The Dead Horse Creek Catchment: effects of logging and forest fires on the eutrophication of Big Payette Lake, McCall, Idaho

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INTRODUCTION

The 5 $mi.^2$ Dead Horse Creek catchment extends from a base elevation of 4986 ft. at Big Payette Lake to an elevation of 7803 ft. at the summit. Dead Horse Creek is one of six subcatchments of Idaho's Big Payette Lake watershed that were studied to determine the impacts of logging practices and the 1994 Payette Region forest fires on the water quality of the lake. The undeveloped land has been logged continually since at least 1912 (P. Johnson, pers. comm.) but has not burned as have the other five catchments. This makes the Dead Horse Creek catchment an ideal location for comparing the effects of logging and burning on water quality. Surficial geology, groundwater levels, hydrologic response, and water chemistry of the subcatchments were the primary means of comparison. Nitrate and phosphate levels were of particular interest as they are the limiting nutrients for algal blooms and other eutrophication processes. This study concentrates on nitrate levels as phosphate concentrations were too low to be detected with the available instruments.

METHODS

Geology. Surficial geology was mapped in the field and sediment thickness was estimated over the entire catchment and verified with seismic refraction techniques. Forward and reverse shots were taken using an EG&G 12 channel exploration seismograph. Depths and velocities were modeled using RefractModel and RefractSolve Macintosh software (Burger 1992).

Hydrology. Whenever a stage change of 0.1 ft. or greater was observed, discharge in cubic feet per second (cfs) was measured using a Swoffer current meter and the cross-section method. Multiple discharge measurements were taken on two occasions for QC/QA purposes. Groundwater levels and chemistry were monitored in a 102 cm dug well. Average depth of snowpack in the watershed was estimated and water equivalence of snowpack was determined using a snow tube and a hand-held scale.

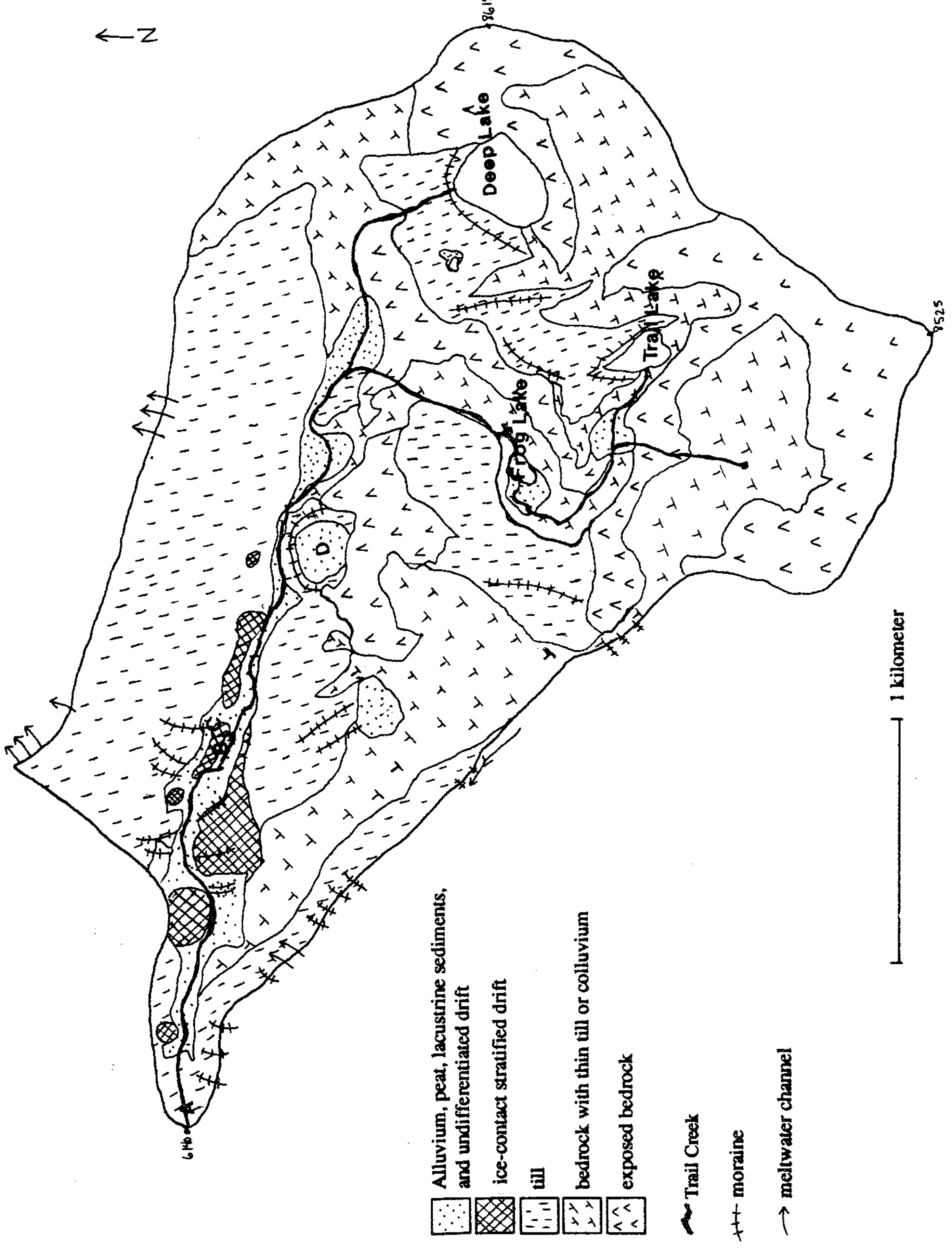
Chemistry. Groundwater, snowpack, and stream samples were collected at numerous locations throughout the catchment. Samples were collected at the gauge station (80 m upstrream of the termination of Dead Horse Creek into Big Payette Lake) throughout the study at different flows. Sample pH was analyzed within 24 hours with a temperature compensating Fisher Scientific Accumet 1002 digital pH meter. Acid Neutralizing Capacity (ANC) was calculated by Gran Titration. Specific conductance of samples was measured with a YSI Model 34 specific conductance-resistance meter. Samples were filtered through 0.45 mm syringe filters and analyzed using a Dionex Model 2000-I Ion Chromatograph to determine the concentrations of chloride, nitrate, and sulfate ions. Field replicates and laboratory splits were collected simultaneously and analyzed independently to determine QC/QA standards for each of the chemical analyses.

RESULTS

Geology. The catchment's surficial geology is predominantly glacial and colluvial deposits. The Dead Horse Creek catchment was glaciated in at least two, and possibly four, periods (Colman and Pierce 1986). The most obvious glacial features in the area are moraines deposited during the Pinedale Glaciation, 30 +/-5 ka.

The bedrock in the Dead Horse Creek catchment is approximately 60% tonalite of the Idaho Batholith, identified by large hornblendes (2-20mm) and plagioclase feldspar phenocrysts up to 30 mm in length. Granite intrusions in the tonalite account for approximately 30% of the outcrop. The remaining 10% of outcrop is metamorphic rock. Thick till (unconsolidated, poorly sorted sediments over 3 m in depth) covers 67% of the catchment's surface area. The average depth of this material, estimated from seismic data, is 13 m and the volume of till covering this area is calculated to be 113,000,000 m^3. This volume of till must contain a substantial groundwater reservoir.

Hydrology. 5.19 in. of water flowed off the catchment during the period of study as calculated from integration under a unit hydrograph [Fig. 1]. The overall trend in flow over the period of record was toward a lower


N
Deep Lake
Trail Lake
Frog Lake
D
9619
9525
Alluvium, peat, lacustrine sediments, and undifferentiated drift
ice-contact stratified drift
till
bedrock with thin till or colluvium
exposed bedrock
Trail Creek
moraine
meltwater channel
1 kilometer

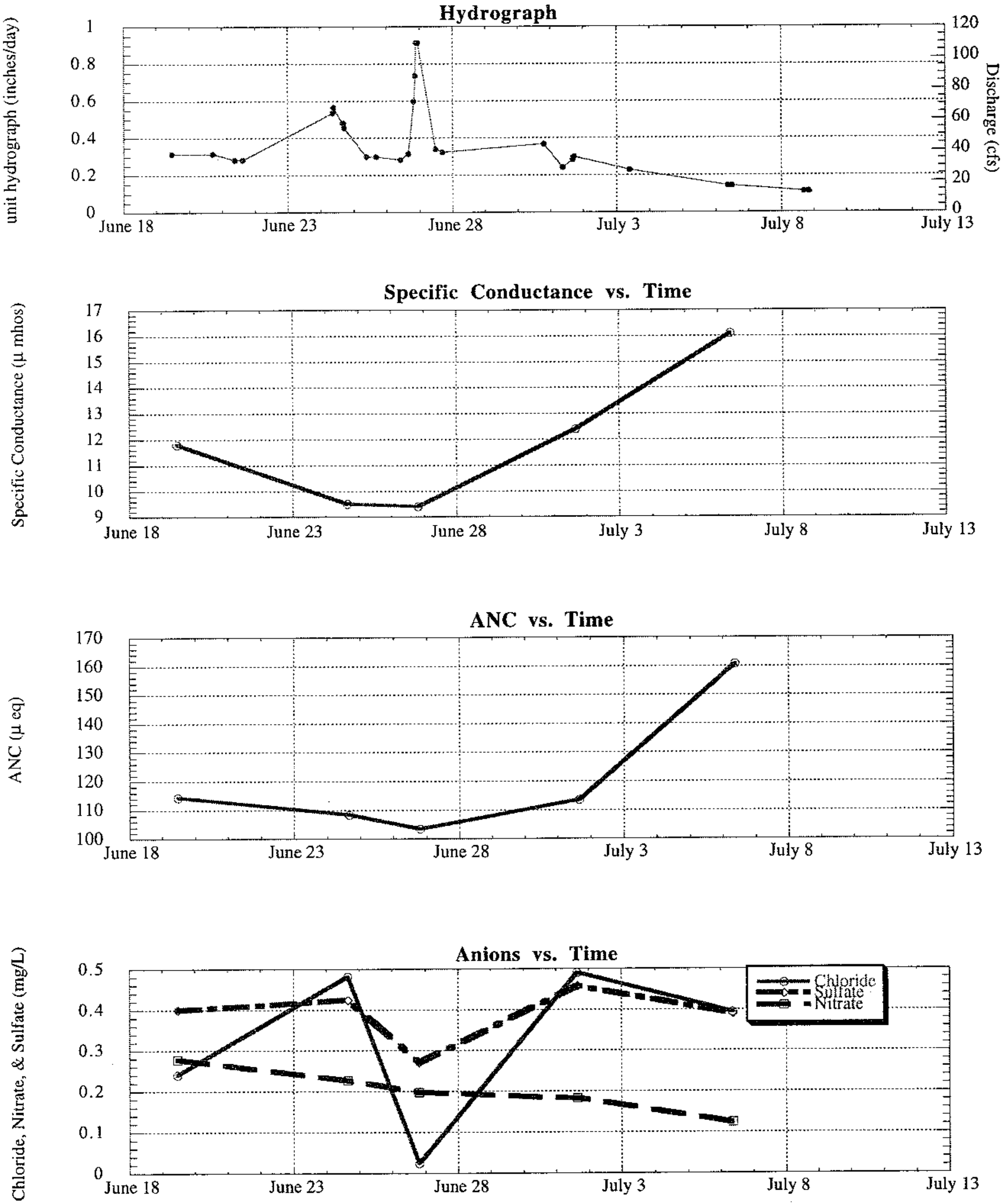


Figure 1: Specific Conductance, ANC, and Anions vs. date. The unit hydrograph is provided for comparision of these properties to Discharge.

discharge [Fig. 1].

Chemistry. The pH at the gauge station ranged from a low of 6.29 on June 19, 1996 to a high of 7.13 on July 6, 1996. Values for specific conductance, ANC, and anions are presented in Fig. 1.

DISCUSSION

Dead Horse Creek Catchment. Over the period of record, 5.19 in. of runoff were recorded over the entire catchment area. Water stored in snowpack accounts for 4 in. of this runoff. Of the remaining 1.19 in., approximately 0.2 in. came directly from precipitation; the remainder came from groundwater. The hydrograph became smooth in July once most of the snowpack had melted and the percentage of discharge originating as groundwater increased. This trend of decreasing snowmelt and increasing groundwater (as percentages of total discharge) heavily influences changes in water chemistry over the period of study.

At the gauge station, sample pH increased over the period of record from 6.3 to 7.1. Snow has a lower pH than groundwater because snow cannot neutralize acids picked up in the atmosphere. As snowmelt decreased, the ratio of groundwater to snowmelt increased, and the pH of the stream rose.

Specific conductance and ANC at the gauge station are inversely related to discharge levels [Fig. 2]. This is a function of the percentage of snowmelt in the stream. Snow has low specific conductance and low ANC because it has little opportunity to dissolve solids or contact products of weathering reactions. Snowmelt dilutes the groundwater and reduces the overall ANC and specific conductance of the stream.

Chloride levels are inversely related to discharge [Fig. 1]. At high flows discharge is composed predominantly of runoff in which evapotranspiration and evaporation have had little opportunity to concentrate chloride. At low flows, discharge is predominantly groundwater where chloride has concentrated.

Snow and organic rich soils are the main sources of nitrate. Nitrate in snow is the result of atmospheric deposition. It is expected that the nitrate level naturally occurring in snow is higher than the measured value of 0.19 mg/L as some nitrate probably had leached out of the snow by the time of sampling. Nitrate in soils is a product of microbial decomposition.

The decreasing nitrate levels at the gauge station [Fig. 3] can be explained by the leaching of nitrate out of the snowpack. Initially nitrate levels in the snow were at least 0.19 mg/L. As the snow melts, nitrate levels drop, and the runoff contains less nitrate. Another hypothesis is that nitrates from organic rich soils are absorbed by overland flow. As overland flow decreases, nitrate levels drop [Fig. 1].

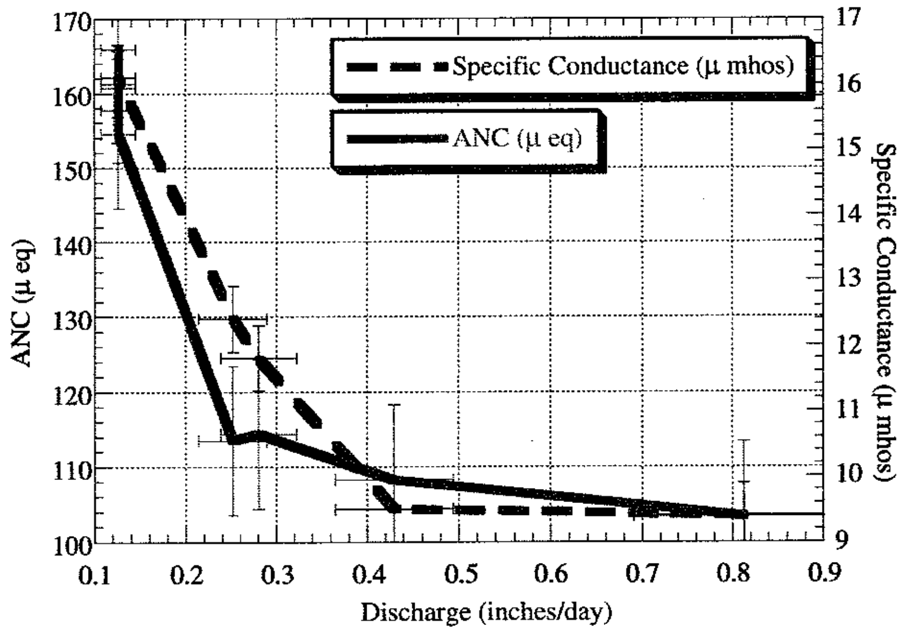


Figure 2: Specific Conductance and ANC vs. Discharge. Both Spec. Cond. and ANC have an inverse relationship with Discharge. X-axis error is +/-15%. ANC error is +/- 10 μ eq and Spec. Cond. error is +/- 0.5 μ mhos.

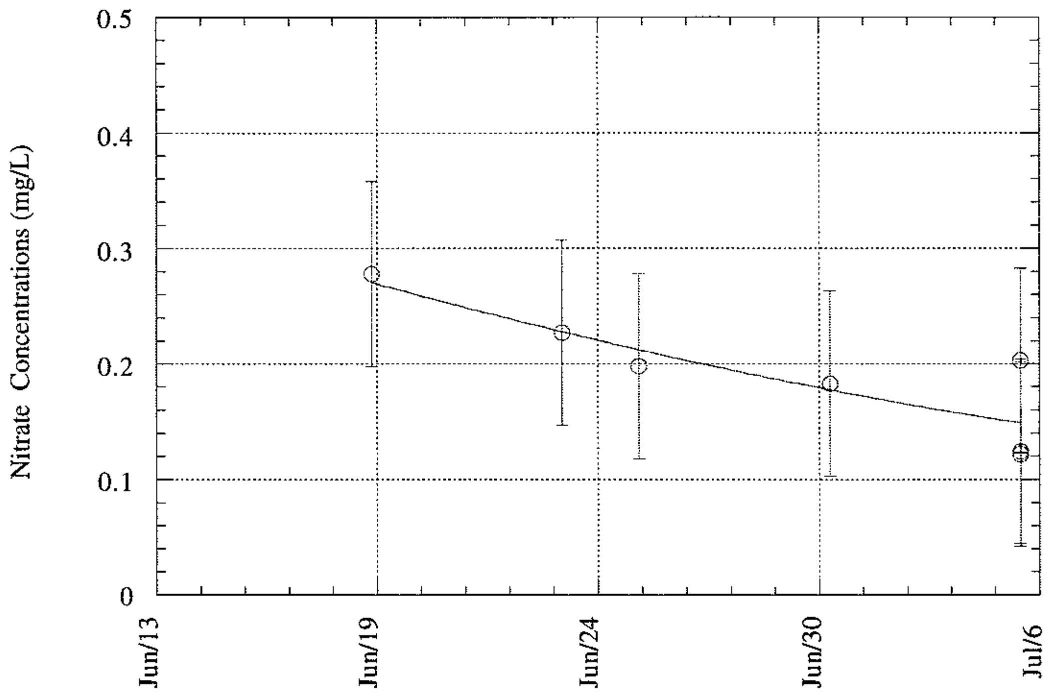


Figure 3: Nitrate Concentration at Gauge vs. Sample. Error is +/-0.04 mg/L, as calculated from the field replicate and lab split on July 6.

Dead Horse Creek's nitrate load over the study period was 340 kg; the significance of this relative to concentrations in Big Payette Lake is unknown. The nitrate concentration in the lake is approximately 0.2 mg/L (Newton 1996, pers. comm.), insignificantly different from observed concentrations in Dead Horse Creek.

Comparison with Other Catchments. Low nitrate levels released from the Dead Horse Creek catchment in comparison to burned catchments suggest that logging has a minimal impact on nitrate levels relative to forest fires. However, as no active logging occurred in the Dead Horse Creek catchment during the period of study, short term effects of logging are unknown. Data from the other catchments, all of which are at least 15% burned, suggest that burning and heating of organic materials releases a large supply of nitrates.

Nitrates released during logging are mostly the result of agitating the upper, organic rich layer of soil. With the cessation of logging the agitation ends and the soil surface soon restabilizes. Burning reduces vegetation cover and creates hydrophobic soils, increasing runoff that carries the easily erodible, nitrate rich ash. As the ash compacts and mixes with the soil, nitrates in surface runoff decrease. At the same time, water percolating through the nitrate rich ash dissolves nitrates and the nitrate levels in the groundwater increase. The nitrate rich groundwater of burned catchments explains the continuing high levels of nitrate discharged into the lake.

CONCLUSIONS

Data collected in this study suggest that medium and long term effects of logging in the Dead Horse Creek catchment have a negligible effect on the nitrate levels and overall water chemistry of Big Payette Lake. More data are needed to determine the short term effects of logging on the water quality. In comparison to nitrate loads generated in the catchments burned during the 1994 Payette Region forest fires, logging is not a significant contributor to nitrate levels in Big Payette Lake.

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Geomorphology, hydrology, and geochemistry of a burned and logged stream catchment: Lemah Creek, McCall, Idaho

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INTRODUCTION

Payette Lake, a glacial remnant dammed by an end moraine and partially controlled by a modern dam, is the only reliable water source for the community of McCall, Idaho. It is located in west-central Idaho at the northern end of Long Valley in a heavily glaciated area near the contact of the Idaho batholith and metamorphosed sedimentary rocks. The lake is in transition from oligotrophy to mesotrophy, and has had its first algal bloom in two decades. Recognizing the importance of high-quality lake water, residents of McCall have instituted a comprehensive water-quality study. In the summer of 1996, the Keck Consortium funded a project to supplement the Payette Lake water-quality study. Twelve students analyzed six stream catchments discharging into Payette Lake in order to determine whether water coming from the catchments is contributing to the nutrient load of the lake, and to ascertain the effects of logging and extensive forest fires on catchment-water quality. In particular, we studied the south Lemah Creek catchment, 86% of which was burned in the 1994 Blackwell Fire, and 5% of which was later salvage logged.

METHODS

We mapped surficial sediments, exposed bedrock, and logged and burned areas by reconnaissance. A Brunton compass and topographical maps were used to position and define contacts. Areas of map units were determined by using a planimeter.

We established a gaging station for taking stream stage readings using a staff, and discharge measurements using a Swoffer flow meter. A datalogger was installed and linked to a pressure transducer calibrated to the staff gauge to determine stream stage. The logger also recorded stream temperature and air temperature via thermocouples. Data were collected every five seconds and averaged over ten-minute intervals. Snow melt, response to hydrologic events, and high and low flow could be monitored. The thousands of measurements recorded by the datalogger were used to develop graphs of the relationship between stream stage and discharge. These data were further developed into a unit hydrograph, which took into account catchment size, and therefore allowed comparison with the discharges of the six catchments in the study.

A well was installed in order to monitor the level of the water table, groundwater depletion, and groundwater chemistry. Data obtained from the well allowed for the assessment of groundwater hydrology and the relationship of groundwater to surface-water properties. The well site was 50 yards below the gaging station, 8 feet from the stream at high water. The well is a 2-inch by 11-foot pipe, sunk into 9 feet of till bottomed by sand. We used a Trimble Global Positioning System to determine the height of the well water table in relation to the stream.

Surface-water samples from throughout the catchment were analyzed for pH, specific conductance, and acid-neutralization capacity. Chloride, nitrate, and sulfate concentrations were measured through ion chromatography. The results helped to determine how contaminants are entering the system and how long they are retained.

GEOMORPHOLOGY

The geomorphology of the Lemah Creek catchment has been shaped by the flow of both a major glacier in Payette Valley and a smaller tributary glacier that originated in the cirque at the top of the Lemah Creek watershed (fig. 1). The Payette Valley Glacier moved from the north to the south, carving out the lower bedrock of the Lemah tributary valley, and leaving till [thick (>10 ft.) and thin till (<10 ft.)] below the curved end moraines of the Lemah Creek glacier. Lateral moraines from this ice sheet were identified in the north Lemah Creek catchment, and can be seen throughout the Payette Lake valley. Ice moved into Lemah and its neighboring valleys from the Box Glacier cirque on the eastern side of the divide (R. Newton, 1996, personal communication). An ice tongue crested the eastern ridge and spilled into the Lemah valley, depositing the lateral moraines that constitute the catchment boundaries. The Lemah Glacier continued west, carved out a hanging valley, and contacted the Payette Valley Glacier. An end moraine defines the edge of the hanging valley, and has subsequently been eroded by runoff and