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.

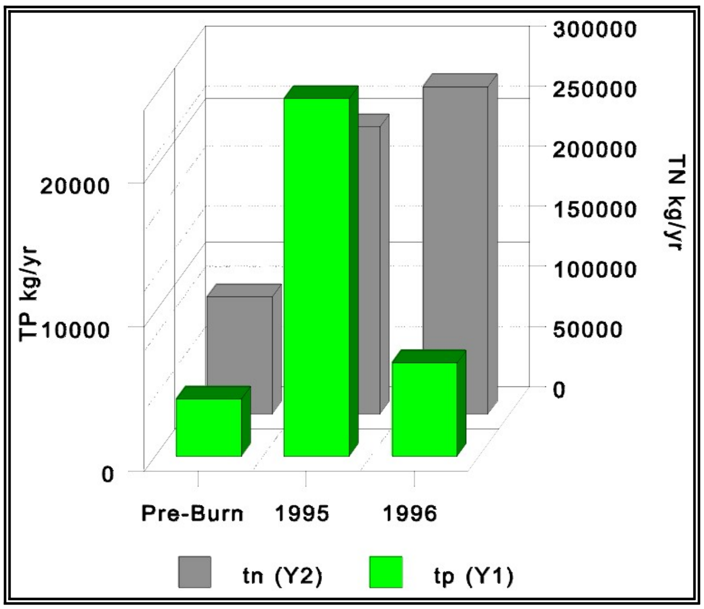
Quantity and Quality of Runoff

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.

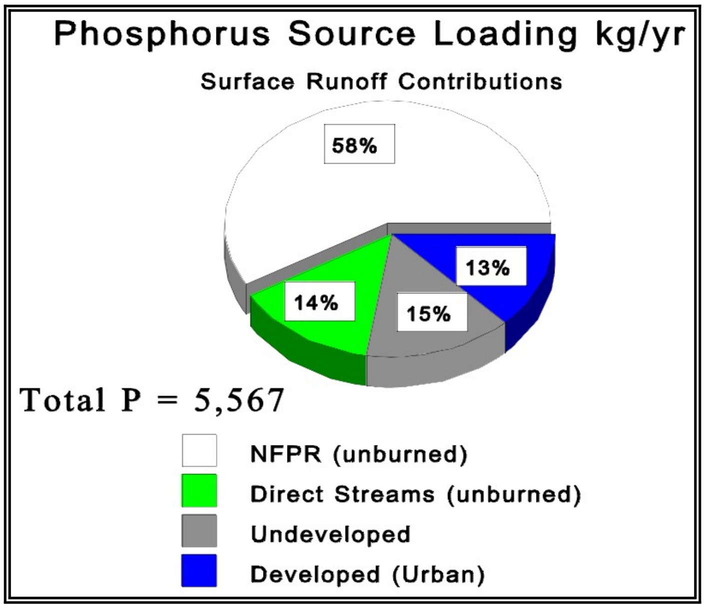
As a result of the 1994 fire, nutrient loading to Big Payette Lake increased above the estimated pre-fire loading rates (Figure 6-1). Phosphorus loading roughly doubled the first year following the fire (1995) but was only slightly greater during the second (1996). Nitrogen loading remained well above 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).

	Background				Management			
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).

Subbasin	Background				Management	
	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.

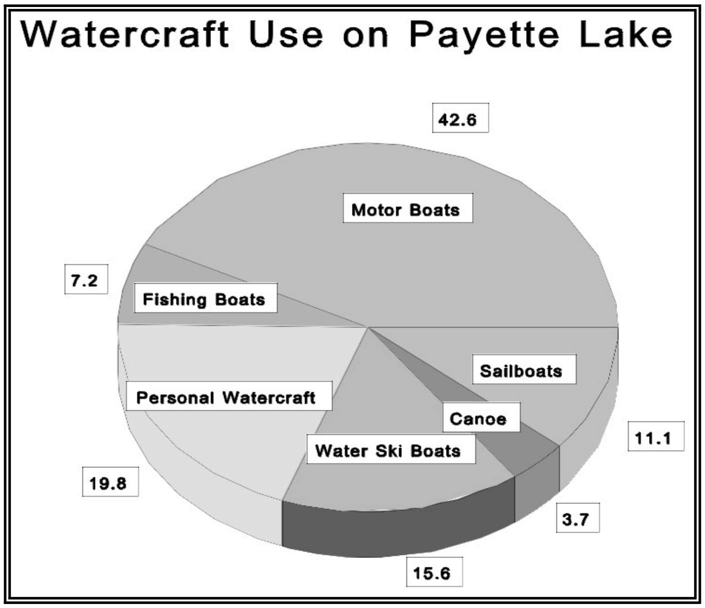
Results of these comparisons revealed that stream habitat quality in the Payette Lake Watershed generally falls within the natural range of undisturbed streams but key indices reflect higher levels of impairment related to sedimentation. All streams exceeded state and federal standards for temperature 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

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 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

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