The role of glacial deposits in influencing the hydrology and water chemistry of the Trail Creek watershed, Payette National Forest, Idaho

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INTRODUCTION

Trail Creek lies 20 miles north of McCall, Idaho, and is a tributary of the North Fork of the Payette River, which flows into Payette Lake. The Trail Creek catchment was extensively burned in the forest fires of 1994 and has been logged both before and after the fire. The portion of the watershed studied is 3.85 mi^2 in area, and varies in elevation from approximately 6,140 to 8,168 ft. The terrain is mountainous, including four peaks and three alpine lakes. The Trail Creek study consists of three parts: surficial geologic mapping, stream and groundwater hydrology, and water chemistry. The watershed was studied in conjunction with five other catchments ultimately feeding Payette Lake, and is unique in that glacial deposits dominate the surficial geology. Catchments represent areas that have been significantly logged, burned, logged and burned, or remained untouched. The goal of the entire study was to evaluate processes controlling nitrate export from each watershed, as nitrate levels are increasing in Payette Lake, the only source of drinking water for McCall.

METHODS

Hydrology. The concentration of nitrates leaving the catchment is a direct function of the amount of water flowing out. Therefore it was important to determine discharge, which was measured at the gage station located just upstream of the Warren Wagon Road bridge (A on map). Discharge was calculated by multiplying the cross-sectional area of the stream by the velocity, measured with a Swoffer current meter. This method was used at six flow levels to establish a stage-discharge relationship for Trail Creek. A datalogger connected to a pressure transducer was calibrated to the staff gage and digitally recorded stage level at ten minute intervals. The data logger was in place from June 26 to July 5, 1996, and recorded air temperature, stream temperature, and rainfall from a tipping bucket rain gauge in addition to stage. To determine depth to the water table, a well was installed in stratified drift in the lower part of the catchment (B on map). A seismic line was run near the well to determine the depth to bedrock by refraction, and thus the thickness of the aquifer in this area.

Chemistry. Both surface water and groundwater samples were collected during the study. Surface water samples were collected at various locations upstream of the gage station, and at the gage station at different stream stages. Samples were analyzed in a temporary lab facility shortly after collection. The anions: nitrate (NO_3^-), chloride (Cl^-), and sulfate (SO_4^{2-}) were analyzed by ion chromatography. Acid neutralizing capacity, specific electrical conductance and pH were also measured.

GEOLOGY

Bedrock geology. The type of surficial geology determines groundwater storage and therefore capacity to buffer ions leaving the catchment in groundwater. Geologic mapping of the Trail Creek watershed was completed on the 1:24,000 Victor Peak quadrangle. The Trail Creek watershed is carved out of part of the Atlanta Batholith of Cretaceous Age (Alt and Hyndman, 1989) at the contact between tonalite and granite. Cirques in the upper portion of the watershed are underlain almost exclusively by granite; which is generally porphyritic and contains pegmatites rich in muscovite, feldspars, and quartz. The region of the catchment below the cirques contains an increasing amount of tonalite; the ratio of tonalite to granite is about 1:1 in the area of exposed bedrock north of Frog Lake. Tonalite rich in granitic dikes dominates the lower reaches of the catchment.

Quaternary geology. The Quaternary history of the Trail Creek watershed is characterized by multiple stages of glaciation. Although a detailed account of the order of glacial events can not be constructed with the available data, evidence indicates possible ice sources.

Two cirques in the upper catchment indicate ice originated within the Trail Creek watershed at some time. However, a U-shaped saddle southeast of Deep Lake and smooth bedrock between this saddle and Deep Lake

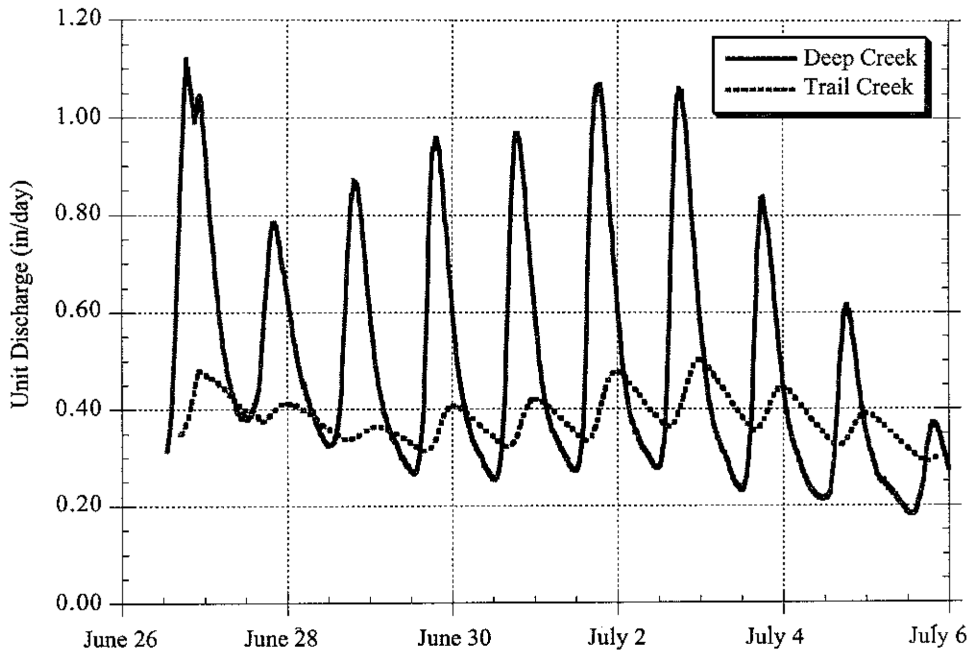


Figure 2. Unit hydrographs of Deep and Trail Creeks. Discharge variations are much greater in Deep Creek where there is only a small groundwater reservoir to buffer daily variations in flow.

ACKNOWLEDGMENTS

This research was part of the Big Payette Lake Study. Peter Johnson, Chairman of the Big Payette Lake Water Quality Council provided students with background information and encouragement throughout the study. Dewey Worth a hydrologist with the Idaho Division of Environmental Quality provided data and assistance in the field. Dr. Paul Woods of the U.S. Geological Survey provided information on the quality of Big Payette Lake and David Alexander and John Rhyg of the U.S. Forest Service provided information on forest practices in the study watersheds.

indicate that Trail ice was supplemented by ice originating in Victor Creek valley. Moraines and kame terraces in the lower reaches of the catchment indicate that the watershed was also affected by ice in the North Fork Payette River valley.

Multiple stages of glaciation are indicated by a orientations of moraines and stratified drift deposits. Ice-contact stratified drift (ICSD) in Trail Creek valley is abundant; land forms include: eskers, kames and kettles, and kame terraces. The complex relationship of land forms of ICSD and moraines in close proximity suggests a varying regimen of the retreating ice. For example, a moraine on the north side of the valley is perpendicular to and abuts an esker extending both downvalley and upvalley from the moraine (C on map).

During the deglaciation of Trail Creek valley, a lobe of ice extended north from the Frog Lake area. This lobe and/or its moraine forced Trail Creek to the north side of is valley. Deep and Trail Lakes are in cirques partially dammed by the youngest Pleistocene moraines. Trail Creek became the principal force altering the topography of the valley following deglaciation. Parts of the valley floor are covered with alluvium, peat, and lacustrine sediment.

HYDROLOGY

Hydrologic units. The Trail Creek watershed has been divided into five units: bedrock, thick till, ICSD, valley floor deposits (alluvium, peat, lacustrine sediments, and undifferentiated drift), and modern lakes. The units were chosen based on their importance to the hydrology and water chemistry of the catchment. Bedrock (in places with thin till or colluvium) has minimal ground water storage. Thick till, defined as till greater than 3m (10 ft) thick, stores limited ground water; both ablation and lodgment till are found within the catchment, with varying permeability. ICSD varies in grain size within the catchment, but in general has a high porosity and hydraulic conductivity; the thick deposits act as efficient ground water reservoirs. Valley floor deposits have variable grain size and organic content, and therefore variable porosity and permeability. Auguring into a bog (D on map) revealed peat with no clastic sediment to a depth of at least 1m. Modern lakes and their sediments are also effective reservoirs.

Discharge. The hydrograph established for Trail Creek reflects a general decline of stream discharge over the course of the period studied: mean discharge of 44.54 cfs on June 26, and mean discharge of 34.47 cfs on July 5. The unit hydrograph divides the area of the catchment by the discharge for a measurement in in/day [fig. 1]. High flows are attributed to late spring snowmelt, and the decline in discharge is attributed to the decreasing amount of snow available as a water source. The daily peaks are interpreted to be the result of snowmelt events following the daily high temperature. The daily low flow at the Trail Creek gaging station generally occurred at 2 PM, while high flow occurred at midnight. The peak flow time shows evidence of basin lag time. The discharge increase in the middle of the testing period reflects a corresponding increase in air temperature, causing excess snowmelt. Once the temperature began to fall to previous levels, the discharge returned to a state of declination.

A graphed relationship between rainfall and stage shows that stage did not rise substantially following rainfall. The immediate effects of precipitation are believed to be buffered by the large area of both ground and surface water reservoirs described above. The result is a minimal amount of runoff into Trail Creek, with the majority of the flow being stored in the various water reservoirs.

Water table depths measured at the well declined nearly linearly over time. The steady decline is resultant of the large storage area in the catchment units, and therefore continuous baseflow.

CHEMISTRY

The prime interest in this study is in nitrate levels in the water leaving the catchment via Trail Creek. Two of the water samples were taken at the stream gage, one on June 19 and the other on July 12. The nitrate load of Trail Creek at the gaging station for the nine-day period of June 26 through July 5 was calculated by averaging these two nitrate concentrations and multiplying the result by the discharge for the sum of each of the nine days. Nitrate load is calculated at 320 kg total for the nine days, with an average of 35.6 kg/day.

The additional 11 sample sites were chosen to supplement the data from the stream gage. Sites were chosen based on their volumetric and/or chemical influence on the creek.

Site Description	lab pH	Spec. Cond. (μ mhos)	ANC (μ eq)	Cl^- (mg/L)	NO_3^- (mg/L)	SO_4^{2-} (mg/L)
TC gauge station	6.67	11.40	91.10	0.727	0.632	0.950
TC Deep Lake outlet #1	6.69	7.20	78.94	0.525	0.182	0.679
TC Trail Lake outlet #1	6.46	6.70	69.04	0.687	0.260	0.479
TC yellow-rock stream (log rd)	6.38	17.74				
TC meltwater #1	6.73	6.70	77.14	0.560	0.213	0.376
TC snowmelt #1	5.93	2.20	15.11	0.833	0.174	0.115
TC well #1	5.97	11.10	89.55	1.240	0.328	0.449

TC Frog Lake Outlet #1	6.75	7.70	73.61	0.845	0.186	0.627
TC drainage-till-below Frog Lake	7.05	9.30	73.61	0.778	0.286	1.270
TC main stream-end of west swamp	7.17	10.00	95.64	0.789	0.193	0.697
TC auger hole at end of west swamp	5.81	13.00	94.54	1.065	1.264	1.736
TC algae stream N side of catchm.	6.35	10.80	123.89	0.549	0.000	0.205
TC gauge station, low late flow	7.13	10.50	119.50	0.362	0.083	0.555
TC Control: gauge station rerun	6.54	10.00	93.73			

A decline in nitrate concentrations from the beginning to the end of the study period suggests that nitrates build up in the soil over the winter months and are leached out in the spring and summer. Continuous snowmelt may flush out nitrates stagnant during winter months, including nitrates from burn material remnant from the fire. Each of the other catchments that were significantly burned, Cougar, Lemah and Pearl Creeks, exhibited a notable decline in nitrate levels during the study as well. New plant life, drawing upon nitrates for sustenance, could also progressively lower nitrate levels in the spring and summer. Organic control also explains the low nitrate level of the algae-choked stream in the Trail Creek catchment.

Another hypothesis of nitrate decline is the change in source of water feeding the stream. During winter months, snow melt and water from the upper portions of the storage units are the major stream inputs. This water contains more nitrates due to burn material. In the summer water originates mainly from deep storage areas, which lack burn material from the surface. The Lemah Creek watershed, which is approximately 76% bedrock, showed very low nitrate levels at the end of the study, which suggests that nitrates were included in surface run-off of meltwater.

Logging was considered a potential cause for nitrate level increase, as plant removal denies opportunity for nitrogen fixation. However, because the Trail and Deep Creek watersheds exhibited nitrate levels comparatively low in relation to the other catchments, logging as a source of nitrate increase is not suspected.

CONCLUSIONS

- The Trail Creek watershed consists of more extensive glacial deposits than the other catchments studied. These deposits act as effective groundwater reservoirs.
- The large storage capacity caused a slower, more steady decline in stage level and stream discharge than the other catchments.
- Trail Creek and the other burned catchments exhibited higher nitrate levels than those unburned.
- The larger storage capacity is also believed to buffer the nitrate content exported from the catchment, explaining lower nitrate levels than the other burned catchments.
- There is not sufficient evidence to claim the logging in Trail Creek as a cause for high nitrate levels.

REFERENCE

Alt and Hyndman, 1989, Roadside Geology of Idaho: Missoula, MT, Mountain Press Publishing Co., p. 101.

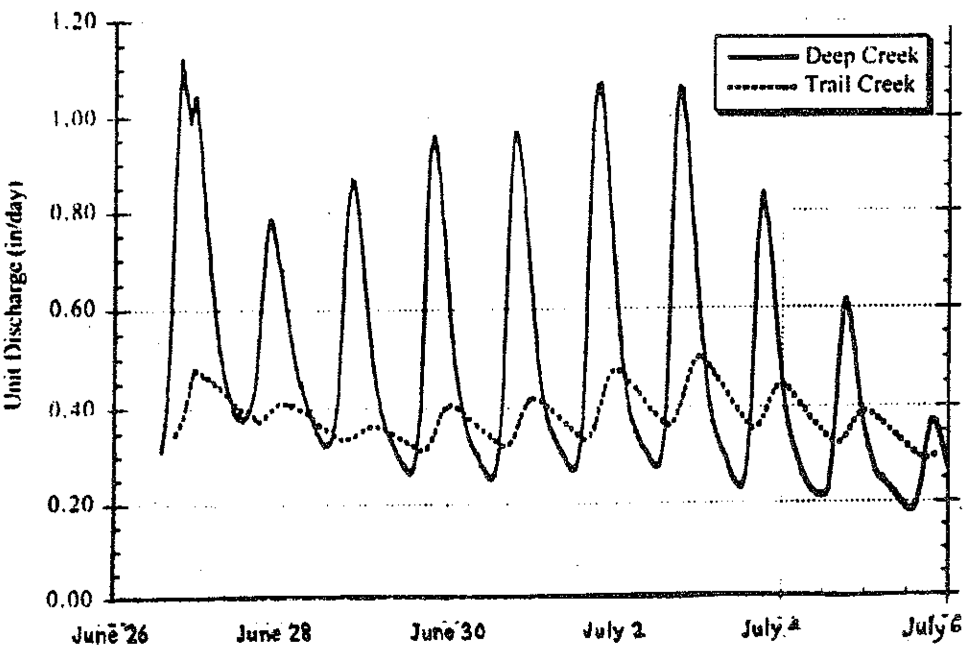
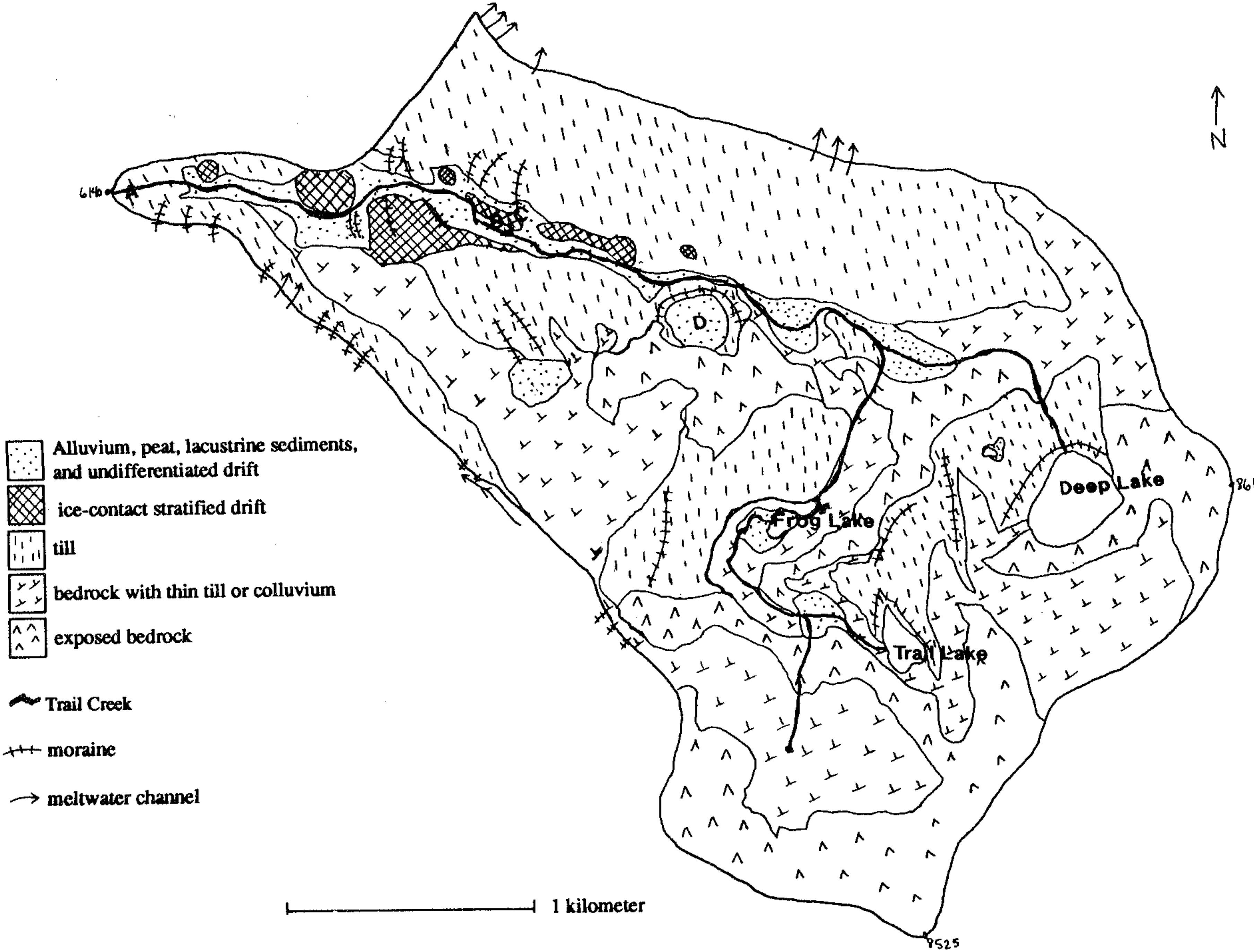


Fig. 1. The Deep Creek watershed was approximately 85% thin till and bedrock, whereas the Trail Creek watershed has large proportions of glacial deposits. Glacial deposits provide a large storage capacity and therefore slower decline in discharge. Julian days represent days since Jan. 1, 1996. June 26 is 178; July 5 is 185. Courtesy of Robert Newton, Smith College.


N
Deep Lake
Frog Lake
Trail Lake
D
6146
8618
8525
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

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