ENVIRONMENTAL GEOCHEMISTRY AND HYDROLOGY OF THE PAYETTE LAKE WATERSHED, IDAHO

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Environmental Geochemistry and Hydrology of the Payette Lake Watershed Idaho

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INTRODUCTION

Big Payette Lake is a 20 km^2 lake located approximately 160 km north of Boise, Idaho. The lake is over 100 m deep and was formed by the action of alpine glaciers during the Pleistocene. It is a major recreational and water resource for area residents and is the only source of drinking water for the City of McCall. During the late summer of 1994 much of the lake's 370 km^2 watershed was burned during the worst outbreak of forest fires in the history of the Payette National Forest. One of the impacts of the fires was to release nutrients from the soils into the rivers and streams which drain into Big Payette Lake. These nutrients stimulate the growth of algae and other aquatic plants which degrade lake water quality. During the summer of 1995 bottom waters in parts of the lake went anoxic for the first time, an indication that the lake may be beginning to undergo eutrophication.

This project was designed as a comparative watershed study to determine the impact of the fires on water quality. Six small subcatchments within the Big Payette Lake watershed (Tables 1 and 2) were studied to determine the factors controlling the rate of nutrient release. These projects were designed to complement the Big Payette Lake Study, a research project mandated by the Big Payette Lake Water Quality Act passed by the Idaho Legislature in 1993.

Table 1. 1996 Keck Idaho Project Study Catchments

Watershed	Area (mi^2)	Lowest Elev (ft)	Highest Elev (ft)	Relief (ft)	Condition
Pearl	3.92	5,840	8,610	2,770	burned/logged
Trail	3.91	6,150	8,618	2,468	burned/logged
Cougar	3.73	5,580	8,460	2,880	burned
Deep	4.46	5,400	8,460	3,060	burned
Lemah	3.18	5,100	8,270	3,170	burned
Dead Horse	5.00	5,000	7,803	2,803	logged

FIELD AND LABORATORY METHODS

Students applied a variety of methodologies in the field in order to determine the major factors influencing stream chemistry. Surficial sediments were mapped by observing the distribution of outcrops and other geomorphic features. Seismic refraction lines were run to determine the thickness of surficial units and the extent of potential groundwater reservoirs. One shallow groundwater well was installed in each watershed and water levels were monitored throughout the project. Samples were taken to compare the groundwater and surface water chemistry (Figure 1.).

Figure 1. Sampling groundwater in the Pearl Creek watershed.

A gage station was established in each watershed to monitor stream discharge. Staff gauges were installed and stage-discharge relationships were determined from velocity and cross-sectional area measurements. In four of the catchments data loggers equipped with pressure transducers were installed and stage was continuously recorded. The data loggers were also equipped with thermocouples to measure air and stream temperature and one was attached to a tipping bucket rain gauge.

Stream discharge in these subcatchments is strongly influenced by snow melt. Snow depths in excess of 3 m were common at higher elevations at the beginning of the project. Melting during daylight hours produced strong diurnal variations in flow. The high daily variations in stream discharge during the snowmelt period makes short term monitoring of stream discharge important in determining the total load of nitrate out of these systems. For example, a single daily measurement of discharge in Deep Creek is totally inadequate in estimating flow as there is often a 4 fold change in flow during the course of a day (Figure 2). Some discharge data was obtained from measurements made by the Forest Service as part of the Big Payette Lake Study.

Water samples were collected from the stream gage sites during both high and low flow conditions. In addition, samples were collected from the upstream segments and tributaries. All water samples were analyzed at a temporary laboratory set up in the faculty Condominium in McCall for specific conductance, pH, acid neutralizing capacity (ANC), chloride (Cl^-), nitrate (NO_3^-), and sulfate (SO_4^{-2}). ANC was measured by Gran titration within 48 hours of sample collection. The anions (Cl^-, NO_3^-, SO_4^{-2}) were analyzed within one week of sample collection by ion chromatography. Replicates and splits were periodically collected for quality control

Table 2. Watershed Investigators

Watershed	Students	
Cougar Creek	Brian Monteleone College of Wooster	Justin Ries Franklin and Marshall
Dead Horse	Mac Harmon Williams	Jacob Sewell Washington and Lee
Deep Creek	Andrew Logan Amherst	Mantez McDonald Central Michigan
Lemah Creek	Rachel Howse Beloit	Kirsten Murch Smith
Pearl Creek	Rose Lauck Whitman	Vionette Sánchez Univ. of Puerto Rico
Trail Creek	Beth Bartel Whitman	Caroline Harris Pomona

PRINCIPLE FINDINGS

Although nitrate is being exported from all the watersheds, the highest values are found in Cougar, Lemah, and Pearl. These three catchments were all extensively burned in the 1994 fires (Table 3.). However, not all burned catchments have high nitrate concentrations. Most of the Trail Creek catchment was burned but its average nitrate concentration is relatively low. This is due to the presence of thick glacial sediments which cover most of the lower half of this watershed. These sediments allow infiltration of much of the snowmelt into the groundwater reservoir. In the other catchments, which only have limited areas of thick surficial sediments, the snowmelt moves as surface runoff directly into the streams. The effect of a groundwater reservoir on a steam is demonstrated by comparing the unit hydrographs of Trail Creek and Deep Creek (Figure 2). The ultimate impact of burning or logging will be a function of the surficial geology within a watershed. Not all watersheds will be impacted to the same degree by the same amount of disturbance.

Table 3. Nitrate Concentrations in Streams Draining the Study Catchments.

Watershed	Highest Nitrate at Gage	Average Nitrate at Gage	# of Samples	Standard Deviation
Pearl	1.19	0.73	2	0.65
Trail	0.63	0.36	2	0.39
Cougar	1.22	0.83	5	0.30
Deep	0.47	0.33	6	0.15
Lemah	1.25	0.77	4	0.36
Dead Horse	0.28	0.22	4	0.04

The highest nitrate concentrations at the gage stations on all streams occurred during the early part of the study (June 19 samples) suggesting that the highest nitrate concentrations are associated with the early part of the spring snowmelt. Since this is also the period of highest stream discharge, then the highest nitrate loading to the lake occurs at this time.

High nitrate concentrations were observed in shallow groundwater in burned areas (Table 3). The highest concentrations (Pearl Creek Catchment) occurred where the water table was close to the surface in areas of glacial till. The concentrations were lower in burned areas that are underlain by permeable sands and gravels. The lowest concentration observed in a burned area occurred at Trail Creek where the water table was relatively deep (≈2m) below the surface. Groundwater nitrate may help keep baseflow nitrate levels high in areas having thick surficial sediments. There was essentially no nitrate in groundwater in unburned areas.

Table 3. Average Nitrate Concentrations in Groundwater

Watershed	Groundwater Nitrate	Surficial Material	Site Condition	# of Samples
Pearl	2.29	Till	burned + logged	2
Trail	0.33	Sand and Gravel	burned	1
Cougar	0.94	Lacustrine Sand	burned	1
Deep	0.03	Alluvium	natural	1
Lemah	0.02	Till	natural	2
Dead Horse	0.00	Till	natural	2

The 1994 forest fires in the Payette Lake watershed had a dramatic effect on nutrient loading. Increased nitrate leaching from watershed soils has had a negative impact on the quality of Payette Lake. The response of individual watersheds is, in part, a function of the flowpath by which water moves through the catchment. Watersheds containing thick deposits of stratified drift have larger groundwater reservoirs and water moving along this flowpath is likely to have lower nitrate concentrations.

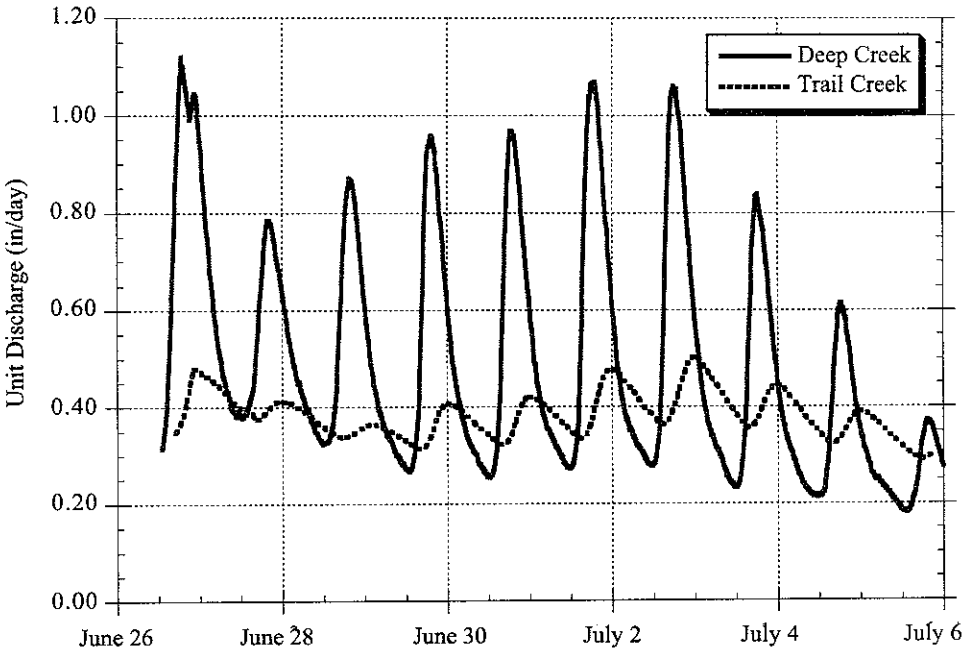

Figure 2. Unit hydrographs of Deep and Trail Creeks. Discharge variations are much greater in Deep Creek where there is only a small groundwater reservoir to buffer daily variations in flow.

ACKNOWLEDGMENTS

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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