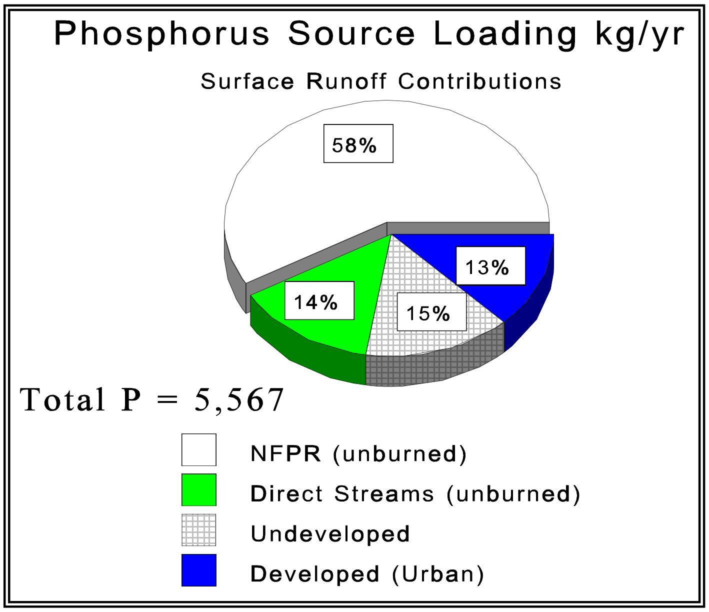
As a result of the 1994 fire, nutrient loading to Big Payette Lake increased above the estimated pre-fire loading rates (Figure 6-1). Phosphorus loading roughly doubled the first year following the fire (1995) but was only slightly greater during the second (1996). Nitrogen loading remained well above levels estimated for pre-fire conditions and actually increased the second year due to higher streamflow and concentrations. Pre-fire contribution of nutrient loads and suspended sediments by all streams was estimated based on a unit area export coefficient calculated from unburned watersheds. The resulting annual loading of sediment and nutrients to Big Payette Lake was estimated to be 3,953 kg total phosphorus, 97,399 total nitrogen and 552,696 kg suspended sediments. The corresponding pre-burn annual loading to Upper Payette Lake was calculated to be 1,236 kg total phosphorus, 27,295 kg total nitrogen, and 106,127 kg suspended sediments. Assuming the current fire impacts on the watershed stabilize to their pre-burn status, the impact of a future wildfire of similar extent (i.e., the remaining 50% of the watershed burns) is expected to briefly (2-5 year period) produce a two fold increase in the sediment and nutrient loads over the estimated yields prior to burning. The additional nutrient loading that might result from reoccurrence of wildfires in a previously burned forest could not be estimated.



Comparison of the inflows and outflows from Upper Payette Lake revealed this lake is an important sink for nutrients and sediments transported in runoff from the upper basin. Upper Payette Lake retained roughly 11% of the total phosphorus, 22.8% of the nitrogen and 53% of suspended sediments entering the lake in 1995. Similar amounts of phosphorus and slightly lower amounts of suspended sediment (35%) were retained in 1996.

Stormwater runoff from developed areas around the Big Payette Lake shoreline were highly concentrated sources of nutrient and bacteria pollutants. Concentrations of phosphorus in stormwater runoff were 10 to 100 times greater than typical streamflows, 10 to 15 times greater for nitrogen and 40 to 250 times greater for suspended sediments. Total loading of phosphorus and nitrogen from developed and undeveloped areas directly draining to the lake was estimated to be 700-800 kg TP and 3,000-3,500 kg TN during this study.

Figure 6-2 compares the phosphorus and nitrogen loading attributed to all the major sources of surface runoff entering Big Payette Lake after adjusting for the fire contributions. The percent contribution of phosphorus attributed to the N.F.Payette River was 58%, with 14% from other direct stream inputs (Fall Creek, Deadhorse Creek, Sylvan Creek, Wagon Bay Creek and Lemah Creek). The remaining land area directly draining to the lake includes developed and undeveloped lands around the lake perimeter. Of this land area, approximately 2,231 hectares of undeveloped land (5,514 acres) contributed 15% of the total phosphorus in runoff while 704 hectares (1,739 acres) of developed (urban) land contributed 14% of the total phosphorus in runoff. Thus, developed (urban) land around the lake perimeter contributed about three times the phosphorus load as undeveloped land. A breakdown of the nitrogen sources shows that the N.F. Payette River contributed the largest proportion of the load, accounting for 80%. Developed (urban) lands were the second largest source and accounted for 18% of the nitrogen loading through surface water runoff.



Sediment Sources and Contributions

Total sediment input from background and other management sources is summarized in Table 6-1. The summary table includes two estimates of background sediment input as described previously, and gives a range of average annual total background input. The sediment input from the 1994 Corral-Blackwell fire is listed separately and includes total input predicted for 1995 and 1996 (not average annual input). Future surface erosion from the fire will be much smaller as burned areas re-vegetate and stabilize. Table 6-1 lists two sediment input rates for harvest: average historical input which averages total input from harvest activities from the 1950's to the present; and the average 1990-1995 input rate which provides more recent rates for comparative purposes.

Table 6-1 includes all sediment produced in the watershed that is delivered to either a stream or lake. It should be noted that all sizes of sediment is included in Table 6-1, however, the larger sized sediments (coarse sand, gravel, cobble, boulder) that make up a portion of the soil creep and mass wasting inputs become part of the bedload of the streams they enter, and do not likely contribute directly to altered water quality in the stream or lakes. The percent of coarse-grained sediment comprising the total from these two sources depends upon the soil types being eroded; it is likely 10 to 40 percent of the total is coarse. Sediment from surface erosion sources (fire, harvest, roads) are generally fine-grained (sand, silt, clay). These sediments will be transported much further in the stream system than the coarse sediments, and can contribute to increased turbidity in streams and lakes.

Table 6-1. Summary of average annual sediment input from background and management sources delivered to streams and lakes (estimated tons/yr).

Bac		Man						
Subbasin	Soil Creep	Alternate Background Estimate	Mass Wasting	Total Back-ground	Total Fire 95-96	Roads	Average Historical Harvest	Average 90-95 Harvest
Box Creek	56	208	333	389-541	39	2	0.3	2.4
Brush Creek	41	212	291	333-503	27	14	0.5	1.1
Camp Creek	36	154	178	199-317		131	1.5	0.1
Copet Creek	12	72	0	12-72		2	-	-
Cougar Creek	39	94	1,388	1,428-1,483	17	5	-	-
Dead Horse	67	121	0	67-121		27	0.6	2.3
Deep Creek	57	110	175	232-267		0	-	-
Fall Creek	79	169	14	93-183	32	24	0.2	-
Fisher Creek	161	450	286	447-736		65	1.2	0.8
Lemah Creek	81	126	0	81126	70	11	0.6	4.7
Middle Payette	48	139	35	83-174		82	-	-
No Name Creek	9	34	0	9-34		0	-	-
Payette Lake	27	463	24	51-487		69	-	-
Pearl Creek	53	128	0	53-128		61	0.5	-
Sylvan Creek	24	53	0	24-53		5	0.8	0.1
Twah Creek	102	181	0	102-181	41	9	0.4	2.9
Twenty Mile	104	400	3,906	4,010-4,306	34	10	0.4	0.1
Upper NF	142	438	612	735-1,030	90	359	0.2	0.1
Wagon Bay	27	54	0	27-54		17	-	-
Total	1,166	3,606	7,242	8,376-10,814	350	892	7.2	14.6

The actual amount of sediment supplied to Big Payette Lake is less than the total listed in Table 6-1 because much of the eroded sediment is stored in other intermediate lakes in the watershed or in low gradient stream valleys. A detailed analysis of sediment retention times in the various-sized lakes and stream channels was not made, however, the following assumptions can be made in order to estimate sediment supplied to Upper Payette Lake and Big Payette Lake:

(1) The majority of sediment supplied to a lake will settle out in that lake. Very little sediment (only the clay sized sediments) will remain in suspension and flow out of the lake. Based on this assumption, it was assumed that sediment from mass wasting supplied to alpine lakes (Table 4-26) did not deliver to either Upper Payette Lake or Big Payette Lake and all sediment supplied to Upper Payette Lake remained in that lake and did not deliver to Big Payette Lake.

(2) An average of 30 percent of the total mass wasting and soil creep sediment supplied to streams was assumed to be coarse grained (coarse sand, gravel, boulders based on soil data reported for land types in the basin). These sediments are stored in low gradient portions of stream channels and floodplains for long periods of time. If this coarse grained sediment does reach a lake, it is deposited in a delta at the upstream end of the lake and does not likely contribute nutrients in sufficient quantity to degrade water quality.

The results of this analysis for historical conditions (reflecting the period of time for which aerial photographs are available and harvest data for about the mid 1940's to the present) are shown in Table 6-2. It should be noted that the road erosion rates listed in Table 6-2 reflect current conditions; data on when individual roads were constructed was not available at the time of this analysis. In the past, there were fewer roads to produce sediment, but the road construction and maintenance practices were not likely as good as at present, so the roads that did exist produced more sediment than they do presently.

The majority of delivered mass wasting in the watershed occurs in the Upper Payette Lake (about 3,000 tons/yr). This is supported by the large delta formed in Upper Payette Lake, indicating large quantities of coarse sediment are supplied to the lake. About half of the total road and harvest sediment is supplied to Upper Payette Lake (about 440 tons/yr). Management-related sediment comprises about 15 percent of the total supplied to Upper Payette Lake. Big Payette Lake receives about 850-2,000 tons of sediment annually from background sources, with comparatively little of the background coming from mass wasting. About 450 tons of sediment (20-35 percent) is delivered to Big Payette Lake from management-related sources each year, primarily road erosion.

Table 6-2. Summary of average annual historical sediment input delivered to Upper Payette Lake and Big Payette Lake (estimated tons/yr).

Bac **Manage**

Subbasin	**Soil Creep**	**Alternate Background**	**Mass Wasting**	**Total**	**Roads**	**Average Historical Harvest**
Delivered to Upper Lake:						
Camp Creek	15	65	24	39-88	63	0.1
Cougar Creek	28	662	681	708-746	5	0.1
Twenty Mile Creek	73	280	1,876	1,949-2,156	10	0.7
Upper NF Payette	100	307	241	340-547	359	3.0
Total to Upper Payette Lake	215	717	2,820	3,036-3,358	437	3.9
Delivered to Big Payette Lake:						
Box Creek	39	146	-	39-146	2	0.6
Brush Creek	29	148	-	29-148	14	0.9
Camp Creek	10	43	-	10-43	68	0.1
Copet Creek	8	50	-	8-50	2	-
Dead Horse Creek	47	85	-	47-85	27	1.2
Deep Creek	40	77	86	126-163	-	-
Fall Creek	55	118	7	62-125	24	0.5
Fisher Creek	112	315	132	244-447	48	2.3
Lemah Creek	57	88	-	57-88	11	1.2
Middle Payette	34	97	17	51-114	82	-
Payette Lake	19	324	12	31-336	69	-
Pearl Creek	37	90	-	37-90	61	1.1
Sylvan Creek*	17	37	-	17-37	5	1.6
Unnamed Creek	6	24	-	6-24	-	-
Wagon Bay Creek	19	38	-	19-38	17	-
Twah Creek	72	126	-	72-127	9	0.8
Total to Big Payette Lake	602	1,807	253	855-2,060	438	10

*There is a small lake near the bottom of Sylvan Creek that prevents some sediment from reaching Big Payette Lake.

Stream Habitat Quality

Numerous streams in the Payette Lake watershed were evaluated to determine their relative stability, quality of aquatic habitats and support of aquatic organisms (macroinvertebrates and fish). Information collected by the U.S. Forest Service, Payette National Forest, Idaho Division of Environmental Quality and Idaho Department of Lands was synthesized into a common database. Streams were sampled prior to and after the wildfires in 1994. This report, however, provides analysis of pre-burn conditions. A post-fire assessment is expected to be completed by early summer 1997.

A total of twelve streams were analyzed and results were compared with standards from undisturbed streams in the Northern Rockies Ecoregion, a local stream of high quality, and available State (cold water biota water quality standards) and Federal (INFISH) standards.

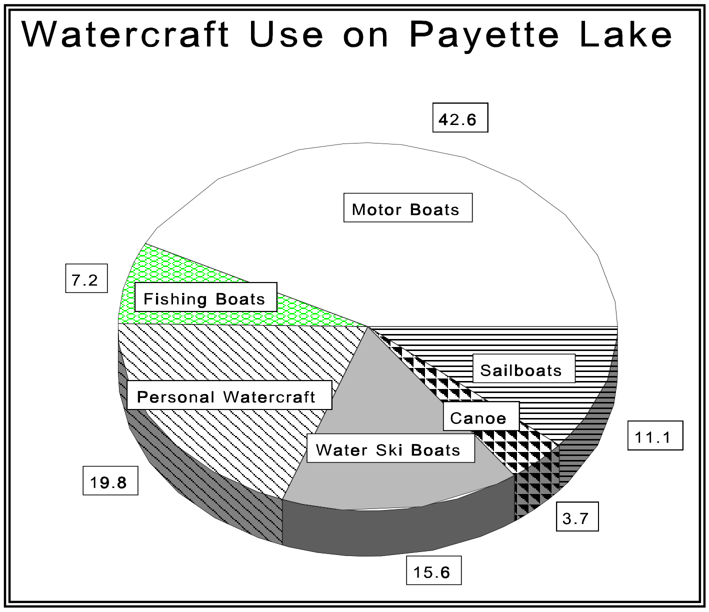
Results of these comparisons revealed that stream habitat quality in the Payette Lake Watershed generally falls within the natural range of undisturbed streams but key indices reflect higher levels of impairment related to sedimentation. All streams exceeded state and federal standards for temperature but were generally acceptable for dissolved oxygen content. Most of the streams fell below the INFISH standard for width to depth characteristics and were rated as poor or suboptimal by IDEQ standards except for Cougar and Deadhorse Creek. Streams were generally wider, shallower and less than optimal quality compared to natural conditions streams. Streams also generally contained adequate amounts of woody debris compared with most standards although many were below comparable natural streams surveyed in Idaho. Fall Creek and Box Creek contained the lowest amounts of LWD. Given the availability of LWD, pool complexity was lower than expected compared to undisturbed conditions. Moreover, pools and pool/riffle ratios for streams are generally below optima indicating a scarcity of high quality fish habitat. Sediment filling of pools may be attributed to the lack of pool quality. Fine sediment accumulation within stream substrates was prevalent in many of the streams surveyed. Channel erosion, however, did not appear to be a major contributor of sediment since stream banks were largely rated as highly stable. Exceptions were Landing Creek and Box Creek which scored low on bank stability. These sites also scored low on width to depth ratios.

These abiotic processes were also manifested in the macroinvertebrate and fish data. Common biological indices (% scrapers, taxa richness, %EPT and %Dominance) indicate a majority of streams have macroinvertebrate communities exhibiting some degree of environmental stress, again related to accumulation of fine sediments. The exceptions were Box Creek and Twenty Mile Creek with indices reflecting high water quality and minimal disturbance. Fish densities, as might be expected, appeared to increase among streams with more favorable habitats. Brook trout, rainbow trout and cutthroat trout were widely represented throughout the watershed. However, the number of habitat types (pools/riffles), frequency and complexity is less than optimal.

Further comparisons of habitat quality will be made using post-fire monitoring data from the same stream sites. This analysis will be completed by early summer of 1997. These comparisons will provide additional insight as to the character of the stream habitats altered by wildfires.

Recreation Survey

With the increased growth of population in Idaho, Payette Lake has become a recreational favorite due to its high water quality, large size, parks and other amenities. Boating use for general pleasure dominates recreational water use (Figure 6-3). On three separate dates, the number of boats on the lake surface exceeded 700 (including boats moored at docks and those in active use). Anglers spent an estimated 11,489 hours pursuing lake trout, kokanee, rainbow trout, and cutthroat trout. Kokanee were the most important species, in numbers, harvested from the lake. An analysis of the kokanee migration and recruitment showed that spawning kokanee run has been adequate to maintain lake population levels. Population numbers have actually increased since 1992 perhaps in response to increased lake productivity or other factors (less predation). Accordingly, the number of spawning kokanee utilizing the N.F. Payette River has increased.



A bacteria survey conducted on several popular camping sites within the watershed indicated surface contamination of streams was prevalent during summer months when recreational activity is greatest. The more undeveloped sites were most prone to soil disturbance and bacteria contamination.

Efforts by the State Department of Parks and Recreation have been made to better equip the primitive camping areas with sanitary facilities and designated parking facilities. Additional facilities are needed to reduce erosion and stabilize surrounding surface areas. As recreational demand increases, the more primitive sites will be prone to additional usage and could increase the potential for bacterial contamination and erosion.

North Fork Payette River Minimum Stream Flows

The IDFG conducted a survey of minimum stream flow requirements necessary to maintain and enhance fish habitat on the N.F. Payette River between Upper and Big Payette Lake. An Instream Flow Incremental Methodology (IFIM) was used to identify critical thresholds of streamflow for resident fish populations. These results indicated that existing low streamflows during late summer fell below levels needed to sustain adequate numbers of pools for fish. It was determined that a minimum baseflow of 60 cfs (as measured at the USGS gauge below Fisher Creek) was required in the mainstem river from July 1 to September 7. This flow rate provided an acceptable minimum quantity of water depth and pools for rainbow trout and spawning kokanee. Habitat conditions would be improved but would remain below optimal conditions (with respect to water levels). To accomplish this goal, it was determined that 35 cfs discharge from Upper Payette Lake would be required in addition to the base flows provided by tributaries draining to the mainstem N.F. Payette River during this time period.

Maintenance of a minimum flow would enhance other beneficial use requirements such as water quality and river recreation (rafting, canoeing, etc.). Extremely low discharge rates can further degrade water quality in the N.F. Payette River by accelerating the decomposition of periphytic algae that accumulates in the lower reaches of the river. During low discharge periods, additional river bottom is exposed, increasing the potential for accelerated decomposition of organic matter and mineralization of nutrients. These materials are subsequently flushed from the river when water levels later re-flood exposing substrates and are then available to further enhance algal growth within the lake. The availability of sufficient water from upstream sources to meet these needs and associated impacts on other competing water demands was not evaluated.

Sediment Accumulation Rates in Upper and Big Payette Lake

Sediment cores were extracted from Upper and Big Payette Lake to determine the historical rates of surface erosion from the surrounding watershed and other inputs. While all lakes are in a natural state of filling with sediments due to their ability to trap and store these inputs, the natural rate of this filling process can be accelerated by land disturbances within the drainage basin. In addition, nutrients which affect the productivity of lake systems are often attached on eroded sediment particles when transported to the lake. These inputs, in turn can have a profound influence on the limnological processes within the lake, such as depletion of oxygen as deposited organic sediments decompose.

A historical profile of deposited sediments was constructed using lead-210 activity as an estimate of the age when sediment layers were deposited. Cores were extracted from the NE and SW basins of Big Payette Lake and from a single location in Upper Payette Lake. All cores were sampled from the deepest areas within the respective basins to maximize the temporal resolution of sediment accumulation.

Good quality records of lead-210 activity were obtained from each core which allowed dating of sediments to be established beginning around circa 1840. Calculated sediment accumulation rates (SARs) established a background rate of 0.1-0.2 g/cm^2/yr for both the NE and SW basins of Big Payette Lake and 0.3-0.4 g/cm^2/yr for Upper Payette Lake.

Stratigraphy of the cores indicate SARs increased at a steady rate over the next 80-100 years (1920-1940) increased nearly 3 to 4 fold in both Upper and Big Payette Lake. These increases were attributed to non-cataclysmic promoting events such as increased development and utilization of the basin (construction of roads, grazing, early timber extraction and fires).

Approximately 50-60 years ago (circa 1940), SARs changed dramatically in Upper Payette Lake increasing to nearly 5 times the historical background while rates in the NE basin of Big Payette Lake ceased increasing but leveled off at three times the natural background. In contrast, SARs in the SE basin of Big Payette Lake began declining until present where rates are now equal to those in 1840. The exact cause of these results are difficult to isolate in the broader perspective with continued growth in population of the region, additional road construction in the watershed and development of the lake shoreline. One advent of importance was the concerted effort to harness and manage the region water resources through construction of dams on Upper and Big Payette Lakes as well as other smaller reservoirs in the watershed. Construction of these dams likely altered the hydrology of these water bodies and altered the retention and storage of eroded sediments these lakes receive from the watershed. Trends observed in the changes of SAR in the basins were consistent with what might be expected in hydraulically connected lakes where increased trapping efficiencies have a cascade effect on the removal of suspended sediments and the subsequent downstream transport and deposition of sediments.

Analysis of the nutrient content of deposited sediments showed phosphorus, nitrogen and carbon were highest in deposited sediments in Upper Payette Lake followed by the NE basin and SW basins of Big Payette Lake. Calculated C:N and N:P ratios show these patterns of nutrient content in deposited sediments has likely remained consistent over time. Evidence of increased sediment mobilization of phosphorus and nitrogen resulting from decline in sediment redox (anaerobic conditions) was present in the Big Payette Lake SW basin core stratigraphy. This confirms that oxygen depletion in the lake hypolimnion has promoted release of nutrients from lakebed sediments in this basin (internal recycling).

The enhanced sedimentation of Big Payette Lake above the historical background has likely contributed significant quantities of oxygen demanding substances to the lake. This has resulted in increased demand of oxygen for decomposition processes which in-turn can trigger release of sediment bound nutrients. Future contributions of fire related sediment erosion could further aggravate the oxygen demands on the lake hypolimnion should erosion rates increase.

6.1.2 Lake Assessment

Lake assessments included monitoring of the nutrient inputs and outputs, lake water quality, aquatic macrophyte composition of the shoreline and growth of periphyton in the lake littoral zone. Nutrient and water mass balance budgets were calculated to assess source loadings and subsequently used as input to a lake response model. The model was used to predict potential changes in the trophic status of the lake in response to simulated increases and decreases in the source loading of nutrients. This information will provide inferences concerning the importance of controlling source loads through implementation of best management practices (BMPs) and identify which source load reductions would have the greatest influence on water quality at least cost.

Hydrologic inputs during 1995-96 were larger than the long-term mean and, thereby, reduced the residence time of water in Payette Lake by 22 % in 1995 and 40 % in 1996. Loads of nitrogen and phosphorus delivered to the lake were increased by the larger flows and by the effects of the 1994 forest fires that burned about one-half of the lake’s watershed. The percentage contribution of nutrient loads from the lake's primary tributary, the North Fork Payette River during 1995-96 averaged 28.2 % for phosphorus and 70 % for nitrogen. On the basis of two earlier studies of nutrient loads to Payette Lake, this indicates a decrease in the influence of the primary tributary on phosphorus loads and an increase in the relative contribution from nearshore areas and smaller tributaries draining directly to the lake. A similar conclusion would have been reached for nitrogen if the forest fires had not increased nitrogen loads by a factor of about five.

The trophic state of Payette Lake was oligotrophic during 1995-96, on the basis of concentrations of total phosphorus, total nitrogen, and chlorophyll-a. The forest fires increased total and dissolved concentrations of nitrogen throughout the lake; no such increases were apparent for phosphorus. In that the lake's phytoplankton productivity is strongly limited by phosphorus, the large increase in dissolved inorganic nitrogen did not dramatically increase chlorophyll-a concentrations. Increases in chlorophyll-a concentrations were only about two-fold in comparison to those measured two years prior to the 1994 forest fires.

Despite its oligotrophy, Payette Lake did develop anoxia in the lower hypolimnion of the southwest basin for about four months in each year. Substantial oxygen depletion also was measured in this basin under winter ice cover in February, 1996. Low dissolved-oxygen concentrations in the southwest basin were measured in 1981 and 1992-93; thus, they are not a by-product of the 1994 forest fires. Payette Lake has a much larger hypolimnetic dissolved-oxygen deficit than was predicted by the nutrient load/lake response model's empirical relation of hypolimnetic dissolved-oxygen deficit with nutrient and chlorophyll-a concentrations.

Payette Lake's propensity to develop a substantial hypolimnetic dissolved-oxygen deficit is rooted in several factors, not all of which are anthropogenic. Long-term human development of the watershed and the nearshore area has produced small, but cumulative, increases in the lake's nutrient budget and, consequently, increased the lake's biological productivity as shown by the 1975 and 1981-82 studies which concluded the lake was mesotrophic, or moderately enriched. The increased biological production from phytoplankton and periphyton has generated additional organic matter. The portion of organic matter that is not flushed out of the lake exerts an oxygen demand while settling, and is eventually deposited onto the lakebed sediments (See Figure 6-4). The lakebed sediments in the southwest basin contained much more phosphorus than the other three basins. Therefore, one can conclude that the majority of oxygen-demanding organic matter was produced in or transported to the southwest basin because it has the largest amount of nearshore development and is the terminal basin in the lake.

Several non-anthropogenic factors influence the development of the hypolimnetic dissolved-oxygen deficit. The lake's long residence time, as determined by lake volume and outflow volume, facilitates water-column retention of the oxygen-demanding organic matter produced within the lake or delivered to it from terrestrial sources. The lake's depth, especially in its southwest and northern basins, retards water-column circulation and consequent re-aeration of the hypolimnion into December, despite the loss of thermal stratification a month or two earlier. The delay in hypolimnetic re-aeration extends the time over which organic matter exerts an oxygen demand on the hypolimnetic oxygen supply. That oxygen supply is finite in that it is delivered during the spring water-column circulation and is not replenished if thermal stratification persists over the summer. At station 1, the lack of complete re-aeration during spring water-column circulation exacerbates the hypolimnetic dissolved-oxygen deficit problem because the southwest basin begins the thermal stratification period with an incomplete supply of dissolved oxygen with which to satisfy its hypolimnetic oxygen demands.

Figure 6-4. Relation of natural and human related processes contributing to the loss of hypolimnetic oxygen in the southwest basin of Big Payette Lake.

Although oligotrophic, the lake accumulates organic matter in its lakebed sediments. When the oxygen supply becomes exhausted at the sediment-water interface, as it was at station 1 from September into December of 1995-96, redox conditions can develop that allow release of nutrients from the sediments into the overlying water column; such releases were measured in 1995 but not in 1996. If anoxia were to become a persistent feature in Payette Lake and extend upward in the hypolimnion, then the release of sediment-bound nutrients would constitute an additional, internal load of nutrients with which to fuel biological production.

The question implied by the title of this report, "Eutrophication Potential of Big Payette Lake, Idaho", should perhaps be re-stated as "Can Eutrophication in Payette Lake Be Reversed?" The substantial hypolimnetic dissolved oxygen deficits and development of anoxia constitute strong symptomatic evidence that Payette Lake has undergone eutrophication, despite its trophic state classification as oligotrophic. The lake's lengthy water residence time and incomplete water column circulation in the spring and autumn have prevented the lake from discharging some portion of its annual biological production. Consequently, a long term build up of nutrients and oxygen demanding substances in the lakebed sediments, coupled with the lake's biological production, has been large enough to create hypolimnetic dissolved oxygen deficits and in some years, anoxia. The calibrations and simulations used in the nutrient load/lake response model indicated the hypolimnetic dissolved oxygen deficit was relatively insensitive to moderate, and realistic, reductions in nutrient loads to the lake. Such insensitivity is due, in part, to the strong limitation by phosphorus of phytoplankton production. Given this insensitivity and low concentrations of phosphorus in the lake, the annual development of hypolimnetic dissolved oxygen deficits may be expected to continue, despite reductions of nutrient loads from nearshore and watershed sources. Conversely, an important water quality management goal may be to prevent increases in phosphorus loads to Payette Lake, given the strong limitation by phosphorus of phytoplankton production.

6.2 Recommendations

The following recommendations are based on the synthesis of information gathered during the technical study and represent the best professional judgement as to practical considerations where actions can enhance water quality protection. There are any number of alternatives that might be considered depending on time and costs.

6.2.1 Implementing Storm Water Controls for Stormwater Water Quality Management

Control of stormwater runoff and associated water quality is often difficult and expensive in urban areas. Homeowners frequently have no restrictions as to the type and amount of chemicals that may be applied to landscapes (fertilizers, pesticides, fungicides and herbicides) or structures which may leach materials during rain storms. Other pollutant sources include road surfaces (greases, gas, oil and heavy metals) and sediments from ground disturbance during construction. Contributions from this latter pollutant source were responsible for high concentrations of suspended sediments, turbidity and phosphorus entering the lake during the course of this study.

There are numerous site control measures or best management practices (BMPs) that can be implemented to address and reduce contributions of these contaminants entering the lake (Table 6-3). Many studies have shown the removal efficiency of specific substances such as sediments, nutrients and bacteria are highly variable depending on local topography, density of commercial and residential use, rainfall, soils and other characteristics. Table 6-4, adapted from Schuller (1987), lists some of the more common pollutant concerns for Big Payette Lake based on monitoring and the potential removal efficiency.

Table 6-3. Comparison of key pollutant removal efficiencies using an array of stormwater runoff control techniques (adapted from ASCE, 1992 citing Schueler, 1987).

BMP Design	Design Event	Suspended Sediment	Total Phosphorus	Total Nitrogen	Trace Metals	Bacteria	Overall Removal Efficiency
Extended Detention Pond	First flush runoff detained for 6-12 hrs	60-80%	20-40%	20-40%	40-60%	X	Moderate
	First 1.0 inch runoff detained 24 hrs	80-100%	40-60%	20-40%	40-60%	X	Moderate
	First 1.0 inch runoff detained 24 hrs plus filtration through shallow marsh	80-100%	60-80%	40-60%	60-80%	X	High
Wet Pond	Permanent pool equal to 0.5 inch storage per impervious acre	68-80%	40=60%	20-40%	20-40%	X	Moderate
	Permanent pool equal to 2.5 times the mean storm runoff volume	60-80%	40-60%	20-40%	60-80%	X	Moderate
	Permanent pool equal to 4 times the mean storm runoff = 2 week detention	80-100%	60-80%	60-80%	60-80%	X	High
Infiltration Trench	Exfiltrate first flush; 0.5 inch runoff per impervious acre	60-80%	40-60%	40-60%	60-80%	60-80%	Moderate

	Exfiltrate first 1.0 inch runoff per impervious acre	80-100%	40-60%	60-80%	80-100%	60-80%	High
	Exfiltrate all runoff up to the 2 yr storm event	80-100%	60-80%	60-80%	80-100%	80-100%	High

Table 6-3. Continued - Comparison of key pollutant removal efficiencies using an array of stormwater runoff control techniques (adapted from Schueler, 1987).

BMP Design	Design Event	Suspended Sediment	Total Phosphorus	Total Nitrogen	Trace Metals	Bacteria	Overall Removal Efficiency
Infiltration Basin	Exfiltrate first flush; 0.5 inch runoff per impervious acre	60-80%	40-60%	40-60%	40-60%	60-80%	Moderate
	Exfiltrate first 1.0 inch runoff per impervious acre	80-100%	60-80%	60-80%	80-100%	60-80%	High
	Exfiltrate all runoff up to the 2 yr storm event	80-100%	60-80%	60-80%	80-100%	80-100%	High
Porous Pavement	Exfiltrate first flush; 0.5 inch runoff per impervious acre	68-80%	60-80%	40-60%	40-60%	60-80%	Moderate
	Exfiltrate first 1.0 inch runoff per impervious acre	80-100%	60-80%	60-80%	60-80%	80-100%	High
	Exfiltrate all runoff up to the 2 yr storm event	80-100%	60-80%	60-80%	60-80%	80-100%	High
Filter Strip	20 foot wide turf strip	20-40%	0-20%	0-20%	20-40%	X	Low
	100 foot wide forested strip with level spreader	80-100%	40-60%	40-60%	80-100%	X	Moderate
Grassed Swale	High slope swales with no check dams	0-20%	0-20%	0-20%	0-20%	X	Low
	Low gradient swales with	20-40%	20-40%	20-40%	0-20%	X	Low

check dams

Gravity storm drains located along the perimeter of the lake discharge variable quantities of stormwater runoff and pollutants. From a volume pollutant perspective, the Art Roberts Park and Marina storm drains consistently provide the largest volume of runoff and higher concentrations of pollutant measured. The Art Roberts Park drain currently has a sand trap incorporated into the design for removal of larger sized particles. The sand trap has not been maintained, however, and is no longer functional.. The trap also appears to be undersized for the volume of material passing through the system based on field observations during several storm events. An aggressive street cleaning program would significantly reduce the quantity of material washed from the streets during each storm event and reduce finer particle materials that are not retained by the sand trap from reaching the lake.

The Marina site is somewhat unusual in that a low volume discharge from this drain is present throughout most of the spring and summer even in the absence of local storm activity. During storms the discharge rate is greatly increased. These base flows are attributed to groundwater seepage into the system during periods when the groundwater table is high or through drainage of perched wetlands located to the east near the railroad grade. There is no sand trap or other filtration on this system. The existing outfall for this drain terminates at a headwall on the lake shoreline. A large deposit of fine silts and mud have collected in the vicinity of the outfall which re-suspends by turbulence during high flows following storms. Plumes of highly turbid water were observed on two occasions moving toward the lake following storms. Reconstruction of the outlet to reduce turbulence and transport of silts into the lake would be beneficial.

Smaller storm drains along the shoreline convey much smaller volumes of runoff but on a collective basis appear to influence a substantial length of the lake shoreline water quality. During one storm event, the entire shoreline from the dam eastward to the marina site was affected by an intense runoff event that produced a highly turbid plume throughout the shoreline. It was not possible to determine how long this material may remain in the vicinity before it is carried with long shore currents toward the dam outlet or migrates toward the lake. Many of these drains currently spill onto the lake shoreline and promote additional erosion. Additional retrofitting of these pipes may be required to extend the invert into deeper water to reduce turbulent erosion. A final site of consideration is the vicinity of Legacy Park. Several smaller storm drains are located near the public beach. These drains convey small but highly concentrated loads of bacteria and sediments from the downtown street drainage. The City is planning to divert some of this drainage to alternate outfalls as part of the redevelopment project. Diversion of storm drains away from the public beaches is encouraged and would reduce the potential of health risks.

6.2.2 Recommendations to Reduce Management-Caused Sediment Inputs

Two areas in which management activities can influence sediment contributions to streams and lakes in the watershed deal with surface erosion from construction and maintenance of roads and landslides from related road activities.

Surface Erosion

The majority of sediment contributed to aquatic systems from management-related sources in the Payette Lake basin is produced from road surface erosion. The USFS has compiled a Watershed Improvement Needs Inventory (WINI), listing sites on USFS land that could be improved to reduce erosion (USFS 1994). Road segments contributing large amounts (over 10 tons/year) of sediment to streams in the basin include: 903, 904, 41, 901, 38, 28, 46, 76, 30, 108, 905, 89, and 17 (Map 4; Appendix B). In addition, during the field work for the present project, road segments that the following road erosion sites were noted (Table 6-5). These sites are also marked on Map 4.

Table 6-5. Road erosion sites.

Road Segment	Road	Comments
56	IDL - Deadhorse Creek	Stream crossing; culvert and road fill eroding.
57	IDL - Deadhorse Creek	Culvert has overtopped, undermining and washing out road tread and fill. Approximately 20 cu yd eroded.
77	USFS 50432	Culvert has plugged, diverting creek down ditch, eroding ditch.
89	USFS 50437	Culvert blocked with debris; overtopped road, washed out road and fill. Approximately 10 cu yd eroded.
M38-M42	Main road E side of Payette Lake (Lake Drive)	Sand and gravel from road delivers directly into creeks and Payette Lake; sand visible in channels.
M50	USFS 50281	Cutslope/fillslope failures; undersized and blocked culverts.
M51	USFS 50281	Undersized culverts, severely eroded road tread.
M53	USFS 50281	Undersized culverts, road washed out.
M60	USFS 51498	Gully erosion

Figure 6-5. Payette Lake Watershed Roads

Mass Wasting

As shown in Figure 4-27, the watershed contains numerous areas that have high hazard ratings for mass wasting, and thus are sensitive to the possibility of the creation or reactivation of landslides from management activities. In the Payette Lake watershed, because of the present low incidence of management-caused mass wasting features, the primary management sensitivity is to future road location, construction and maintenance practices. In all high-rated areas the locations of the roads should be carefully engineered to ensure that natural failures are not reactivated, and that failures are not created in the future. Construction practices should ensure that fills are not too large for the general steep character of the slopes in areas rated as high. The fill also needs to be well-drained with numerous relief pipes that have the capacity to carry large quantities of runoff. Maintenance practices should not pile bulldozed materials at the outside edges of the roads, as these areas are particularly susceptible to fill failures. Finally, both cut and fill slope angles should be low enough to allow them to quickly re-vegetate, and should not be increased by maintenance practices.

6.2.3 Monitoring and Trend Analysis

The significance of the water quality problems identified by this study indicate a need for a long term program of water quality monitoring for Big Payette Lake and its watershed. The primary purpose of the monitoring program would be to assess the effectiveness of nutrient reduction actions designed to preserve and protect water quality in Big Payette Lake and its watershed. In addition, the monitoring program would yield trend analyses for important water quality features such as water volumes and nutrient loads delivered to and exported from the lake and the rate of the lake's recovery from the effects of the 1994 forest fires.

Upper Payette Lake should also be monitored because it plays an important role in protecting water quality of Big Payette Lake and in sustaining fish habitat in the N.F. Payette River. The trophic status of Upper Payette Lake is unknown, but the continued ability of this lake to assimilate sediment and nutrient inputs can be crucial to Big Payette Lake. Upper Payette Lake currently provides an effective trap for reduction of sediments and nutrients carried in runoff from local streams that would otherwise be transported to Big Payette Lake. The nutrient loading to Big Payette Lake would likely be greater than present without this filtration capability as evidenced by the analysis of core samples. Core samples from Upper Payette Lake contained higher concentrations of nitrogen and phosphorus than sediments collected from Big Payette Lake. Under anaerobic conditions, phosphorus and nitrogen can be released from these sediments and potentially be transported downstream. Because of the smaller size and volume, this lake has a much greater potential to degrade in water quality at a faster rate than Big Payette Lake. Establishing baseline environmental conditions via a monitoring program for Upper Payette Lake would provide needed information for future assessments of the lake trophic condition. Periodic monitoring would measure the rate of change in important water quality conditions. Water regulation of Upper Payette Lake is an important consideration in maintaining lake water quality and downstream fish habitat conditions. At the present time, no records of discharge quantity are maintained. A monitoring system is needed to better determine the timing and quantity of discharge for downstream fish habitat quality and to determine seasonal patterns of hydraulic flushing. These records could be used to better define operation schedules and evaluate changes in lake water quality.

A suggested monitoring program for Upper and Big Payette Lakes that encompasses the elements needed to achieve the stated purposes of monitoring is described as follows. Streamflow should be monitored at the two existing USGS gages on the inlet and outlet of Upper Payette Lake. A new streamflow gaging station should be established at the outlet of Upper Payette Lake. Water Quality samples should be collected periodically at the three gaging stations; the samples should be analyzed for nutrient concentrations in order to compute nutrient loads. Limnological sampling of Upper Payette Lake should initially be at a reconnaissance level. Three sampling trips should occur between June (shortly after iceout) and September to assess important limnological conditions, especially the status of dissolved oxygen in the hypolimnion. If no water quality problems were detected during the reconnaissance phase, then monitoring could be scaled back or eliminated. However, if a substantial dissolved oxygen deficit were detected, the monitoring should continue and might be expanded in scope. Limnological sampling of Big Payette Lake should concentrate on monitoring the hypolimetic dissolved oxygen deficit. Seven sampling trips should be scheduled: five from May through September, one in mid-December, and one in early March during ice cover. Nutrient and chlorophyll samples should be taken between May and September to assess trophic state and the rate of decline in the fire effects on the lake.

6.3 Recommended Standards for Water Quality Protection Specific to Big Payette Lake

6.3.1 Hypolimnetic Dissolved Oxygen Requirements

The current oxygen depletion of the lake hypolimnion is a product of past and present influences on the lake. State Water Quality Standards for cold water biota require a dissolved oxygen minimum of 6 mg/l, but presently exempt the bottom 7 meters of Idaho lakes from any minimum dissolved oxygen requirements if lake depth exceeds 35 meters (IDAPA 16.01.02 250,02.b.iii.(c), (1991). For Payette Lake, further development of anoxic conditions could seriously degrade future water quality. Establishing a site specific minimum would provide additional guidance in management of those activities that might introduce additional oxygen demanding substances into the lake.

The current water quality conditions in Payette Lake support good populations of coldwater gamefish species including lake trout *(Salvelinus namaycush)*, kokanee salmon *(Oncorhynchus nerka kennerlyi),* westslope cutthroat trout *(Oncorhynchus clarki lewisi*) and rainbow trout *(Oncorhynchus mykiss)*. Other coldwater, nongame fish species such as shorthead sculpin *(Cottus confusus)*, northern squawfish *(Ptychocheilus oregonensis)* and largescale sucker *(Catostomus macrocheilus)* provide fish community complexity and are prey fish for lake trout. All of these fish species rely on the hypolimnion for thermal refuge when the epilimnion warms. Lake trout are especially dependant on a well oxygenated hypolimnion to remain in suitable water temperatures.

Lake trout prefer water temperatures less than 10°C (50°F) and depths of 18-53 meters (60-175 feet) for long-term physiological well being (Scott and Crossman, 1973). These conditions exist within the hypolimnion in Payette Lake and account for the good growth and survival of this lake trout population.

Additionally, the current trophy fishing regulation for lake trout in Payette Lake requires that most of the fish caught must be released. Hooking mortality of lake trout increases dramatically when fish are released into water without a well oxygenated thermal refuge. Lee, 1994 found that released fish escape to the bottom to recover from hooking stress. He reported that hooking mortality was 11.7% when a thermal refuge of _12°C with dissolved oxygen levels over 3 mg/l was available. Mortality increased to 87.5% when dissolved oxygen was less than 3 mg/l.

The dissolved oxygen objectives shall include the hypolimnion of Big Payette Lake and shall be measured in the lake's southwest basin at the following coordinates: 44 degrees 55 minutes 50 seconds North, 116 degrees 05 minutes 50 seconds West. Dissolved oxygen concentrations during June through September shall be equal to or greater than 6 milligrams per liter between the lake's surface and the 200 foot depth. Below the 200 foot depth and above 3 feet of the lakebed, the overall average dissolved oxygen concentration from June through September shall be greater than or equal to 3 milligrams per liter.

6.3.2 Nutrient and Chlorophyll Standards

At the present time, Payette Lake productivity is phosphorus limited. The U.S. Environmental Protection Agency (EPA) recommends a phosphate phosphorus standard not to exceed 50 mg/m^3 for surface waters entering lakes to reduce the risk of eutrophication. This limit presumes that inflow concentrations would be further reduced in the receiving lake through dilution and sedimentation of phosphorus so that the resulting lake concentrations would remain below threshold levels that would alter the trophic status. Idaho does not currently have a numerical standard for nutrients or chlorophyll (a photosynthetic pigment in algae that roughly estimates algal biomass or quantity) applied to lakes.

For Big Payette Lake, the median concentration measured in the lake epilimnion, where the majority of algal growth takes place, was 4-6 mg/m^3 total phosphorus and chlorophyll was 0.8-2.4 mg/m^3. Measures of trophic status use a lake concentration of 10 mg/m^3 total phosphorus (TP) as a break-point in determining that higher concentrations of TP would likely result in the classification of the lake as mildly productive (mesotrophic). A median TP standard of 6 mg/m^3 for Big Payette Lake would limit the productivity of the lake from further increases that would significantly alter the trophic status and related beneficial uses. A corresponding median standard for chlorophyll of 3.0 mg/m^3 would provide an acceptable level of productivity without significant impact to existing beneficial uses.

Appendix Tables: Habitat Quality

Chapter VII

7.0 Bibliography

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