Water Resources Research Institute

Annual Technical Report

FY 2000

Introduction

The Idaho Water Resources Research Institute supports and directs water research for the State of Idaho and the region. Our research results routinely lead to cutting-edge discoveries in such vital areas as water quality, water supply and water management. More importantly, these discoveries regularly lead to a greater understanding of our surroundings, offering sensible solutions toward maintaining a healthy balance between the economy and the environment.

Research Program

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Basic Information

Title:	Phosphorus Source/Sink Dynamics in a Flood-Irrigated Agriculture System in Central Idaho
Project Number:	1434HQ96GR02667-0008
Start Date:	3/1/2000
End Date:	2/28/2001
Research Category:	Water Quality
Focus Category:	Agriculture, Non Point Pollution, Irrigation
Descriptors:	Irrigation, Agriculture
Lead Institute:	Water Resources Research Institute
Principal Investigators:	Jan - Boll

Publication

1. Sánchez, M., D. Davidson, E.S. Brooks, S.M. McGeehan, J. Boll. 2000. Estimation of phosphorus loading from irrigated pasture land to Cascade Reservoir in central Idaho. Presented at the 2000 PNW-ASAE Regional Meeting, Sept 21-23, Paper 2000-08, ASAE, 2950 Niles Road, St. Joseph, MI 49085-9659, USA. Davidson, D, J Boll, S.L. McGeehan. 1999. Assessing BMP Effectiveness in Reducing Phosphorus Loading in Irrigated Pastures. "Water Quality - Beyond 2000", Boise, ID, Jan 27-29, 1999.
2. None
3. None
4. In progress.
5. In progress.
6. Sánchez, M., D. Davidson, E.S. Brooks, S.M. McGeehan, J. Boll. 2000. Estimation of phosphorus loading from irrigated pasture land to Cascade Reservoir in central Idaho. Presented at the 2000 PNW-ASAE Regional Meeting, Sept 21-23, Paper 2000-08, ASAE, 2950 Niles Road, St. Joseph, MI 49085-9659, USA. Davidson, D, J Boll, S.L. McGeehan. 1999. Assessing BMP Effectiveness in Reducing Phosphorus Loading in Irrigated Pastures. "Water Quality - Beyond 2000", Boise, ID, Jan 27-29, 1999.
7. Article in Long Valley Advocate, September 30, 1998.
8. None

BOLL/PROBLEM AND RESEARCH OBJECTIVES:

Water quality protection through restoration and management of watersheds is receiving tremendous attention in the United States at all levels of government and in local communities. Since contributions of most point sources (e.g., sewage treatment plants and industrial sites) have been reduced to acceptable levels, the main emphasis presently is on the control of non-point sources originating from urban, forest, agricultural, and recreational lands. Non-point sources are covered by sections 208, 303(d) and 319 of the Clean Water Act. Approximately 1000 water bodies are currently classified as impaired or use-limited in Idaho.

Many water bodies are classified as P-limited due to their high nitrogen:phosphorus ratios (N:P >> 10) (Sharpley et al., 1994; Chapra, 1997). Consequently, water pollution abatement strategies frequently focus on reductions in P loading. State and local agencies throughout the U.S. are in the process of setting permissible load allocations, expressed as Total Maximum Daily Load (TMDL), and developing water quality management plans for all use-limited water bodies. A management plan for Cascade Reservoir in central Idaho was submitted to and approved by the Environmental Protection Agency (EPA) in January of 1996.

Prior to the development of this plan, water quality data were collected at different levels of comprehensiveness for forest, urban and agricultural land uses. Partitioning the total P load into the various land uses was a difficult and somewhat subjective process. In particular, P loading from agriculture, mainly flood-irrigated pasture and hay land, was not done very accurately due to limited monitoring data and the lack of representative model parameters. The agricultural P load is currently estimated to be ~15,800 kg P/yr or 44% of the annual P load to the reservoir. This value is determined from the area-weighted difference between the estimated total nonpoint load (~35,700 kg P/yr) and estimates for natural (~11,000 kg P/yr), forest (~5,900 kg P /yr) and urban sources (~3,000 kg P/yr). Clearly, better estimates of phosphorus (P) loading from agricultural land use in western states are needed.

Although P loading has received considerable attention in the research literature in the past two to three decades, annual estimates of P loading from subsurface/flood or sprinkler irrigated pasture land have not been reported. Many reports available on non-irrigated pastures are mostly applicable to soils in the eastern and midwestern portions of the United States (e.g., Edwards et al. 1996; Austin et al. 1996; Beaulac and Reckhow, 1982; Loehr, 1974; Harms et al., 1974). Miller et al. (1984) reported net loss of P from flood irrigated grass and alfalfa hay land in Nevada, but measurements only covered the irrigation season, ignoring P loading during spring snowmelt.

Several studies show that loading from nonpoint P sources is seasonally dependent, a fact not addressed in the current Cascade Reservoir load allocations. Given the inherent uncertainties associated with estimating nonpoint P sources, it seemed critical to pursue an improved assessment of the agricultural contribution. This study contributes to this need by documenting relationships between P loading and field parameters. It is hoped that this study will 1) provide a more accurate value for agricultural P loading in the Cascade Watershed and 2) provide information that will be transferable to other agricultural regions in the western United States. The relationships in this study are developed from direct measurement of flow volumes and soil-water P concentrations monitored throughout the year to determine seasonal P dynamics.

Objectives

The overall objective of this proposal is to develop seasonal P source/sink relationships for irrigated pastures. P source/sink relationships are compared during *i)* spring snowmelt and rain-on-snow events, and *ii)* the growing season which is characterized by subsurface irrigation. Source/sink relationships are determined by measuring enrichment ratios, extraction coefficients, P desorption in soil/sediment samples and dissolved (DP), particulate (PP), and total (TP) in water samples.

Specific objectives listed in first year's proposal are:

Objective 1. To determine surface and sub-surface P inputs and outputs on a seasonal basis for two subsurface irrigated pasture/hay fields.
Objective 2. To measure P desorption as a function of soil depth, total soil P, soil temperature and soil saturation history in the same fields as in Objective 1.
Objective 3. To develop seasonal P transport relationships for dissolved and particulate P and predict annual P loading.
Objective 4. To determine the dynamics of P transport beyond pasture fields in irrigation ditches.

Important questions we attempt to answer are: "What are the relative magnitudes of P sources from agriculture in the Cascade Reservoir watershed ?", "What time of year do these sources release the greatest P loading?", and finally, "When is the impact of an individual source noticeable in downstream aquatic ecosystems?".

Note: During Year 1, we experienced unusual weather conditions which made data collection during part of the Spring snowmelt period difficult. In order to assure meaningful results in this project, we have initiated a laboratory flume study to simulate special flow conditions observed in the field. This laboratory study will be discussed briefly in this report. Objective 2 will be achieved during the laboratory study instead of in the fields because Dr. McGeehan no longer holds a research position in the Soils Department. Specific hypothesis for the laboratory study are provided in the Methodology section below.

METHODOLOGY:

Location and Description of Study Area

Geological and Hydrogeological Setting

Cascade Reservoir watershed is located in Long Valley, which is part of the mountain building Idaho batholith orogeny occurring during the Cenozoic period. The parent material consists of crystalline igneous granitic intrusive rock formations with other accessory minerals. The valley floor consists of deposits derived from the adjacent mountain with past glacial activity present in the upper portion of Long Valley. The thickness of the alluvial deposit is estimated at over 7000 feet in the north end of the watershed with the thickness decreasing as the valley trends to the south.

Streams in the watershed have gradients which vary from very steep in the mountains to flat as they move towards the reservoir. Stream flow is made up of spring melt off of valley and mountain snows, storm events on snow, overland flow and base flow from ground water. Generally, two melting events occur in the watershed when the valley floor has an early melt during March -April and the higher elevation areas a late season melt in June - July (USFS, 1998). The water from the streams is diverted for land application during the summer irrigation season through a complex system of diversions, canals and laterals. Stream flow during the summer irrigation season is depleted to very low levels. Vegetation in subsurface irrigated pastures have been altered toward hydrophilic (water loving) species thereby altering vegetative water requirement and producing an artificially high water table. Because of the low flow levels and the artificially high water tables, ground water - surface water interaction is believed to occur throughout the irrigation season. Approximately 150 mm of precipitation is received during the growing season in the valleys.

Ground water in the valley is present at multiple depths. Areas with extremely shallow ground water are abundant due to high input of irrigation water and shallow confining layers. Deep confined aquifers exist within the valley but have largely been undeveloped except by some municipalities. Ground and surface water are of good quality except for the existence of reduced iron oxides Fe(III) near the Donnelly-Roseberry region.

Agricultural Setting

Land use within the Cascade Reservoir watershed primarily consists of forest, agriculture and urban/suburban. Steep sloping mountain ranges make up the adjoining forested land, while the flat valley floor adjacent to the reservoir is used for agriculture. Small tracts of land are used for housing development, subdivisions, villages and towns. The agricultural land uses are irrigated pasture, irrigated cropland, non-irrigated pasture and cropland, and private forest. Irrigated lands are the dominant land use type within the valley with irrigated pasture being the dominant agricultural land use. Riparian and non-irrigated pasture make up the majority of the remaining land.

Dominant soils types within the valley are: Archibald, a deep well-drained strongly acidic loam formed in alluvium or glacial outwash occurring in 12% of the watershed; Donnel, a deep well-drained medium acid sandy-loam soil formed in granitic alluvium and occurring in 5% of the watershed; and Roseberry, a deep poorly-drained medium acid sandy-loam formed in alluvium or glacial outwash of granitic origin occurring in 7% of the watershed. Soil depths within the watershed are highly variable, ranging from 30 to 40 inches for Donnel and Roseberry soils and from 5 to 8 feet for Archibald soil types.

Cattle are the dominant grazing animals with a small amount of sheep and horses also present. Most animals are located in the valley only during the summer grazing season which starts in early May and may run through October - November.

The Study Area

The study area is located in the Boulder/Willow Creek subwatershed which drains directly into Cascade Reservoir. This subwatershed is part of the North Fork Payette River (HUC No. 17050123) in the west central portion of Valley County. Elevation at the site is approximately 4900 feet above sea level. Two pasture fields (each 18 ha) within close proximity, approximately 1.5 miles east of the town of Donnelly, Idaho, make up the study area. The valley floor has little relief (1-4%) with a general downward trending elevation from north to south. Water for the irrigation season is supplied from the Roseberry ditch, a diversion of Boulder Creek. Both pastures are subsurface irrigated at this time with controlled multiple irrigation events occurring throughout the growing season.

Currently, both fields are used as cattle pastures and are irrigated using subsurface irrigation practices with one main inlet ditch and one main outlet ditch. Average temperature at this site is 5 °C, average precipitation is 584 mm, with an average of 72 frost free days. Two soil types cover the total field area: the Roseberry coarse sandy loam and the Donnel sandy loam. Roots in both soils extend to more than 150 cm.

Each inlet and outlet ditch in both fields has been instrumented with flumes, automatic water samplers, and dataloggers. Flow and water sampling are event-based throughout the year. Each field also is equipped with nine groundwater wells from which groundwater levels are measured and water samples are taken monthly. Soil sampling is done before and after the irrigation season. Mr. Davidson from the Soil Conservation Commission has assisted the PI's in instrument installation, field sampling, and maintenance.

The mass balance: predictive equations and parameter selection

Due to limited funds, P source/sink relationships for P loading are determined for two forms: PP and DP (see Table 1). Predictive equations have been reported in the literature and are reviewed briefly to show which parameters are to be estimated and which water quality constituents are measured in our study. These equations serve as a starting point for the data analysis.

PP in runoff sediments: As soil erosion is a selective process with respect to particle size, selectivity has been observed for P loss in runoff sediments, with the result that eroded soil is usually richer in P than the surface soil from which the eroded soil comes (Sharpley, 1980). Particulate P transport, therefore, is predicted from an equation of the form (Edwards et al., 1996):

$$PP = TSS_y \times \text{Soil TP} \times ER \qquad (1)$$

where PP is the (event) particulate P transport (kg/ha), TSS_y is the event total suspended sediment yield (kg/ha), Soil TP is the TP content of the surface soil (kg/kg), and ER is the enrichment ratio (= PSED/Soil TP where PSED is the TP content of eroded soil). We assume that the use of TSS_y for total sediment yield is reasonable for pasture land (Edwards et al., 1996). Sharpley (1980) developed a relationship between ln(ER) and $\ln(TSS_y)$ as:

$$\ln(ER) = a_0 + a_1 \times \ln(TSS_y) \qquad (2)$$

where coefficients a_0 and a_1 appear to vary with soil and land use with approximate values of 2.2 for a_0 and -0.24 for a_1 representing a variety of soil and cover conditions.

DP in runoff water: A general, predictive equation for DP in runoff water is as follows (Edwards et al., 1996):

$$DP = 0.01 \times D \times \text{Soil TP} \times XC \qquad (3)$$

where DP is (event) soluble P transport (kg/ha), D is event runoff (mm) and XC is an extraction coefficient considered to represent the mixing of soil and runoff as well as the P desorption properties of the soil. The factor 0.01 assures consistent units. High runoff interaction and easily desorbed soil P would be reflected in an increase in XC.

To develop and test above relationships for subsurface irrigated pastures, we are determining all parameters in Eqns. 1- 3 either by direct measurement or derived from measured parameters. Exceptions are a_0, a_1, and XC, which are determined by regression analysis. Table 1 summarizes the parameters measured and derived, and includes abbreviations used throughout this section of the report.

Table 1. Measured and calculated parameters in the proposed study and abbreviations used.

Parameter	Abbreviation	Measured/Derived	Origin
runoff depth	D	derived	measured discharge (Q)
total P	TP	measured	runoff water
dissolved P[1]	DP	measured	runoff&subsurface water
particulate P	PP	derived	runoff water: TP - DP
total suspended solids	$TSS_{y\ or\ l}$	measured	runoff water
total P in soil	soil TP	measured	surface soil in field
enrichment ratio	ER	derived	runoff water & soil: $TP_{eroded\ soil}$/soil TP
a_0 & a_1	-	derived	Eqn. 2 (regression)
extraction coefficient	XC	derived	Eqn. 3 (regression)

[1] dissolved P is assumed to consist mostly of ortho-phosphate (Sharpley et al., 1994).

Measurement of parameters in Table 1

Each flume at inlet and outlet was automated so that discharge was recorded continuously. When discharge was relatively constant, the ISCO sampler obtained one full sample every 24 hours consisting of four 6-hourly composites. When discharge increased or decreased such as at the onset or end of an irrigation event, or during a storm event, the ISCO sampler obtained one full sample every hour consisting of four 15-minute composites. All samples were then collected in a timely manner, split into a filtered and unfiltered sample, treated, and transported to Dr. Boll's laboratory. Water quality samples were analyzed for TSS, TP, and DP as discussed under Analytical Methods with help of Morella Sanchez and Josh Linard. Inlet ditches were monitored only during the irrigation season, since during the non-irrigation season little flow entered the fields.

Groundwater levels in piezometers in both fields were determined monthly. Each month, a groundwater sample also was collected, filtered and analyzed for DP in Dr. Boll's laboratory with help of Morella Sanchez. Total P in soil in each field was determined before and after the irrigation season. One soil sample per two acres was removed from the 0 to 5 cm depth. They were analyzed in the Analytical Science Laboratory under the supervision of Dr. McGeehan.

P desorption determination

P desorption was determined on 48 soil samples taken from field 1 and 2. The procedure is explained below in Analytical Methods. Twenty-four samples were analyzed after air-drying and 24 samples were analyzed at field-moisture content.

Seasonal P transport relationships and annual P loading

PP was determined as the difference between TP and DP. ER was calculated as the ratio of PP in eroded soil to TP in soil samples. The parameters a_0 and a_1 in Eqn. 2 then were determined by applying simple linear regression to TSS and ER. Values for XC in Eqn. 3 were determined from measured data of D, Soil TP and DP in runoff water. Annual TP loading (mg P ha^{-1} yr^{-1}) was estimated using measured TP in runoff water and the discharge measurements.

The dynamics of P transport beyond pasture fields in irrigation ditches.

Six locations were selected for ditch sampling: locations #1 and #2 were before the inlet to field 2, locations #3 and #4 were the inlet and outlet of field 2, respectively, and locations #5 and #6 were after the outlet of field 2. The established flow path connected Roseberry Ditch to Willow Creek. Measurements at each location included the determination of flow rate and P concentrations during one irrigation event on September 7, 1999. Each location was visited twice. Unfortunately, irrigation was ceased for the year afterwards and natural events have not occurred since. Two of Dr. Boll's graduate students and Mr. Davidson performed the sampling.

Flow rates in irrigation ditches were determined as the product of cross-sectional area (m^2) and velocity (m/s). Flow velocity (v) was determined using a portable current meters using the Velocity-Area method. During each visit, a sample for P determination was collected using depth-integrated sampling procedures outlined in Edwards and Glysson (1988). Where waters were of sufficient depth, the US-DH48 depth integrated sampler was used. For shallow waters, grab samples were taken at different locations in the cross-section. During this first sampling event, ditch sediments and vegatation samples were not collected.

Laboratory flume study

During Spring of Year 1 (1999), we experienced severe flooding of the fields forcing us to take out all instrumentation. During the Fall of Year 1 (1999), weather conditions did not cause runoff events. To assure data collection for specific field conditions while controlling environmental conditions, we have initiated a laboratory flume study. This laboratory study has not produced results, but the design is discussed here briefly.

The objectives of the flume study in essence are the same as for the field study. However, objective 2 was eliminated for the field study but is included in the laboratory study. P mobilization and transport parameters will be determined in triplicate in aluminum flumes 1 m long, 0.2 m deep, and 3x0.1 m wide (Fig. 2). Soils from field 1 and 2 were collected on October 10, 1999 including the undisturbed surface sod layer. Soil is packed in the flumes to the same bulk density as at the field sites. Subsurface flow, surface flow and rainfall are simulated followed by event-based sample collection. P sorption/desorption capacity are related to soil redox potential and concentration of dissolved metals to better explain chemical mechanisms controlling P mobilization. These experiments are performed by Morella Sanchez to fulfill the requirements of her Ph.D. dissertation.

To understand the outcome of the laboratory study, its relationship to field conditions is given here. Environmental conditions that occur in the Cascade area vary through the year according to temperature changes (Table2). This determines different soil treatments and different water flow paths in the soil that are crucial to consider in the simulation of the field conditions.

Table 1. Seasonal variations affecting water flow paths and soil conditions in the Cascade Reservoir Area

Season/Water Temperature	Water source	Water flow paths	Soil Saturation Conditions
Late summer ~15°C	Flood or sprinkler irrigation	Some flow horizontally but mostly vertically down, and then slowly back up while evaporating or transpiring.	Soil is aerobic as is possible; most air in the soil of any season. Soil is very dry; it will shrink and crack, allowing even more air to enter lower levels.
Fall into winter ~4°C	Rains	Most water is absorbed into the soil with some surface runoff. Evaporation or transpiration is very small.	Soil experiences periods of wet with time to drain in between.
Winter <0°C	Snow	There is not much flow. Water close to the surface is frozen. Water deep within the soil can flow but it is not replenished.	Soil is frozen in the surface with snow cover. Any warming on a sunny day melts just flows into the snow and is held in place.
Spring >0°C	Snow melting rains.	Big surface flows, flows into and out of the soil lenses. Evaporation not observable.	Soil is saturated. The soil is muddy from freezing and thawing. It has been submerged for months.
Late spring into summer >4°C	Rain or irrigation	Rainfall generally is absorbed and drains into the soil, which emerges as subsurface flow.	Soil is warming and drying with air following the retreating waters into the soil.

Water flow paths from the input source--precipitation or irrigation-- to the runoff destination are modified in nature by the seasons of the year because precipitation and temperature affect the free water surface level. For example, in summer, or during dry periods, the water table remains below the surface and the runoff follows a subsurface path, unless the pasture is irrigated, and the water table rises again. During this period water is relatively warm. On the other hand, during early spring, snowmelt saturation conditions bring the water surface level to the top layer of the soil and produce an overflow runoff to the surrounding water bodies. During this period, water table temperature is relatively cold.

Soil conditions also cycle seasonally, as follows: 1) A dry, completely aerated, occasionally subsurface-irrigated soil observed from June through September, 2) A moist, cool soil observed during early fall in October and November, 3) A saturated soil observed during winter, and 4) a completely waterlogged soil during spring runoff after a prolonged period of saturation, in April-May.

The different water flow paths through the soil, the duration of the soil saturation period, and consequently, the different degrees of interaction between water and the soil's top layer (mixing layer) represent a set of physical and biochemical mechanisms that affect P mobility and, consequently, enhance its transport to surrounding water bodies.

The main objective of the flume study, therefore, is to characterize the physical and biochemical mechanisms that provoke P transport to adjacent water bodies. Important in this objective is the main hypothesis that P release is enhanced when (1) the mixing layer is traversed, and (2) the soil profile experiences biochemical changes after prolonged periods of water saturation. To accomplish the main objective we test the following specific hypotheses in a known parcel of soil:

- The different runoff routes, especially through the P-rich-surface or “mixing layer”, are chiefly responsible for the varying amount of phosphorus leaving the study site. Consequently, if water saturates and traverses the mixing layer, the phosphorus concentration in any of the sampling ports of the flumes will be higher compared to the condition that the mixing layer is not traversed.

- The release of P in any of the sampling ports of the flumes will be higher as the saturation period is more prolonged. This would be a consequence of the progression of soil saturation from water, decreases in redox potential (Eh), and increases in soil and water pH.

- The release of P in any of the sampling ports of the flumes will be higher at higher temperatures.

Description of the Flumes

The flumes are waterproofed troughs, open on the top, and with several holes in both ends to facilitate the introduction and removal of water at various depths (Figure 1).

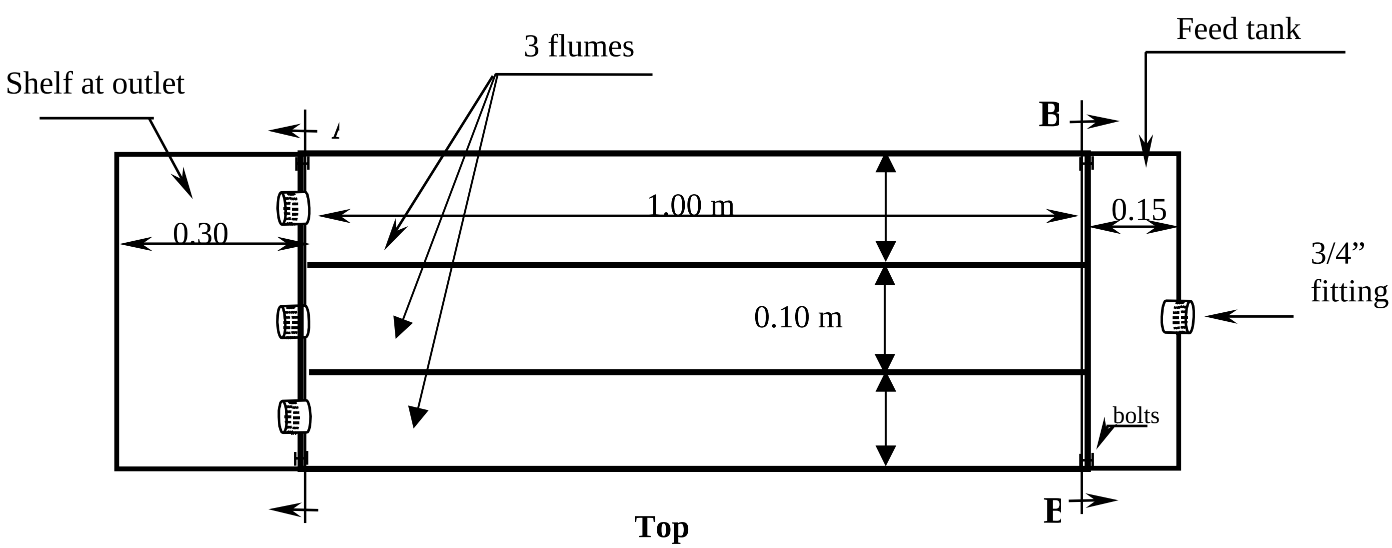


Figure 1. Top view of the flumes.

The flumes are operated by adding soil to the inner body of the chamber and flowing water through (Fig. 2). A representative sample of the soil from the Cascade pasture fields was collected to fill the flumes.

A tank is located at one end of the flume with holes at the points A, B, C, and D. Any combination of feed or water introduced through these holes can be used to simulate the field environment. Water can also be introduced to the soil by overflowing a level in the tank onto the surface of the soil as indicated by “A”. Rainfall or sprinkler irrigation can be accomplished using a rainfall simulator, and snow can be applied on top during wintertime by shoveling. Water is removed by overflowing at “E”, via the V-notch, or by flowing out of F, G, or H.

Experiments are conducted working with two flumes at the same time. Flume 1 is the control, contains only soil and no P-enriched mixing layer on top. Flume 2 was doped on top with a simulated P-enriched mixing layer at P concentration equal to 1000 mg/kg. This P concentration is representative of the P concentration on the soil top layers in the fields.

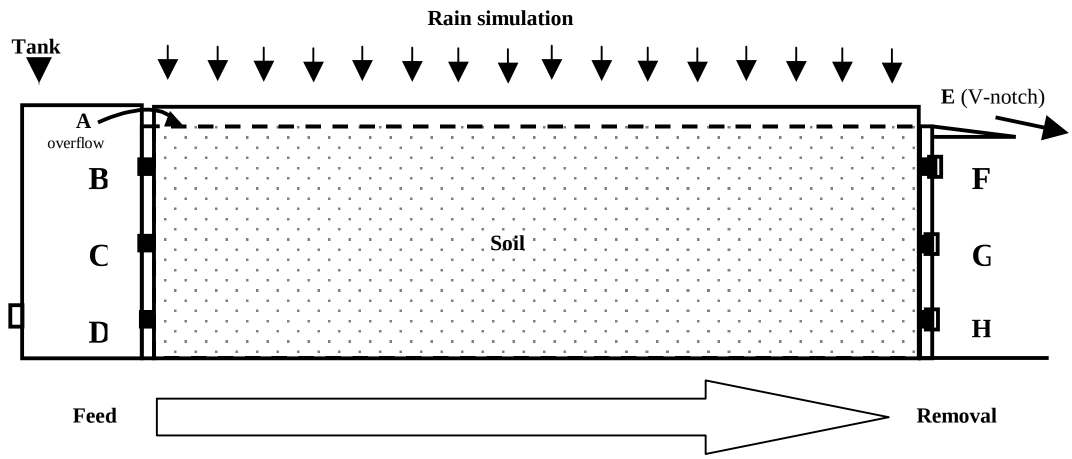


Figure 2. Side view of the flumes.

Simulations

We evaluate P release by simulations of the different seasonal-changing water flow paths and different conditions of soil saturation controlling the soil saturation period (flooding period), the method of water application, and the temperature, as illustrated in Table 3 below.

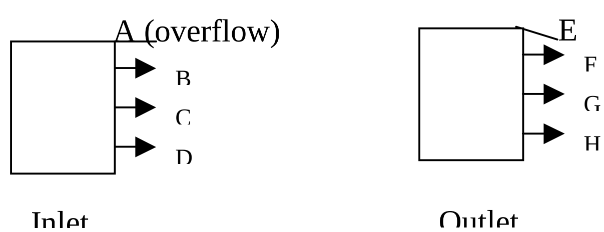
1. In the first configuration the rains of fall moisten the dry pastures and water drains down into the soil changing the water table. Water flow path is vertical; therefore if P is transported down from the mixing layer at the surface, it should be measurable at the port H. This water is flowing through aerated dry soil that has oxidized.
2. Early spring will be the next flow time after a long saturation period during winter, with no flow in any direction. This early spring flow occurs as a result of snowmelt, which occurs only at the surface of the soil. The rest of the soil profile is frozen still and overland, horizontal flow results. Soil saturation determines anaerobic conditions.

3. As the season progresses and the soil thaws, water is allowed to move vertically in the soil as well as horizontally. Areas that have absorbed large amounts of water will often re-emerge as springs or outflow. This outflow traverses the P-enriched mixing-layer carrying with it DP in the surface water. Soil is saturated.
4. In late spring the last of the spring rains move submerged under the soil surface to drainage ditches around the fields. Since there is no crossing of the surface of the soil, little DP is carried with this. Soil has drained, saturation is decreasing and aerobic/oxidizing conditions are taking place again.

When applicable, the experiments are performed at two different temperatures: 4°C and 25°C. Temperature control is possible in the environmental chamber.

Table 3. Simulations of the Water Flow Paths and Soil Saturation Conditions

Simulation	Feeding Port	Sampli ng Port	Flow Path	Soil Conditions
1. Rain or sprinkler irrigation during summer or fall.	Rainfall simulator on top.	H	Vertical. Flow vertically traverses the mixing layer.	Aerobic
2. Overland flow in early spring (thawing) or summer during irrigation.	A	E	Horizontal. Flow is parallel to the mixing layer.	Anaerobic, soil is saturated.
3. Return flow as in the case of hill-slope	D	E	Flow traverses the mixing layer.	Gradually changes from Aerobic to anaerobic
4. Subsurface flow in late summer.	D	H, G	Water does not traverse the mixing layer.	Aerobic conditions.
5. Repeat 4, creating anaerobic conditions.	D	H, G	Subsurface flow Water does not traverse the mixing layer.	Anaerobic conditions



Analytical methods

Phosphorus fractionation of water samples followed the methods of Sharpley (1993). TP was determined on unfiltered samples following four-acid digestion (EPA Method 3050). DP was determined on filtered (0.45 μm) samples. DP is assumed to consist mostly of ortho-phosphate (Sharpley et al., 1994). PP was calculated as the difference between TP and DP. Soil TP was determined using EPA Method 3050. P desorption profiles were determined using a 10-cycle sequential technique described by Oloya and Logan (1980). Cumulative desorbed P was calculated from the total P released from each sample through 10 desorption cycles. TSS (Total Suspended Solids) were determined by filtering a well-mixed sample through a weighed standard glass-fiber filter (0.4 μm) and drying the residue retained on the filter to a constant weight at 103 to 105°C (Method 2540 D in APHA, 1995). Eh is measured with platinum electrodes. pH is measured with a standard probe attached to an Orion desktop meter.

The phosphorus concentration in the various fractions of water and desorption equilibrium solutions was quantified using the ammonium molybdate method (EPA Method 365.2) in Dr. Boll's laboratory with the help of Morella Sanchez and one undergraduate student trained through this project. Soil TP was determined by ICP spectroscopy at the University of Idaho Analytical Sciences Laboratory.

Standard Quality Assurance procedures were followed as outlined in the Standard Methods for the Examination of Water and Waste Water (APHA, 1995) and Standard Methods of Soil Analysis (Klestra and Bartz, 1996). All sampling and analytical procedures followed written Standard Operating Procedures. Water samples, except those for TP analysis, were filtered on site prior to transport. To address field soil variability, a series of subsamples were collected and thoroughly mixed to form a composite sample. Chemical analysis of the samples followed Good Laboratory Practices regarding sample storage, timeliness of analysis, analytical precision and accuracy, data collection and record keeping. Each analytical batch included 10% quality control samples such as duplicates, spikes, and reagent and field blanks. Determination of DP in water samples took place within 48 hours of collection and filtration in the field. TP was preserved at $pH<2$ using H_2SO_4 and analyzed within 24 days.

PRINCIPAL FINDINGS AND SIGNIFICANCE:

We show and discuss: P loading results, P transport parameters, ER and XC coefficients, preliminary export coefficients(kg/ha), and preliminary results from the laboratory flume study. Source/sink relationships and results from ditches will be revisted in the next study period.

P Loading

Both fields acted as P sinks or sources at different times during the year. These differences are explained by differences in flow rate and concentration. Differences in flow during spring snowmelt seasons and irrigation seasons are illustrated in Figure 3 and 4. Figure 3 shows daily cycles in flow rate during spring snowmelt as a result of fluctuating temperatures. During flood irrigation water is turned on and off for periods of five to six days during which flow is more or less continuous (Figure 4). Flow rates are always higher at the inlet than at the outlet of both fields, and, at the outlet, flow is higher during spring snowmelt than during flood irrigation.

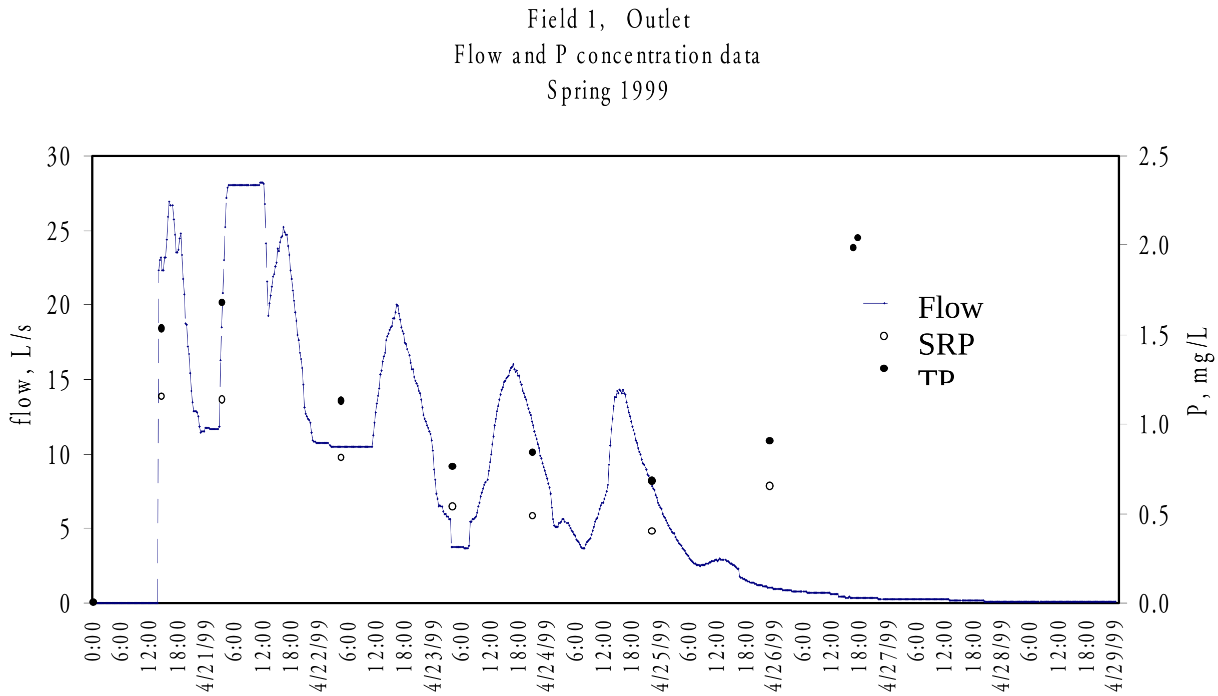


Figure 3. Typical pattern of a snowmelt event from the outlet of Field 1 with times at which samples were taken illustrated.

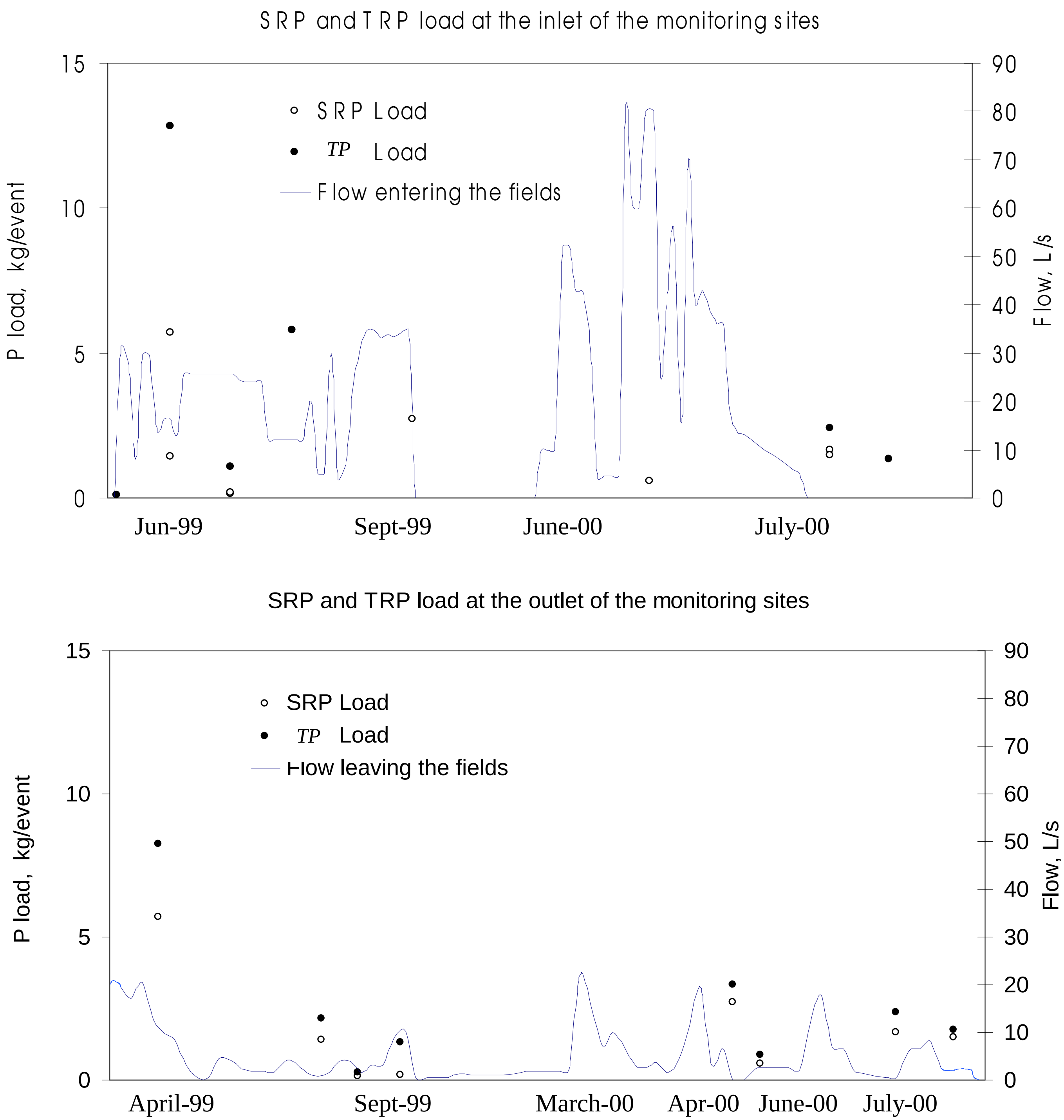


Figure 4. SRP and TP load at the inlet and outlet of the monitoring sites.

SRP concentrations in surface water ranged from 0.020 to 0.092 mg/L at the inlet and 0.064 to 1.548 mg/L at the outlet. TP concentrations in surface water range from 0.034 to 0.910 mg/L and 0.104 to 2.038 mg/L at inlet and outlet, respectively. According to Sallade and Sims (1997) these measured concentrations are higher than concentrations associated with surface water eutrophication (0.02 mg/L). The highest values were observed in during the spring of 1999 when anaerobic conditions had prevailed for several weeks prior to snow melt. During anaerobic conditions, iron oxides become more soluble which is associated with P desorption.

TSS concentrations are low (0-245 mg/L), and as a result, particulate P (PP) is low as well. The average TSS value was 43 mg/L in 1999 and 46 mg/L in 2000.

Results of the P loading calculations are presented in Table 4 for inlet versus outlet for the irrigation seasons in 1999 and 2000, and for the overall period between April 1999 and July 2000. During the irrigation season in 1999, both fields acted as a sink for SRP and TP, while during the 2000 irrigation seasons, they acted as sources despite the high flow at the inlet during 2000. The main difference between both years is the much lower observed concentrations at the inlet in 2000 compared to 1999.

The comparison between inlet and outlet for the full study periods shows that the fields acted as a sink for TP but not for SRP. A similar finding was reported for pasture fields by Edwards et al. (1996). In other words, the P fraction transported away from these fields is the immediately available for accelerated eutrophication.

Table 4. P load entering and leaving the monitoring site

Sample Point	Event	Event Mean Flow	SRP load (kg/ha)	TP load (kg/ha)
Inlet	Irrigation (Jun-Jul 1999)	19.9	1.6	12.9
Outlet	Irrigation (Jul-Aug 1999)	2.8	1.5	2.4
Inlet	Irrigation (Jun-Jul 2000)	36.8	1.9	3.7
Outlet	Irrigation (Jun-Jul 2000)	4.3	3.1	4.0
Inlet	Full period (Apr'99 - Jul'00)	NA	4.0	23.5
Outlet	Full period (Apr'99 - Jul'00)	NA	13.8	20.4

In the above analysis, the contribution of groundwater as a source/sink for phosphorus was not included because ground water flow was assumed to be smaller than surface water flow. Mean concentrations in the ground water observed in the nine wells in field 1 and 2 and their respective standard deviations are shown in Figure 5. The range of SRP concentrations in field 1 was from 0.011 mg/L to 0.230 mg/L. The range of concentrations in Field 2 varied from 0.007 mg/L up to 0.7 mg/L. Groundwater concentrations in 1999 were higher than in 2000. The highest SRP values were measured in April 1999 after the prolonged anaerobic conditions mentioned earlier.

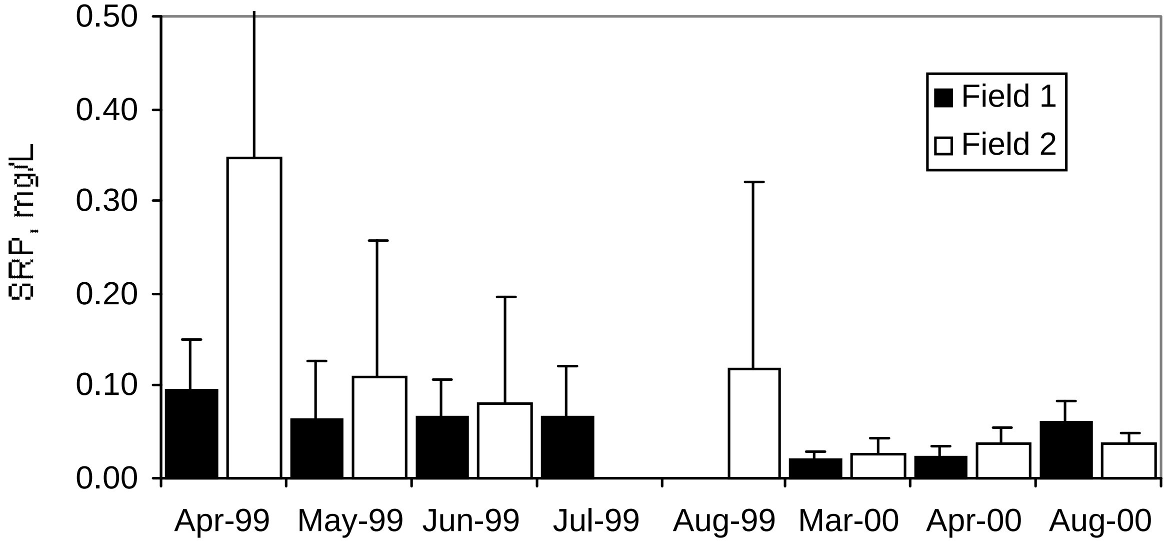


Figure 5. Mean SRP in groundwater from April 1999- August 2000 (from nine wells in each field). Whiskers represent standard deviation for each set of nine wells.

P transport parameters

Equations 1 and 2 were solved for ER and XC, respectively. Table 5 lists values of ER for events grouped by different periods during the study period, and mean TSS, the regression parameters a_0, a_1, and r^2. For comparison between the regression parameters, Menzel (1980) and Sharpley (1980) reported values of a_o equal to 2.2 and a_1 equal to –0.24 as approximations for the regression equation (3) using data from a variety of soils and cover conditions. Values of a_0 in Table 5 are very comparable (mean 2.29 in Table 5) with the 2.2 value. The mean a_1 (-0.54) is approximately twice the values reported by Menzel (1980) and Sharpley (1980), but very similar to the mean a_1 (-0.46) reported by Edwards et al. (1996). The range of coefficients of determination for regression (r^2) in Table 4 also are comparable to the range (0.16-0.54) reported by Edwards et al. (1996). It is interesting to note that these similarities occurred despite much higher total P in soils at our site (i.e., 954 mg/kg and 1250 mg/kg in field 1 and 2, respectively) than in soils at Edwards et al. (1996) sites (i.e., 177 - 364 mg/kg).

Table 5. ER and the regression parameters a_o and a_1 .

Period	Mean ER	Mean TSS (kg/ha)	a_o	a_1	r^2
Accumulated 1999-2000	11	21	2.08	-0.53	0.27
Spring 1999 and Spring 2000	15	21	2.71	-0.61	0.34
Summer 1999 and Summer 2000	7	20	1.47	-0.49	0.34
Accumulated 1999	19	22	2.77	-0.42	0.48
Spring 1999	33	23	3.89	-0.39	0.38
Summer 1999	10	25	2.36	-0.59	0.33
Accumulated 2000	7	19	1.77	-0.61	0.48
Spring 2000	10	20	2.43	-0.75	0.60
Summer 2000	5	17	1.11	-0.47	0.44
Mean	13	21	2.29	-0.54	

Figure 6 shows an example of ln(ER) versus ln(TSS) for the period March-July 2000. The best fit straight line during this period provided a_0 lower than the mean a_0 in our study and also lower than the reported values. On the other hand a_1 was close to the mean a_1 value in our study.

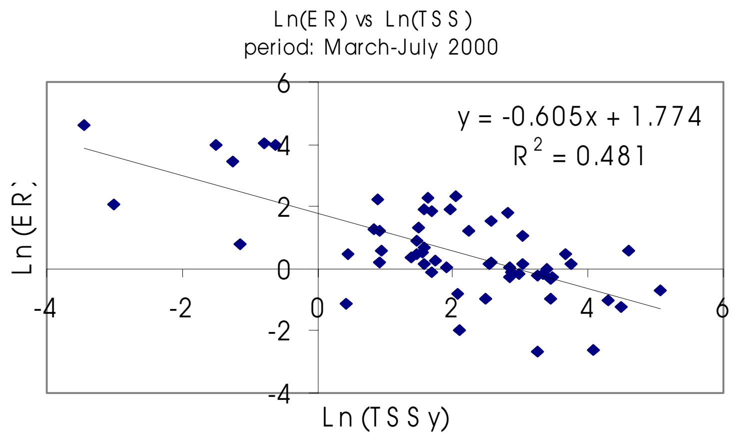


Figure 6. Relationship between ER and TSS_y to obtain the regression parameters a_0 and a_1 (period March-July 2000)

Extraction coefficients listed in Table 6 are one order of magnitude lower than values reported by Edwards et al. (1996). Their range was from 0.027 to 0.097. However, the XC value of 0.006 reported by Sharpley and Williams (1990) is comparable to the highest XC value of 0.007 obtained in this study during spring 1999.

Table 6. Summary of XC values from this study.

Event	Apr-99	Jul-99	Aug-99	Sept-99	Mar-00	Apr-00	Jun-00	Jul-00
XC	0.0070	0.0033	0.0012	0.0006	0.0021	0.0020	0.0030	0.0031

Export coefficients

Export coefficients calculated from FY1999 data ranged from 0.105 kg/ha during the 1999 irrigation season to 0.473 kg/ha during late spring (April 20/May 19, 1999). These estimates were very preliminary and have not been updated yet.

Laboratory Flume Study

Water pathway: subsurface flow

Saturation Duration

The soil gradually saturated at a temperature of ~22°C. Sample retrieval was in succession at the H, G, F, and E ports (DP in E are not included in these Figures). Daily record of dissolved P in water samples, Eh, and pH changes was carried out. The duration of the saturation period provoked changes on the DP concentration values as pH and Eh changed over time. Eh decreased from ~ +400 mv to a ~ (-100 mv) in both flumes; while the range of soil pH variation was from ~4.9 to 5.4 and from 5.7 to 6.1 in water samples. The range of the DP values was approximately the same for both flumes: 0.03-0.12 mg/L. The lowest DP value occurred when the soil was still aerobic, at the beginning of the experiment (Eh~ +150mv).

No DP significant differences were observed at the different sampling ports, indicating that DP did not move downward. As time progressed, the DP increased to a peak of DP=0.11 mg/L that occurred at about 80-90 hours of water flow. A similar trend occurred in a desorption analysis performed in soil samples taken in Fall 1999. At that time, the peak of DP=0.13 mg/L occurred during the 6^{th} cycle and the lowest DP concentration was approximately equal to 0.04 mg/L.

Mixing layer.

DP concentrations in ports F, G, and H were very similar in both flumes. DP concentrations in port E show a clear P desorption trend as time and water flow progresses.

Water pathway: overland flow

Saturation Duration

The overflow experiments were carried out with water flowing on top of the flumes (A port) and retrieving samples progressively at the E, F, G, and H ports. These experiments were performed immediately after the subsurface flow experiments finished, which essentially increased the soil saturation period. Eh during these runs was always negative, from (-40 to –240 mv). The lowest DP concentration was about 0.08 mg/L in both flumes (twice the lowest observed during the subsurface flow experiments). DP concentrations from Flume 1 (no P added) are at the threshold limit for eutrophication, even after all these many hours of water flowing. This illustrate that this soil is a constant source of DP to the Cascade Reservoir. The higher DP values were in samples colleted form the H port in Flume 2 (~0.20 mg/L during the entire run of 160 hrs). These samples were the last to be collected, which implies that the saturation period effectively could affect P release.

Mixing layer

DP concentrations in E showed again the DP desorption trend, as the continuation of the P flushing out effect observed during the subsurface flow experiments.

CONCLUSIONS

Despite the variability in the data collected during the study period, and given that the data cover slightly more than one year, some interesting observations can be made. The pasture/hay fields in our study can act as sinks for phosphorus during an irrigation season. Over longer periods of time, the fields are sinks for TP and sources for SRP. When anaerobic conditions prevailed prior to snowmelt, P concentrations at the outlet of both fields, and subsequent P loading, were the highest observed. ER and XC values obtained in this study compared well with values listed in the literature. The laboratory experiments performed showed two combined effects (1) the duration of the saturation period (changes on Eh and pH as saturation progresses) and (2) the role of the water traversing the saturated P-enriched mixing layer on P release. Further studies are ongoing.

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Basic Information

Title:	Near Surface Hydrology of the Eastern Palouse Region
Project Number:	1434HQ96GR02667
Start Date:	3/1/2000
End Date:	2/28/2002
Research Category:	Ground-water Flow and Transport
Focus Category:	Non Point Pollution, Water Quality, Solute Transport
Descriptors:	Perched Water Tables; Water Quality; Agricultural Ecosystems
Lead Institute:	Water Resources Research Institute
Principal Investigators:	Paul McDaniel, Jan - Boll

Publication

1. None
2. None
3. In progress.
4. In progress.
5. O'Geen, A.T. and P.A. McDaniel, 1999. Soil stratigraphic influences on recharge mechanisms through loess in northern Idaho. p.275. In. Annual Abstracts. Soil Science Soc. Am. Salt Lake City, UT. O'Geen A.T. and P.A. McDaniel, 2000. Using environmental tracers to assess soil stratigraphic influences on ground water recharge mechanisms in the Moscow- Pullman Basin. p. 13. In. Abstracts for the 73rd Annual Meeting Northwest Scientific Association. Moscow, ID.
6. None

MCDANIEL/Problem and Research Objectives:

Most soils in the eastern Palouse region of northern Idaho contain hydraulically restrictive subsurface layers such as fragipans and argillic horizons. These horizons cause percolating precipitation to perch above them in shallow water tables and to move laterally rather than vertically through the soil. As a result, shallow perched water tables exist in these soils for up to seven months of the year. Perched water tables represent a significant seasonal, near-furface aquifer throughout the region. Furthermore, because of their proximity to surface-applied agrichemicals and their ability to promote rapid, lateral water flow, perched water tables may potentially impact surface water quality.

The overall objective of this research is to conduct a landscape-based study of perched water tables and model their impacts on subsurface-to-surface return flow and surface water quality. Specific objectives are to:
(i) Conduct detailed monitoring of seasonal perched water tables in a representative catchment of the region receiving 850 mm of annual precipitation;
(ii) Determine rates and patterns of lateral flow of perched water within the catchment, and;
(iii) Obtain necessary data to develop and validate models for predicting the impacts of perched water tables on local water resources in managed agricultural ecosystems.

Methodology

A 1.7-ha catchment near Troy, Idaho was selected for use in this study. The catchment was instrumented with a grid of 120 shallow wells, a full weather station, and a flume to measure surface outflow from the catchment. Within each well, a pressure transducer was placed at the interface between the hydraulically restricitve horizon and the overlying soil horizons. Transducers were calibrated to read the thickness of the perched zone of saturation and wired to dataloggers. Dataloggers were programmed to collect readings every 12 hours for 4 water seasons. Time-domain reflectometry probes were installed in soil horizons at two locations to monitor soil water content. Saturated hydraulic conductivity was determined from soil cores and also measured *in situ* using a Guelph permeameter. Data collected from the catchment was used to develop and validate a soil moisture routing model that predictis perched water table responses to climatic and landscape variables. In addition, Br- and Cl- tracers were applied in trenches on the upper part of the catchment and the direction and rate of their movement was monitored.

Principal Findings and Significance

Using well data in conjunction with precipitation, catchment outflow, soil water content, and potential evapotranspiration (PET) data, we have been able to construct a soil water budget for the catchment. Moisture inputs from precipitation lead to a rapid increase in perched water table (PWT) height. There is a relationship between perched water table (PWT) height and the depth to the fragipan surface within the catchment – greater depth to fragipan corresponds to highere PWTs. PWTs increase and decrease rapidly in Ap, Bw, and BE horizons with less than a 5% change in volumetric soil water content. Catchment surface outflow mainly occurs between late December and early April, and represents as much as 36% of the precipitation received for 1 Nov. through May 31. Maximum catchment outflow occurs when average PWT is in the Ap horizon; outflow ceases when average PWT height drops into the less permeable E horizon. Lateral throughflow and surface outflow are the two main mechanisms by which water is lost from the catchment during the winter months. Following snow melt, evapotranspiration increases and leads to a gradual disappearance of PWTs in the catchment. Our results show that the majority of precipitation (~80%) received when PWTs are present is lost via surface runoff and lateral throughflow, thereby increasing potential for agrichemical transport and decreasing potential recharge to groundwater.

Perched water tables are able to transport applied Br tracer considerable distances – we measured movement greater than 66 m over the course of a single season. Overall seasonal rates of movement are on the order of approximately 0.5-1.0 m/day. However, very rapid bypass flow can occur during periods when PWTs are in the Ap horizon – in one experiment, we were able to measure 7 m of movement of applied Br in 9 h. This again demonstrates the potential for rapid transport of agrichemicals in these PWT systems. Direction of tracer flow via PWTs is governed by the topography of the fragipan surface. The fragipan surface does not necessarily correspond to the soil surface, and this creates subsurface zones of concentrated perched water flow. Observed patterns suggest that perched water flow is not uniform across hillslopes and is extremely difficult to predict from surface features.

Finally, the intensive data collection associated with this project has provided a unique opportunity to validate a soil moisture routing model developed at Cornell University. Our data demonstrate that, with adjustments for saturated hydraulic conductivity values, this model is able to accurately predict PWT levels in soils that occupy summit and upper hillslope landscape positions. However, it does a much poorer job of modeling PWT dynamics in soils occupying lower-lying landscape positions.

Basic Information

Title:	Evaluation of Recharge Mechanisms and Rates Through Loess in the Moscow-Pullman Basin Using Environmental Tracer and Soil Stratigraphy
Project Number:	1434HQ96GR2667-0006
Start Date:	3/1/2000
End Date:	2/28/2002
Research Category:	Ground-water Flow and Transport
Focus Category:	Water Quality, Irrigation, Groundwater
Descriptors:	Water Movement; Nonpoint Source Pollution; Water Quality; Perched Water Table
Lead Institute:	Water Resources Research Institute
Principal Investigators:	Paul McDaniel

Publication

1. None
2. None
3. In progress.
4. In progress.
5. Barndt, S.L., P.A. McDaniel, J. Hammel, M. Regan, and A. Falen. 2000. Tracer movement through a perched water table on convex and concave slopes in the eastern Palouse region. p. 2 In Northwest Scientific Assoc. 73rd Annual Meeting Program and Abstracts. March 17-18, Univ. of Idaho, Moscow. Regan, M.P., P.A. McDaniel, and E. Brooks. 2000. Perched water table dynamics of an eastern Palouse catchment basin. p. 15 In Northwest Scientific Assoc. 73rd Annual Meeting Program and Abstracts. March 17-18, Univ. of Idaho, Moscow. Regan, M.P., and P.A. McDaniel. 2000. Perched water table dynamics and hydrologic processes in an eastern Palouse catchment. p. 58 In Program with abstracts. Western Society of Soil Science Annual Meetings. Am. Soc. Advance. Sci. - Pacific Division. June 11-14, 2000. Southern Oregon University, Ashland.
6. Barndt, S.L. 2000. Tracer movement in perched water tables of an eastern Palouse catchment: implications for agricultural practices. M.S. thesis. Univ. of Idaho. Moscow. Regan, M.P. 2000. Perched water table dynamics and hydrologic processes in an eastern Palouse catchment. M.S. thesis. Univ. of Idaho. Moscow.

MCDANIEL/Problem and Research Objectives:

Ground water is the principal water supply for the Moscow-Pullman Basin of eastern Washington and northern Idaho. Municipal water use by Pullman, Moscow, and the two universities has resulted in a continual decline in the regional basalt aquifer system since 1890 and a steady decrease of 1.5 ft per year in response to pumping from 1976 to 1985 (Barker, 1979). Concerns regarding this diminishing water supply have prompted development of several models that propose a wide range of recharge estimates, recharge mechanisms, and possible solutions to ensure a sustainable groundwater supply.

The specific objectives of the project were to:

(i) select three loessial catchments that reflect the climatic gradient across the Moscow-Pullman Basin and determine their stratigraphic and chronologic contexts;

(ii) determine environmental tracer (^{18}O and Cl^-) depth profiles in the loess sections at each site, and;

(iii) estimate modern-day and paleo-recharge of water through the loess mantle to the basalt aquifers in the Moscow-Pullman Basin using loess stratigraphic and chronologic boundaries in concert with Cl^- and ^{18}O depth profiles.

Methodology

Our approach was to select three representative catchments in which to study the effect of less cover on basin hydrology across a climatic gradient. Site #1 was selected in the eastern portion of the Basin where loess is moderately deep (3-20 m), soils contain hydraulically restrictive horizons, and the climate is moist (~800 mm MAP). Site #2 was selected in the central Basin where loess is deep (~5-35 m), soils are slightly permeable, and the climate is drier (~630 mm MAP). Site #3 was selected in the western Basin where loess is very deep (~6-60 m), soils are slightly permeable, and the climate is even drier (~450 mm MAP).

After representative hillslopes were selected, continuous 6-m vertical soil cores were collected at 4-6 positions within each catchment, including top, mid slope, and valley bottom. Strata was differentiated based upon soil horizon and paleosol boundaries using soil morphological field criteria, chronologic boundaries (tephra layers, & ^{14}C dating of $CaCO_3$), and physical properties (density, mineralogy, & texture).

Cl^- was extracted and analyzed on an ion chromatograph. Cl^- depth profiles were constructed, and the shape of the profiles was used to interpret the response of water movement to stratigraphic boundaries. Recharge rates can be estimated using the following mass balance technique:

$$R = (Cp \times P)/Cr$$

where R = recharge rate cm/yr
Cp = $[Cl^-]$ in precipitation
P = effective MAP
Cr = $[Cl^-]$ in pore water

The ^{18}O signature of water will be determined through direct equilibration of soil with CO_2 using a vacuum line, and measured on a mass spectrometer. ^{18}O depth profiles will be constructed to enhance the resolution of pore water stratigraphy and supplement recharge interpretations.

Principal Findings and Significance

We have been unable to measure the ^{18}O signature of soil water to date due to an unexpected setback in the construction of our vacuum line. We expect to begin analysis by May 2000.

Cl^- profiles have been measured at all sites. Sites 2 and 3, which represent deep loess in the drier portions of the Basin display uniform Cl^- depth profiles indicative of strata lacking water-restrictive horizons. Minimum recharge rates ranged from 2.6 to 2.9 cm/yr. Vertical facies between soft and dense horizons coincided with sharp fluctuations in the $[Cl^-]$ of depth profiles at Site 1, which represent moderately deep loess in the moist portion of the Basin. Minimum recharge rates ranged from 0 to 0.29 cm/yr. Carbon dating of $CaCO_3$ found in a dense layer 200-cm below the soil surface indicates that water is 10,000 cal. yr. old. The pattern of depth profiles and age of $CaCO_3$ suggest that deep percolation of precipitation is unlikely and that water may be trapped within dense layers.

In the eastern portion of the Moscow-Pullman Basin, ground water recharge rates, as inferred by Cl^- depth profiles, are low because soils are well developed and contain water-restrictive horizons. In the central and western portions of the Basin, soils are more permeable, but recharge rates remain low because of less MAP and greater loess thickness. Data suggests that deep percolation of precipitation through loess hillslopes is not significant under contemporary moisture regimes.

Basic Information

Title:	Metal(loid) Cycling in Lake Coeur d'Alene, ID as Controlled by Reduced Sulfur Species
Project Number:	99HQGR0218
Start Date:	9/1/1999
End Date:	8/31/2002
Research Category:	Water Quality
Focus Category:	Sediments, Nitrate Contamination, Toxic Substances
Descriptors:	Heavy metals; Lakes; Mathematical models; Water chemistry
Lead Institute:	Water Resources Research Institute
Principal Investigators:	Leland L. Mink, Leland L. Mink

Publication

1. None
2. None
3. In progress.
4. In progress.
5. None
6. None
7. Niggemyer Allison, Stefan Spring, Erko Stackenbrandt and R. Frank Rosenzweig. Isolation and Characterization of a Novel As(V)-Reducing Bacterium: Implications for Arsenic Mobilization and the Genus Desulfitobacterium. Applied and Environmental Microbiology, December 2001, pp. 5568-5580.

Problem and Research Objectives:

Lake Coeur d Alene (CDA) is the second largest natural lake in the Inland Northwest. It lies between the Selkirk and the Coeur d Alene Mountains and extends northward from the St. Joe River to the headwaters of the Spokane River. Lake CDA is 3.2 km wide and 40 km long, covers approximately 129.5 km^2, contains 2.75 km^3 of water (with mean and maximum depths of 21.2 and 61 m), and has a retention time of 0.48 y (Woods, 1989). Lake CDA provides drinking water for at least six communities and serves as a primary recreational area for inhabitants of the Pacific Northwest. Over the last century Lake CDA became the major collecting bed for sediments impacted by human activities in its two major drainages. These activities include recreation, logging, and agriculture. In the Coeur d Alene River Basin these activities also included mining and ore processing. Mining went largely unregulated in Idaho s Silver Valley from the 1880s until 1968, and as a result, tailings enriched in Pb, Zn, As, and other trace elements were deposited in stream banks and bars along the South Fork and main stem of the Coeur d Alene River. These materials have been regularly resuspended during periods of high stream flow and secondarily transported into Lake CDA. Over the years numerous environmental studies have been carried out in this region (Horowitz et al., 1992, 1993, 1995; Woods, 1989; Ellis, 1940), all confirming that sediments enriched in As, Cu, Cd, Fe, Mn, Pb, Sb, Zn, and other trace metals have been deposited throughout the lake. The USGS has estimated that as much as 85% of the lake bottom is contaminated with metal(loids) (Horowitz et al., 1992).

Our previous work thus indicates that reduced sulfur species play an important role in controlling the cycling of metal(loid) contaminants in Lake CDA. We therefore propose to characterize this key variable controlling metal(loid) transport and bioavailability. More specifically, we will 1) identify and quantify sulfur species present in sediment pore waters, 2) develop an equilibrium model describing metal-sulfur speciation, 3) correlate model predictions with total soluble Pb, Cd, and Zn concentrations, and 4) predict metal flux from the sediment to the overlying water column. Our overall objective is thus to develop a clear understanding of sulfur biogeochemistry within the lake sediments, providing appropriate data that will contribute to the development of models focused on the fate of metal(loid)s within the sediments. Ultimately such models will be used to predict how anthropogenic alteration of the lake will modify metal(loid) cycling and potentially increase environmental deterioration. This research will ensure protection of regional water resources impacting northern Idaho and eastern Washington.

Methodology:

We will sample along a transect to obtain porewater and core samples on which to perform chemical analyses essential to modeling efforts. The study will be conducted over two annual cycles and samples will be collected in the spring, summer, and fall of each year in order to define temporal changes.

Sample collection and processing. Peepers to obtain sediment porewater will be installed by a diver. Peepers will contain sample cells at 1.5-cm intervals to a total depth of 30 cm in order to quantify porewater constituents in both the oxic and anoxic zones of the sediment. Site location will be recorded using the Magellan GPS 2000XL Global positioning system. Sediment cores will also be collected. Three cores will be taken from each site. Cores will be carefully sealed after collection and stored upright in a 4^{o}C cooler flushed with N_2 gas. The cores will be analyzed for sample heterogeneity with respect to Eh, pH, total metals, and C:H:N ratio.
Analysis of sediments and porewaters. Sediment and pore water analyses will be performed with the specific objective of providing necessary data for equilibrium modeling of metal speciation and benthic flux calculations for Pb, Zn, and Cd. Elemental analyses for Pb, Zn, and Cd will be performed as previously reported using a Thermo Jarrell Ash IRIS ICP (Harrington et al., 1998a; 1998b). Except for S speciation, relatively standardized techniques will be used for the measurement of the necessary parameters.
Sulfur speciation. Samples obtained from the peepers will be analyzed using polarographic techniques similar to those reported by Luther et al. (1985; 1986a; 1986b). The techniques allow quantification of a number of sulfur species including thiosulfate, sulfite, polythionates, sulfide, organic thiols, and inorganic and organic polysulfides. We have modified these techniques to increase detection limits and improve speciation capabilities. We will use a Bioanalytical Systems Electrochemical Analyzer (BAS 100B\W) complete with computer control and a controlled growth mercury drop electrode.
Equilibrium modeling. Equilibrium modeling will be done to determine the speciation of metals in the porewater and to assess the importance of various processes in mobilizing metals from solid phases into the porewater. Speciation calculations will consider complexation with inorganic (Cl^-, SO_4^{2-}, CO_3^{2-}, OH^-, HS^-, and polysulfides) and organic thiol ligands. Cysteine will be used as a model compound for the organic thiols because the relevant stability constants are available for cysteine but not for the naturally occurring organic thiols (Huerta-Diaz et al., 1998). The model will consider the role of solubility with sulfidic phases by calculating ion activity products (IAP) and comparing them with solubility constants for the sulfidic phases. In addition, the data will be fit to determine binding constants for metals with solid phases (Benoit et al., 1999). Interactions between metals and solid phases within the anoxic zone will be defined as adsorption reactions onto solid phase organic thiol ligands or as co-precipitation either with metal monosulfides or as pyritization of the metal. The computer program MINTEQA2 and its associated database will be used in the modeling (Allison et al., 1991).
Benthic flux calculations. The flux of dissolved elements across the sediment-water interface by molecular diffusion is calculated using Fick's First Law; *i.e.*,

$$J_S = - D_S [C/x] \quad (1)$$

where J_S is the benthic flux (g cm^{-2} d^{-1}), is the porosity just below the sediment-water interface, D_S is the diffusion coefficient for the element in the sediment (cm^2 d^{-1}), and C/x is the concentration gradient of the element across the sediment-water interface (g cm^{-4}) (Berner, 1980).

Diffusion coefficients in the sediment (D_S) are related to molecular diffusion coefficients in water (D_0) as follows:

$$D_S = D_0/(\ F) \quad (2)$$

where F is the sediment resistivity. For high porosity sediments, as in Lake CDA, F can be approximated as $^{-3}$ (Ullman and Aller, 1982). Therefore,

$$D_S = D_0/\ ^{-2} \quad (3)$$

Values of D_0 at infinite dilution for a variety of ions are tabulated in Li and Gregory (1974). These values depend on speciation of the metals. Metal speciation is a function of pH, redox potential, and the presence of complexing ligands such as carbonate, dissolved organic carbon, and sulfide (Turner et al., 1981; Xue et al., 1995; Luther et al., 1996).

Diffusion coefficients also are a function of temperature. The Stokes-Einstein relationship is used to temperature correct the diffusion coefficients to in-situ conditions as follows:

$$(D_0{}^{0}/T)_{T1} = (D_0{}^{0}/T)_{T2} \quad (4)$$

where ^{0} is the viscosity of water and T is absolute temperature ($T^{0}C$ + 273.15). The temperature dependence on the viscosity of water is tabulated in Dorsey (1940).

The concentration gradient (C/x) across the sediment-water interface is calculated as:

$$C/x = [(Me^{2+})_{BW} - (Me^{2+})_{PW}]/d \quad (5)$$

where $(Me^{2+})_{BW}$ is the concentration of the dissolved metal (Me^{2+}) at the bottom of the water column just above the interface (g cm^{-3} or g L^{-1}), $(Me^{2+})_{PW}$ is the concentration of dissolved metal in the porewater just below the interface (g cm^{-3} or g L^{-1}), and d is the distance between the location of the bottom water and porewater sample (cm).

Principal Findings and Significance:

In October 2000 five sites were sampled during the first phase of the research. Peeper samples were collected and sediment cores were extracted.

Peeper Samples. Site A is located at the mouth of the Coeur d Alene River and has a depth of 3.3 m. The metal concentrations are the highest at this site, with zinc being the dominant metal present in the pore water. Zinc concentrations increased with depth reaching a maximum concentration of 6 ppm. Lead concentrations in the sediment pore water also increased with depth. Site C is 8.7 m deep. The sulfate concentrations were between 1 and 6 ppm. No sulfate was found below 8 cm in the sediment. Over 90 % of the total sulfur existed as sulfate. Site D is 22.5 m deep. Sulfate concentrations throughout the profile were between 1 and 5 ppm, with a spike 12.5 cm below the sediment/water interface. Sulfate represented 30 90 % of the total sulfur species, indicating that there were reduced sulfur species present at this site. Zinc was the dominant metal present, with concentrations below 1 ppm. Zinc concentrations increased with depth. The maximum arsenic concentration occurred 5 cm above the sediment/water interface. Site F is 19.5 m deep and had a sulfate spike at 2 cm below the sediment/water interface. The sulfate concentration ranged between 1 and 16 ppm. Sulfate represented 20 60% of the total sulfur species, indicating that there were reduced sulfur species present at this site. Site F had negligible cadmium concentrations and zinc was the dominant metal, with concentrations below 1 ppm zinc. St. Joe is the uncontaminated site at 9.6 m deep. The dominant anion was chloride. The sulfate concentrations were between 1 and 2 ppm. Zinc was the dominant metal, yet concentrations were generally less than 0.4 ppm throughout the profile.

We are finding that zinc is the dominant metal in the pore water and the general trend is that zinc concentrations increase with sediment depth. Cadmium is found only in trace amounts, while lead and arsenic are present in detectable levels. Sulfate is the dominant sulfur species present, though the results suggest it is worthwhile to identify the reduced sulfur species present. More replicates are needed to establish confident trends for the metal and sulfur profiles in the sediment pore water. We are seeing an increase in reduced sulfur species at the deeper sites. We are also seeing the expected trend of higher metal concentrations at the mouth of the Coeur d Alene River versus the metal concentrations at the control site north of the St. Joe River.

Sediment Cores. Four sediment cores were collected from five different sites, within a 2-3 m radius of where peepers were installed for pore water collection. For each site, two sediment cores were sectioned at 1.5-cm intervals for the first top 10 cm (depth equivalent to depth of peeper cell) and then at 5-cm intervals. These sediment samples were analyzed for the following parameters: pH, Eh, porosity, calcium carbonate, total CNS, inorganic carbon, total concentration of macro-elements (Al, Fe, Mn, Ca, Mg) and trace metals (As, Cd, Cu, Ni, Pb, Zn). The specific objectives of these analyses were to provide necessary input parameters required for the equilibrium modeling of metal speciation and for providing benthic flux calculations. Another focus of this study was to correlate total metal contents with observed dissolved metal concentrations in pore water as a function of both vertical and temporal variability.

Among the investigated sites, A, B, C, and D sediment cores were quite similar in physicochemical characteristics and substantially enriched in trace metals (As, Cd, Cu, Pb, Zn) relative to the uncontaminated St Joe site. Overall, the vertical distribution pattern of the metals remained non-systematic and showed high variability caused by sediment heterogeneity. Seasonal changes in sediment temperature and organic matter input may influence the depth of the anoxic sediment boundary. Therefore, vertical distribution of AVS (acid volatile sulfur) and SEM (simultaneously extractable metals) is being studied in Coeur d Alene sediment as a function of seasonal variations.

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Basic Information

Title:	Completing the Idaho Climate Database
Project Number:	1434HQ96GR02667-0008
Start Date:	3/1/1999
End Date:	2/28/2001
Research Category:	Climate and Hydrologic Processes
Focus Category:	Climatological Processes, Models, Management and Planning
Descriptors:	Climate; 19th Century Climate Data; Climate History
Lead Institute:	Water Resources Research Institute
Principal Investigators:	Leland L. Mink, Leland L. Mink

Publication

1. None
2. None
3. None
4. In progress.
5. None
6. Myron Molnau, Oct, 1999, Progress report on completing the Idaho climate database. Idaho State Climate Services, University of Idaho.

MOLNAU/Problem and Research Objectives:

During the past several years, there has been an increasing reliance on older climate data to study a variety of problems. These range from the obvious (climate change, El Niño) to the less obvious (effect of weather variability on crop diseases, the spread of Yellow Star thistle, Salmon survival). The need for complete quality controlled data has become acute over the past years with many requests for complete datasets for analysis of El Niño effects on many aspects of the Idaho economy.

The Idaho State Climate Services (ISCS) is being increasingly asked to either supply more complete datasets of better quality or to do actual analysis for some of these purposes. These data have been supplied in several forms but requests are now at least 50 percent via e-mail or the Web. Because users have come to expect data on the Web, the ISCS would like to have more data on the ISCS Web page. To have a user obtain the data they desire via the Web is very efficient since they can obtain exactly what they want without going through an intermediary. The problem with doing this is that not all the data are available in electronic form and there is a cost associated with the Web programming.

The objective of this project is to develop a database of the daily Cooperative Climate Network containing all of the available daily data. This will document and preserve the data and information that will be of the most value to the state.

Methodology:

The station history files were used to determine the periods that needed to be keyed. These files were jointly developed by National Climate Data Center, NOAA, (NCDC) and the Idaho State Climate Services (ISCS). These were further broken down into active and inactive stations. Active stations were those that were collecting Coop data as of summer, 1999. The emphasis on keying data was to put on the active stations first since these are the most requested data. This results in a list containing the dates when data were originally collected by each station.

The second step was to compare the digital data held in three databases. These were those at NCDC, the Western Regional Climate Center, DRI (WRCC), and ISCS. It was quickly determined that the data held at NCDC and WRCC were identical while there were more data in the ISCS database than at NCDC, particularly in the 1930-1948 period. From this comparison, a table of data to be keyed for active stations was compiled.

For this project, it was decided to key data from original manuscript forms wherever possible. An inventory of the forms kept at the ISCS was done. Also an inventory of data keyed from formal publications in a previous project for the period 1898-1919 was made. Because there were many missing periods for the 1898-1919 data, it was decided to key data from the manuscript forms and use other data as a quality control check. This followed the procedure used by the Utah State Climatologist and the Midwestern

Regional Climate Center (MRCC) in their projects to key older data.

A program developed by the MRCC was obtained and personnel trained in its use. The program output is nearly the same as the NCDC data format TD3200. This made it possible to develop fairly simple programs to reformat the keyed data into the 3200 format used by NCDC on their Web page. The reasoning behind this was that using the same format would make it easy for both ISCS and others to merge data from the two sources.

Principal Findings and Significance:

At the present time, most of the emphasis in the project is being put on keying data. A great deal of difficulty was experienced in hiring a full-time key operator for the project. Several illnesses and problems with the MRCC program held back the project by several months. By hiring two part-time persons, it was possible to keep data flowing. It has also proved more difficult than originally thought to read some of the manuscript forms. In several cases, the data were simply marked as missing rather than take an inordinate amount of time on one station-month.

The keying of the active station data is about 60 percent completed. Also about 15 percent of the inactive station data are also keyed. This was done both as a matter of convenience and requests by potential users. The data are checked for completeness and run through the reformatting program. All data from the ISCS is being identified as 32UI to distinguish them from the NCDC data 3200 (final daily Coop data), 3202 (preliminary daily Coop data) and 3280 (daily data derived from hourly or airport stations). Thus users will know the source of the data they are using.

Rather than putting data on a CDROM as originally envisioned, it was decided to put data onto the ISCS Web page. A suitable format was developed and is being tested. A partnership with a University of Idaho Library Project titled Inside Idaho was formed. That project will ultimately host all of the daily data held by the ISCS. They have a much more powerful server as well as programmers who can develop excellent programs for users of the daily data. The actual data will be tested on the ISCS server but served to the public on the Inside Idaho server because the large amount of data is more than the ISCS server can handle.

A Web page format for the ISCS server has been developed and is currently being tested. The format for the Inside Idaho server is now being developed but has not been tested yet. It is not possible to use the same programs to serve data on both machines because of software incompatibilities.

Plans for the remainder of the project are to finish the keying of the active stations, now projected to August, 2000. The inactive station data will then be keyed in a station priority order yet to be determined. The requests for data to the ISCS will be scanned to see which inactive stations are most requested and these will be keyed in order until funds are exhausted.

All ISCS data will be on an internal ISCS database by the end of August but probably will not be available to the public over the Inside Idaho until later in the year. An inventory of data already keyed and to be keyed is available and will be added to the ISCS Web site later this summer or fall when the ISCS Web site is reorganized. At that time, the station history file will also be added to the Web site so that users will know the circumstances under which the data were collected.

Descriptors:

Climate; 19th Century climate data; climate history;

Articles in Refereed Scientific Journals:

Book Chapters:

Dissertations:

Water Resources Research Institute Reports:

Conference Proceedings:

Other Publications:

Myron Molnau, Oct, 1999, Progress report on completing the Idaho climate database. Idaho State Climate Services, University of Idaho.

Basic Information

Title:	Decontamination of Acid Mine Waste by Treatment with Solid Humic Acid
Project Number:	1434HQ96GR02667-0008
Start Date:	3/1/2000
End Date:	2/28/2001
Research Category:	Water Quality
Focus Category:	Treatment, Non Point Pollution, Waste Water
Descriptors:	Acid Mine Waste; Water Quality; Treatment Technologies
Lead Institute:	Water Resources Research Institute
Principal Investigators:	Leland L. Mink, Leland L. Mink

Publication

1. Two papers are in preparation.
2. None
3. In progress. 1 M.S. (Chemistry) student (2002 grad) and part of the thesis work 1 M.S. (Env. Sci.) student (2002 grad) 2 undergraduate researchers are involved
4. In progress.
5. Regional ACS meeting - June 2001; ASA-CSA-SSSA meetings - October 2001.
6. None

VONWANDRUSKA/Problem and Research Objectives:

Northern Idaho suffers from environmental contamination caused by leachates arising from former and present mining operations. These waters contain high concentrations of heavy metals and are sometimes acidic. The objective of the research is to develop methods for their treatment and detoxification.

Methodology:

Treatment consists of the continuous elution of mine water through a bed of a natural humic material, which retains dissolved heavy metals through chemical complexation.

Principal Findings and Significance:

The investigation is focused on a crude humic material, *leonardite humic acid crude blend* (LHACB), which is found in association with lignite deposits across North America.. We study both its application to water detoxification and its chemical characteristics.

1. ***Detoxification*** The emphasis is on zinc removal from mine water, since this metal is a fish poison and constitutes a major toxin in waters at the Pinehurst mining district. We use both synthetic samples and actual run-off waters. They are eluted through columns packed with LHACB, both through gravity and pressurized flow. All work is on a laboratory bench scale.

ÿÿ Several column systems were designed and tested. A column of 2-cm i.d. and 30-cm length, packed with 5 g LHA and pressurized to 3 psig gave the best results.
ÿÿ Water samples down to pH 4 do not leach metal from the LHACB itself.
ÿÿ The extraction capacity of LHACB is 0.17 mg Zn/g extractant.
ÿÿ A Zn adsorption isotherm was generated to illustrate the adsorption process.
ÿÿ Zinc removal from synthetic solutions is generally in the 95+% range.
ÿÿ In treatment of mine water containing 13   265 ppm zinc, 5 g LHACB consistently removes 98-99% of the metal in 25 mL of eluent. For acid (pH<4) samples, agricultural lime was first added to the column to adjust the pH and prevent metal leaching. This, however, resulted in additional zinc leaching. The problem was solved by using marble chips instead of lime. With mine water of pH 2.3, these raise the pH to 6 and allow 99.99% zinc removal by LHACB.
ÿÿ In a competition study, Zn, Ca, and Mg were combined in solution at 100, 100, and 50 ppm, respectively. From these 95% Zn, 60% Ca, and 20% Mg were removed, indicating that LHACB has a preference for heavy metals.
ÿÿ In some mine water samples, sulfate concentrations of >580 ppm were observed. Methods for removing sulfate with LHACB are presently under investigation. Preliminary results indicate 68% sulfate removal.

2. ***Chemical Characterization of LHACB:***

ÿÿcomposition   LHACB contains 19% humin, 76% humic acid, 0.5% fulvic acid, and 4.5% mineral matter.
ÿÿelemental analysis   the purified components of LHACB contain:

%	HUMIN	HUMIC ACID	FULVIC ACID
C	40.3	60.1	14.8
N	0.7	1.4	0.3
H	3.5	3.4	1.3
O	55.5	35.1	83.6

- ash content the purified humic acid component has an ash content of 3.2%.
- acidity the acid content of the base soluble portion of LHACB is 3.6 meq/g, including 2.4 meq/g strong acid (-COOH) and 1.2 meq/g weak acid (-OH).
- ^{13}C NMR spectroscopy the approximate carbon distribution among purified components is:

%	aliphatic	aromatic	carboxyl
Humin	54	43	3
Humic acid	21	52	27
Fulvic acid	22	62	16

- Infrared spectroscopy the spectra show the presence of CH_3/CH_2, C=C, and C=O in all fractions, but only a small C=O content in humin.

Basic Information

Title:	Spatial and Temporal Characteristics of Winter Precipitation over Idaho and Their Associations with Pacific Sea Surface Temperature Anomalies
Project Number:	1434HQ96GR02667-0008
Start Date:	3/1/2000
End Date:	2/28/2001
Research Category:	Climate and Hydrologic Processes
Focus Category:	Climatological Processes, Water Supply, Hydrology
Descriptors:	Spacial Characteristics; Precipitation; Climate
Lead Institute:	Water Resources Research Institute
Principal Investigators:	Leland L. Mink, Leland L. Mink

Publication

1. In progress.
2. None
3. 1 MS in progress.
4. In progress.
5. None
6. None

YE/Problem and Research Objectives: to examine and quantify the spatial and temporal characteristics of the teleconnection between Pacific SST anomalies and Idaho's regional precipitation during the winter season.

Methodology: Precipitation records at stations across Idaho are compiled and quality checked. Winter total precipitation is derived from the December, January, and February monthly total. Winter and fall mean Southern Oscillation Index, Nino 3.4 SSTs, and Pacific Decadal index are used to correlate winter total precipitation at all stations across Idaho.

Principal Findings and Significance: Winter precipitation over northern Idaho is found to be closely related to sea surface temperatures (SSTs) over both the northern Pacific (Pacific Decadal oscillation) and eastern tropical Pacific Ocean (El Nino). The fall season's El Nino and Pacific Decadal Oscillation indices are also significantly correlated with northern Idaho's winter precipitation. Thus, the Pacific SST anomalies can be used to predict winter precipitation over northern Idaho.

Information Transfer Program

A vital component in the institute's mandate is to distribute its research results to the general public. In addition to formal research reports published in teachnical journals, our scientists regularly publish results and make presentations designed for a lay audience. We sponsor a range of timely conferences and short-courses and produce audio-visual materials including education videos. Education workshops such as Idaho Streamwalk, Project WET and EMPower are listed as conference projects under Information Transfer.

Basic Information

Title:	Project WET (Water Education for Teachers)
Start Date:	3/1/2000
End Date:	2/28/2001
Descriptors:	Teacher Education, Science, Water
Lead Institute:	Water Resources Research Institute
Principal Investigators:	Leland L. Mink

Publication

1. None
2. None
3. None
4. None
5. None
6. None

Problem and Research Objectives:

Project WET (Water Education for Teachers), Idaho, an interdisciplinary, supplementary water education program for Idaho educators, was established this past year. The goal of Project WET is the facilitate and promote an awareness, appreciation, and understanding of Idaho's water resources through the development and dissemination of classroom-ready teaching aids. Like other successful natural resource education programs, Project WET emphasizes teaching students *how to think, not what to think*.

Methodology:

There were 12 statewide teacher-training workshops. Two and three day sessions were conducted for teachers both in class and in the field. Classes have 20-30 teachers participating. Other professional training and presentations included, presentation to National Project WET Conference; Integrated Watershed Education Field Workshops; Project WET Idaho Advanced Facilitator Training; Correlation of Project WET with Idaho State Standards, Idaho Water Camps (Lewiston and Twin Falls), 2-day field, 2-day classroom water resource workshop
Water Awareness Week, Boise River Water Festival, SPLASH! Water Festival Training.

Principal Findings and Significance:

Approximately 322 teachers were trained this past year and approximately 21,150 student contacts. There were 1,210 direct student contacts.

Basic Information

Title:	EM Power
Start Date:	3/1/2000
End Date:	2/28/2001
Descriptors:	Teacher Education, Science, Water Management
Lead Institute:	Water Resources Research Institute
Principal Investigators:	Leland L. Mink

Publication

1. None
2. None
3. None
4. None
5. None
6. None

Problem and Research Objectives:

EM*Power is a Waste Management youth education program. This program was developed in response to DOE's objective of increasing the level of awareness and understanding of waste management. The 4-H youth component curriculum is well rounded so that youth can be taught "how to think, not what to think" in relation to waste management. This provides 4-H youth with hands-on activities to gather factual information, make informed decisions and develop creative solutions in the realm of waste management.

Methodology:

There were no EMPower workshops conducted this past year; however, self-training teaching manuals were distributed.

Principal Findings and Significance:

Approximately 25 teacher-training manuals were distributed for self-training.

Basic Information

Title:	Idaho Streamwalk
Start Date:	3/1/2000
End Date:	2/28/2001
Descriptors:	Outreach, Science Education, Public
Lead Institute:	Water Resources Research Institute
Principal Investigators:	Leland L. Mink

Publication

1. None
2. None
3. None
4. None
5. None
6. None

Problem and Research Objectives:

Idaho Streamwalk, a citizen volunteer monitoring program, also contributes strength to the IWRRI's outreach program. This program, coordinated through the Institute, was designed by the Environmental Protection Agency, Region 10. The goals of Streamwalk are to encourage citizen commitment to protecting, streams, educate people about the relationship between streams and the watersheds, equip individuals with a screening tool to identify potential problem areas, provide a standardized data collection method so regional and trend comparisons can be made, and focus experts' limited resources on suspected problem areas.

Methodology:

Idaho Streamwalk was presented at the Boise River Festival. It was also presented as a component of Project WET workshops.

Principal Findings and Significance:

Approximately 200,000 people attend the festival annually. It was also presented as a component to 16 Project WET workshops.

USGS Summer Intern Program

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	2	2	0	0	4
Masters	8	5	1	0	14
Ph.D.	1	1	0	0	2
Post-Doc.	1	0	0	0	1
Total	12	8	1	0	21

Notable Awards and Achievements

Dr. Gary Johnson Department of Hydrogeology Idaho Water Resources Research Institute University of Idaho Idaho Falls, Idaho

River/aquifer response functions have been generated that describe the relationship between ground water use and river depletion. These relationships have been determined for each cell of the numerical ground water flow model of the Snake River Plain aquifer. Mapping of the response functions illustrates the degree that different reaches of the Snake River are impacted by pumping or artificial recharge. A spreadsheet has been developed to help water managers and users understand the attenuation of ground water pumping impacts on the river and plan for mitigation. State agencies have adopted the use of the response functions in aquifer management and the results are likely to appear in state water management regulations. This work was funded by the U.S. Bureau of Reclamation.

Dr. Leland L. Mink Idaho Water Resources Research Institute University of Idaho Moscow, Idaho

The following research was a collaborative effort of faculty and students between University of Idaho, Boise State University and Idaho State University faculty. Disciplines including hydrogeology, geophysics, geology, and agricultural engineering.

The Idaho Water Resources Research Institute at the Idaho Falls Field Office was involved in several research projects funded by the U.S. Department of Energy resulting in the following significant accomplishments: The first significant accomplishment is a special publication on the Snake River Plain issued by the Geological Society of America (Spring 2001). Nineteen peer reviewed papers comprise this publication. The subject matter of these papers includes surface and subsurface sedimentary and volcanology studies of the Snake River Plain and surrounding areas, hydrogeological characteristics of surface and groundwater, geostatistical model involving deterministic and stochostic approaches, and the study of geochemical and microbiological processes influencing natural attenuation. The second significant accomplishment was that the data collected from some of these various studies contributed to the development of an enhanced in situ bioremediation process that degrades Tricholorethene in a contaminant plume underlying the Snake River Plain aquifer at the Idaho National Engineering and

Environmental Laboratory. The success of this innovative technology has led to a reversal of the record of decision in the CERCLA clean up action at the site from traditional pump and treat technology in favor of this new bioremediation process saving approximately $8 million in costs to DOE.

Publications from Prior Projects

1. None
2. None
3. Currently in progress.
4. Currently in progress.
5. None
6. None