Idaho Water Resources Research Institute
Annual Technical Report
FY 2006

Introduction

The Idaho Water Resources Research Institute (IWRRI) is housed at the University of Idaho. IWRRI is dedicated to supporting and promoting water and water-related research, education, and information transfer throughout Idaho. IWRRI collaborates with researchers and educators from all Idaho state universities; staff of local, state, and federal agencies; and private water interests.

The IWRRI is the only mechanism in the state that provides an autonomous statewide source of support for water research and training without regard to specific topic or discipline area. This is important because Idaho's water problems cross multiple topics and disciplines and compartmental approaches to these problems are less effective. IWRRI is relied upon by state and federal agencies and private water interests to provide the objective expertise to address the needs of the state and region.

The Institute has been a strong proponent of education and outreach for both youth and adult audiences. It is through education that the public can make informed public policy decisions concerning water. It is also through education that individual citizens become engaged in the process through adjustments of their own attitudes and lifestyles.

Research Program

The Idaho Water Resources Research Institutes research program is comprised of the following objectives: (1) To work with state and federal agencies and non-government organizations to identify water research needs of the state and region; (2) To promote water-related research relevant to state and regional needs; (3) To stimulate, coordinate, and provide leadership for water resources research within IDaho universities and collaborate with sister institutions in adjoining states; (4) To cooperate with and assist state and federal agencies and non-governmental organizations for the benefit of the citizens of Idaho and the region; (5) To encourage and facilitate public involvement in water resource programs within the state; (6) To promote water education within the state at the K-12, undergraduate and graduate levels; and (7) To develop funding for needed research and encourage cooperation with other research organizations.

The projects funded during the 2006 104B Program Fiscal Year spanned the range of water issues facing the State of Idaho. This includes projects that investigate: the impact that irrigated agricultural activities have on an areas surface and ground water quality; identifying the occurrence of arsenic contamination in ground water resources in the major population center of the State; components of the water balance for the Snake River Plain, which is currently undergoing the largest water rights adjudication effort in the United States; and factors that affect water quality in some of northern Idaho’s recreational lakes.

Seasonal variation in anthropogenic nutrient additions and food web response in a large deep lake (Lake Crescent, Olympic National Park)

Basic Information

Title:	Seasonal variation in anthropogenic nutrient additions and food web response in a large deep lake (Lake Crescent, Olympic National Park)
Project Number:	2005ID50B
Start Date:	3/1/2005
End Date:	6/30/2007
Funding Source:	104B
Congressional District:	01
Research Category:	Biological Sciences
Focus Category:	Water Quality, Surface Water, Non Point Pollution
Descriptors:	
Principal Investigators:	Stephanie Hampton, Stephanie Hampton

Publication

Seasonal variation in anthropogenic nutrient additions and food web response in a large deep lake (Lake Crescent, Olympic National Park)

RESEARCH

Shoreline development is known to degrade water quality and nearshore habitat for lake biota. Deep nutrient-poor lakes – particularly prized for their fisheries and beauty in the Pacific Northwest – may be especially sensitive to shoreline development that affects nearshore habitat. Shallow nearshore water in a steep-sided basin comprises relatively little of the total volume and surface area, but may provide the most crucial breeding habitat for fishes and, potentially, the primary feeding habitat. Even if pollutants entering at the shore are not sufficient to change open water conditions, nearshore communities may exhibit biomass and compositional changes that have disproportionately large impacts on food webs dependent on these shallow waters. In Olympic National Park, Washington, Lake Crescent has modest residential development, and nuisance filamentous algal mats are now regularly observed at developed sites.

In May 2005, I brought on Elizabeth Seminet-Reneau as a M.S. student in the Fish & Wildlife department at UI to work on localized effects of nutrient pollution in Lake Crescent. Seminet-Reneau has a strong work and educational background in limnology, fisheries, and quantitative ecology. In her first year, she collected field samples of lake organisms to complete our stable isotope data set characterizing the food web structure of Lake Crescent. The data strongly suggest substantial dependence of the animal community on nearshore resources, as hypothesized. I am presently preparing a manuscript for submission to a peer-reviewed journal, with Seminet-Reneau as second author.

For her own distinct M.S. thesis research, Seminet-Reneau is currently involved in the collection and analysis of periphyton (attached algae) and macroinvertebrate samples, to determine how community composition shifts in response to localized nutrient pollution. As part of this work, she has begun collecting samples at Lake Pend Oreille and Coeur d'Alene Lake in Idaho so that she may make generalizations about periphyton and macroinvertebrate responses to localized pollution from septic systems. In the fall she will also set up experiments designed to determine electivity of macroinvertebrates for different types of periphyton – i.e., those commonly associated with sewage pollution vs. those associated with unpolluted shorelines in oligotrophic lakes. She has formalized her periphyton counting methods but has not yet begun enumeration of samples.

Importantly, we have found that in Lake Crescent, nutrient content of the water column is generally below detectable limits, and therefore differences in nutrient pollution among sites can not be discerned using standard methods. In a lake that is still oligotrophic such as Lake Crescent, but receiving nutrient inputs, monitoring the biota in the area where pollution enters is likely to give the first detectable "early warning" of ecosystem change. We had hoped to discern an anthropogenic nitrogen signal in the algae from polluted sites, but the signature of algae may be too variable for this distinction; there is some indication that macroinvertebrates may carry the signal with more fidelity. Seminet-Reneau's 2006 summer sampling will increase our power to detect anthropogenic signal among the macroinvertebrates. She plans to present her work at the annual meeting of the Washington Lake Protection Association in the

A. **PUBLICATIONS:** No manuscripts are published yet.

B. **INFORMATION TRANSFER PROGRAM:** No activities to report yet.

C. **STUDENT SUPPORT:**

Elizabeth Seminet-Reneau, M.S. Received May 2007

	Section 104 Awards		NIWR-USGS Internship	Supplemental Awards	Total
	Base Grants	Competitive Awards			
Undergrad.					
Masters		1			1
PhD.					
Post-Doc.					
Total		1			1

D. **NIWR-USGS STUDENT INTERNSHIP PROGRAM:** No internships on this project.

E. **NOTABLE ACHIEVEMENTS AND AWARDS:** No activities to report yet.

A Reconnaissance Study of Arsenic Distribution in the Shallow Aquifer of the Treasure Valley: Year 2

Basic Information

Title:	A Reconnaissance Study of Arsenic Distribution in the Shallow Aquifer of the Treasure Valley: Year 2
Project Number:	2005ID51B
Start Date:	3/1/2005
End Date:	9/30/2007
Funding Source:	104B
Congressional District:	1
Research Category:	Water Quality
Focus Category:	Water Quality, Toxic Substances, Hydrogeochemistry
Descriptors:	
Principal Investigators:	Shawn Benner, Shawn Benner

Publication

1. Donato, M.M., K.W. Neely, B. Hoffman, S. Benner, 2005. Geochemical Processes And Mechanisms Of Arsenic Contamination In Southwestern Idaho GroundWater,in Proceedings Geological Society Of America Annual Meeting, October16-19, Salt Lake City.
2. Busbee, M., Benner, S., Hoffman, B., Cosgrove, D. 2006. Controls and mechanisms governing geogenic arsenic mobilization in the Treasure Valley shallow aquifer, Southwestern Idaho. Eos Trans.AGU 87(52),Fall Meeting.

A Reconnaissance Study of Arsenic Distribution in the Shallow Aquifer of the Treasure Valley

Project Summary

Perhaps the greatest emerging threat to water quality in Idaho is naturally occurring elevated arsenic in our groundwater-based drinking water supplies. In the most populated region of the state, the Treasure Valley, more than 40% of all tested drinking water wells exceed the new arsenic standard. The distribution of arsenic in the groundwaters of southwest Idaho is complex and not well understood and the mechanism of release has not been identified. This project is examining existing hydrologic and geochemical datasets to better understand arsenic release mechanisms in a research effort coordinated with state agencies.

Our work is ongoing but we are able to make a number of important observations. There are clear spatial trends in the distribution of arsenic in the Treasure Valley Aquifer with dissolved arsenic concentrations primarily elevated in two areas within the Treasure Valley; the first is in Canyon County and extends from Lake Lowell north and west and the second is located in Ada County north of the Boise River (Figure 1).

We have also conducted a comprehensive assessment of the well log data to reconstruct the previously observed redoximorphic boundary for the entire Treasure Valley as a continuation of work started by Donato et al. (2004). The most notable trend in this geologic dataset is the close correlation between the redoximorphic transition and both land surface and groundwater elevation, suggesting that the boundary may be a post depositional feature reflecting the historical water table across the Treasure Valley.

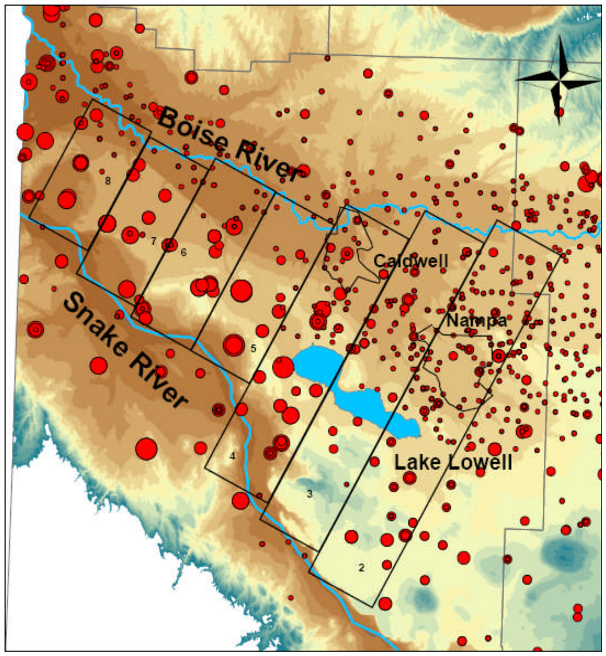

Figure 1. Treasure Valley arsenic concentrations. The size of the red circles increases with concentration.

Evaluation of existing chemical datasets in combination with grant collected samples, reveal a strong correlation between depth below the water table and arsenic concentrations with the majority of high arsenic wells sampling water from the upper 50 m of the aquifer (Figure 2). Furthermore, waters containing elevated arsenic concentrations are also oxic, not reducing, in nature. These observations suggest that elevated arsenic in the Treasure Valley is, at least in part, derived from sediments at or near the water table and is supportive of a release mechanism *other than* reductive dissolution of iron oxides.

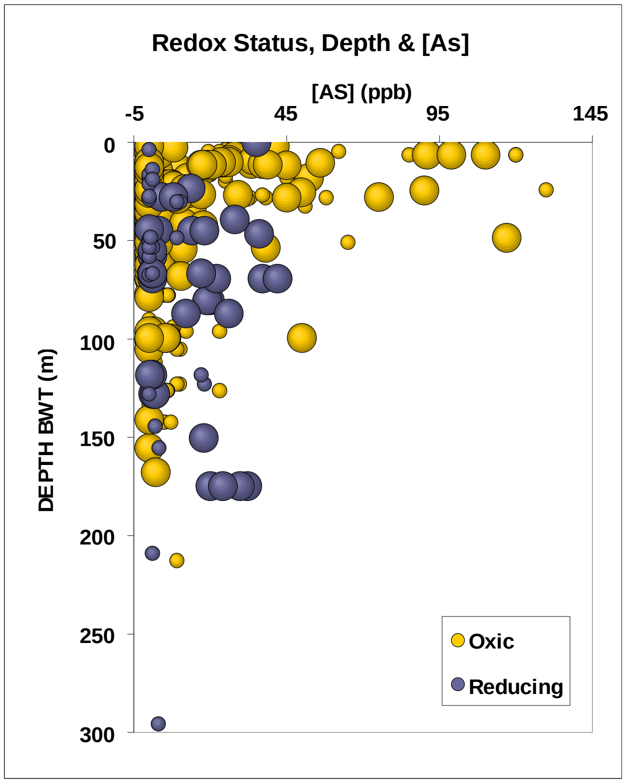

Figure 2. Arsenic concentration with depth below water table (BWT) and oxic vs. reducing conditions.

Sequential extractions conducted on near-surface sediments indicate the presence of significant amounts of easily mobilized arsenic. For example, the addition of deionized water to the sediments produces release of arsenic at concentrations of similar magnitude to those seen within the aquifer.

Collectively, these observations support a conceptual model of arsenic release whereby infiltrating irrigation waters are promoting flushing and/or desorption of arsenic from the unsaturated and near-water table sediments. Ongoing work is focusing on evaluating this conceptual model through further field and laboratory experiments and observations.

Publications Resulting from the Project

Donato, M. M., K. W. Neely, B. Hoffman, S. Benner, 2005.Geochemical Processes And Mechanisms Of Arsenic Contamination In Southwestern Idaho Ground Water, in Proceedings Geological Society Of America Annual Meeting, October 16-19, Salt Lake City.

Busbee, M., Benner, S., Hoffman, B., Cosgrove, D. 2006. Controls and mechanisms governing geogenic arsenic mobilization in the Treasure Valley shallow aquifer, Southwestern Idaho. *Eos Trans. AGU* 87(52), Fall Meeting.

Busbee, M., Benner, S., Hoffman, B., Cosgrove, D. 2006. Controls and Mechanisms Governing Geogenic Arsenic Mobilization in the Treasure Valley Shallow Aquifer, Southwestern Idaho. *Idaho Water Resources Research Symposium* Nov. 18-19, Boise Idaho.

Undergraduate and Graduate Student Researchers supported on the project

M.S. Graduate Student: Bernadette Hoffman
M.S. Graduate Student: Monty Busbee

Notable Achievements or Awards

Evaluation of remote sensing of leaf area index for estimating evapotranspiration on irrigated lands

Basic Information

Title:	Evaluation of remote sensing of leaf area index for estimating evapotranspiration on irrigated lands
Project Number:	2005ID54B
Start Date:	3/1/2005
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	01
Research Category:	Climate and Hydrologic Processes
Focus Category:	Irrigation, Management and Planning, Water Quantity
Descriptors:	
Principal Investigators:	Bryce Contor, Richard Allen

Publication

Technical Completion Report for USGS 104b Project 2005ID 54B: Evaluation of Remote Sensing of Leaf Area Index for Estimating Evapotranspiration on Irrigated Lands

B. Contor and E. Rafn
Idaho Water Resources Research Institute
June 2007

INTRODUCTION

Evapotranspiration is a major component of basin water budgets and consequently knowledge of this feature is essential to studies and planning of water management. For example, in the eastern Snake River Plain, estimates of evapotranspiration (ET) were used to represent the consumptive portion of ground water irrigation pumping in calibration of an aquifer model, and in applications of that model to determine effects of pumping upon spring discharge (Cosgrove et al., 2006) . ET estimates are often used in water balance analyses to help determine lesser-known components such as aquifer recharge.

Remote sensing can be a valuable tool in estimating evapotranspiration on large scales due to the high areal variability of ET and the difficulty of obtaining crop-mix data for large areas. In previous work, algorithms such as METRIC (Allen et al., in press, a; Allen et al., in press, b) and SEBAL (Bastiaansen et al., 1998) have made use of the thermal band data of satellites such as LANDSAT in energy-balance calculations of ET. However, the continued use of these tools is in jeopardy due to the planned discontinuation of distribution of the thermal band of data from LANDSAT (Allen, 2005 a). Additionally, SEBAL and METRIC require significant expertise and processing time, and rely upon operator selection of "hot" and "cold" pixels.

The purpose of this project was to develop and evaluate alternative means of determining the magnitude and areal distribution of irrigated ET, using visible and near-infrared bands from LANDSAT. The goal of this effort was to identify methods that are:

1. not reliant on thermal-band data
2. low cost
3. easily applied
4. objective and repeatable

The project used the existing Normalized Difference Vegetative Index (NDVI) as a proxy for leaf area index, developed relationships between this index and crop coefficients (e.g. the ratio of ET for a specific crop and field to reference ET), and tested relationships developed by others. Other remote-sensing indices using LANDSAT visible and near-infrared data were also explored.

Some of the relationships developed in this project, as well as one externally-developed relationship, were calibrated to METRIC-estimated crop coefficients for specific locations and periods. All relationships were tested by application to another location and comparison with METRIC estimates of crop coefficient for that location. The cost and time requirement for application were also evaluated to help assess the potential for practical application of the method.

This research indicates that NDVI-based estimates of crop coefficient produce full-season, wide-area results that are within ten percent of the METRIC remote-sensing results, even when prediction equations were derived from different areas. In fact, two of the successful relationships were developed in a different state than the test location, and in a different decade. NDVI-based estimates may be prepared at significantly less cost that METRIC estimates, are independent of thermal-band data and require no operator judgment for selection of "hot" and "cold" pixels. Except for very early in the spring, the temporal distribution of NDVI-based estimates is similar to the METRIC estimates. However, the individual-pixel frequency distribution of NDVI-based estimates does differ from METRIC, and this can translate into spatial effects of practical concern at resolutions finer than a township (six mile by six mile) basis if crop distributions are not uniform.

Part of the findings of this research are reported in an article submitted to the journal Remote Sensing of Environment (Rafn et al., in review). A draft accompanies this report as file "Rafn et al_NDVI_Kc_2007.pdf".

METHODS

The study had three basic phases:

1. Review and calculate various remote-sensing vegetative indices.
2. Develop NDVI/K_c relationships and obtain relationships from the research of others.
3. Test relationships.

Review and calculate indices

Reviewed indices included the Normalized Difference Vegetative Index (NDVI, Payero et al., 2004), Soil Adjusted Vegetative Index (SAVI, Payero et al., 2004), MSAVI (Modified Soil Adjusted Vegetative Index, Payero et al., 2004), Second Derivative indices (Li et al., 1993), and the Band 5/Band 7 ratio (Musick and Pelietier, 1988). The procedures and equations for each of these were obtained from the literature, and applied to digital numbers ("raw" satellite data) and at-satellite reflectance values ("processed" data, obtained from M. Tasumi at U of Idaho Kimberly) for LANDSAT Row 30, Path 39 and Path 40, which cover most of the irrigated agriculture in south east and south central Idaho, respectively. Resulting scatter plots were assessed visually, with some statistical testing of promising candidates.

Develop and obtain NDVI/K_c relationships

Evapotranspiration may be estimated using equation (1) (Allen et al., 1998):

$$ET_{crop} = K_c * ET_{ref} \quad (1)$$

where ET_{crop} = actual evapotranspiration for a given crop or parcel
K_c = crop coefficient (also known as ETrF)
ET_{ref} = reference ET; a measure of the evaporative power of the atmosphere, calculated from local weather data or derived from pan evaporation or lysimeter measurements.

An alternative is to separate the evaporation and transpiration components in a "dual coefficient" approach (Allen et al., 1998) as shown in equation (2), or as alternately expressed in equation (3):

$$ET_{crop} = (K_{cb} + K_e) * ET_{ref} \quad (2)$$
$$K_c = K_{cb} + K_e \quad (3)$$

where K_{cb} = basal crop coefficient
K_e = soil-evaporation coefficient

The goal of this research was to develop methods to predict K_c for use in equation (1). Following the selection of NDVI as the index for further work, three equations for predicting K_c were obtained from other researchers, and additional equations were developed within the project.

One method to construct such equations is to use statistical regression with a set of "known" data. Equation (4) is a prediction equation for K_c developed by M. Tasumi of University of Idaho in Kimberly (Tasumi et al., 2006; Tasumi, 2006) using Ordinary Least Squares (OLS) regression. In developing the equation, Tasumi used the K_c or ETrF values from METRIC ET estimates (developed by Tasumi and others) from Path 40, year 2000 as the "known" values for K_c.

$$K_c = 0.05 + 1.1875 * NDVI \quad (4)$$

Working in Colorado, Bausch, Neale and others (Bausch and Neale, 1989; Neale et al., 1989) developed equations (5) and (6) for predicting K_{cb} using a physically-based deterministic approach founded on knowledge of the transpiration processes represented by K_{cb}. Using hand-held devices to read reflected radiation, they identified the NDVI for a bare soil and set this value equal to K_{cb} of zero. Then, the NDVI for full-canopy corn was set to an upper-limit K_{cb} value. Intermediate values of NDVI were linearly interpolated between these limits. The equations were developed at different sites, and the difference between them is primarily due to the difference in bare-soil characteristics.

$$K_{cb} = -0.026 + 1.181 * NDVI \quad (5)$$
$$K_{cb} = -0.053 + 1.092 * NDVI \quad (6)$$

In this project, we applied OLS regression to various data sets, using Tasumi's METRIC K_c or ETrF as the "known" value. We also applied non-parametric regressions (Kendall-Theil Robust Line, Line of Organic Concentration) (Helsel and Hirsch, 2002) to some of these same data sets. In addition, following the lead of Neale and others, we used a physically-based approach. However, rather than measure NDVI in the field, we assumed that cutoff values could be extracted from the data; we set the 2nd percentile NDVI equal to K_{cb} = zero and the 98th percentile equal to K_{cb} = 1.10. We acknowledge that this process could be improved by calibrating the cutoff values to METRIC or other "known" data, though we did not do that. We applied this method to several different full- and partial-area, as well as full-season and single-date, data sets. Equation (7) is an example of one such percentile-based equation, obtained by applying the algorithm to full-season data from the entire Path 40 image:

$$K_{cb} = -0.132 + 1.47 * NDVI \quad (7)$$

<u>Testing of relationships</u>

We tested the applicability of equations to geographic regions other than the area of development by using a formal statistical test to compare the slopes of two Kendall-Theil Robust Line equations developed in different areas. This test failed; the slopes, though similar, were statistically different. Because the assumptions of OLS were not met, this type of test could not be applied to OLS equations.

We tested the practical applicability of various equations by comparing full-season, wide-area ET estimates of mean ET depth to the Tasumi METRIC estimates, using a "two one-sided test" procedure (Manly, 2001) to address the statistical difficulties associated with testing whether two methods are equivalent (traditional statistical testing, and the error protections inherent, are designed for testing whether methods or data sets *differ*). The various equations were deemed acceptable if their mean seasonal depth was within 10% of the METRIC depth at the alpha = 0.05 confidence level. In testing the K_{cb} prediction equations, we applied a very simplistic representation of K_e to equation (3) in order to obtain K_c.

Further testing was done by visually comparing histograms and seasonal patterns of K_c predicted by various methods, and by comparing mean depths across various-sized regions using GIS analysis. These spatial and temporal comparisons were made by normalizing all estimates to equal global mean seasonal K_c so that the comparisons only illustrated spatial and temporal characteristics. This implicitly assumes that any of the methods could be refined by calibration to produce an adequate mean result for a given study area.

FINDINGS

Findings include:

1. Literature suggest that the NDVI index is less robust than some other indices to differences in soil color and condition at low vegetation densities (Li et al., 1993); this would affect accuracy of NDVI-based estimates for early and late growth stages.
2. Despite finding (1), the NDVI index was selected over other vegetation indices for this application, due to its resistance to atmospheric effects (Allen, 2006), its more linear relationship to crop coefficient, its ease of applicability and the fact that it is generally recognized and understood.
3. An index based on LANDSAT band 5 and band 7 data, which is designed to be responsive to soil moisture, was added to the NDVI regression equation in an attempt to overcome obstacle (1). However, the improvement in predictive ability (as indicated by the adjusted R^2 statistic) was too small to justify the addition of an additional predictor in the equation.
4. "Digital numbers" (raw satellite data) do not provide consistent results; satellite data must be processed to "reflectance" values prior to calculating vegetation index.
5. NDVI/crop coefficient relationships are of practical use for estimating wide-area, full-season ET depth on irrigated lands.
6. Relationships developed in other areas may be applied to irrigated lands in eastern Idaho.
7. Relationships developed in a given year may be applied to subsequent years.
8. Except for early-spring differences (when NDVI-based estimates do not capture ET from wet, bare soil), the temporal pattern of NDVI-based crop coefficients matches the temporal pattern of METRIC-based crop coefficients.
9. OLS equations (even when applied to a different path than where developed) are practically useful, though the residuals characteristics resulting from applying OLS regression to these data preclude formal testing of hypotheses (Helsel and Hirsch, 2002).
10. The tested physically-based methods, though developed in Colorado on different soils and with corn, during a different decade, are practically useful in eastern Idaho even using simplistic estimates of K_e.
11. Even though the cutoff percentiles were not calibrated, percentile-based equations produced practically useful results. Though not formally tested against METRIC seasonal totals, equations based on summer-time-only data had very similar slope and intercept to equations based on full-season data, as long as a full range of NDVI values were represented in the data.
12. The Kendall-Theil Robust Line equation uses an intercept based on the median rather than the mean (as does OLS). Whenever data have a skewed distribution, the mean and median will differ. With these data, the Robust Line produced estimates of ET depth consistently higher than other methods.
13. The Line of Organic Concentration equation produced overall estimates similar to other methods (except the Kendall-Theil Robust Line).

14. Regressions (OLS or non-parametric) require a full set of "known" data for calibration. The physically-based method requires measurements of the bare soil and full-canopy NDVI. The percentile-based method requires no outside data but relies upon the assumptions used in selecting the cutoff percentiles (or in the data used to calibrate them).
15. Across multiple pixels, the histogram distributions of the various NDVI-based coefficients are visually quite different from one another, as well as from the distribution of METRIC-based coefficients. This raises concerns with spatial distribution of estimated ET, if crop distribution is not uniform throughout a study area or if localized measures of ET are important to the purpose of the estimates. (Note, however, that crop distribution data for non-remote-sensing methods are often only available at a spatial resolution of county- or state-wide averages.)
16. Testing suggests that on irrigated lands in south-central Idaho for water-year 2000, averaging at a county scale appears to generally overcome differences in spatial distribution between methods, but on a township (six miles by six miles) or smaller basis, differences in methods may approach a level of practical concern.
17. It appears that NDVI-based ET estimates can be prepared in approximately 20 person-days for an area represented by two LANDSAT paths, one row, using 16 images per irrigation season. This contrasts with an estimate of 56 person-days to prepare corresponding METRIC ET estimates (Allen, 2005 b). Further, the METRIC estimates require technicians of greater skill and knowledge than do the NDVI-based estimates.

In addition to the article by Rafn and others, which has been submitted to document findings (5) and (6), it is anticipated that other findings will be the subjects of future journal article(s) by Contor and Rafn.

STUDENT INVOLVEMENT

The project provided a summer internship for one undergraduate geology student, and provided a one summer of work experience for a different student in a master's degree program in GIS systems. The first journal article prepared under this project is part of that student's degree requirements and comprises part of the thesis.

FURTHER RESEARCH

The concept of ET encompasses separate physical processes of evaporation and transpiration. Theoretically, the dual-coefficient approach taken by Bausch, Neale and others (Bausch and Neale, 1989; Neale et al., 1989) is more sound than using NDVI to predict combined K_c, because vegetative indices are designed to respond primarily to vegetation. With further research to provide more robust wide-area estimates of K_e, a dual-coefficient approach could improve upon the results presented here.

The percentile-based approach is attractive because it can be performed without a calibration data set, once appropriate cutoff percentiles are determined. Its good performance in this test, despite the fact that the cutoff percentiles were not calibrated, suggests that this method can be made even more useful with further research to refine understanding of the selection of cutoff percentiles.

Another potentially profitable study area would be to continue to explore indices other than NDVI, in order to better reject the soil signal and more consistently represent leaf cover at low densities (Gardner and Blad 1986).

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Evaluation of temporal variations of the nitrate concentrations in ground-water of the Ashton, Idaho area and potential causative factors.

Basic Information

Title:	Evaluation of temporal variations of the nitrate concentrations in ground-water of the Ashton, Idaho area and potential causative factors.
Project Number:	2005ID55B
Start Date:	3/1/2005
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	01
Research Category:	Water Quality
Focus Category:	Nitrate Contamination, Water Quality, Non Point Pollution
Descriptors:	
Principal Investigators:	Gary Steven Johnson, Mark Lovell

Publication

ANNUAL REPORT: U.S. Geological Survey 104b Program
2005ID 55B and 55B(S): *Evaluation of temporal variation of the nitrate concentrations in ground-water of the Ashton, Idaho area and potential causative factors*
And
2006ID 65B: *Evaluation of levels of success of diagnostic and remediation efforts for nitrate contaminated ground waters with application to the Ashton, ID area*.

Project Summary

The two projects, *Evaluation of temporal variation of the nitrate concentrations in ground-water of the Ashton, Idaho area and potential causative factors* and *Evaluation of levels of success of diagnostic and remediation efforts for nitrate contaminated ground waters with application to the Ashton, ID area* are linked, and the status and progress of these two projects are therefore provided in this single report.

Beginning fall 2005, Mark Lovell received partial funding in support of a sabbatical leave from Brigham Young University-Idaho (BYU-Idaho). This leave provided the opportunity for Lovell to attend the University of Idaho, Idaho Falls campus full time for two semesters. In addition to completing course work, research time was focused on three main topics:

- Procedures and techniques used to identify ground water contamination problems caused by excess nitrates and associated mitigation efforts to remediate the contaminated aquifers.
- The successful components of developing an undergraduate research experience (URE) and the adaptation and development of an ongoing research hydrologic field study for undergraduates.
- Application of case studies for nitrate contamination and remediation to the Ashton, Idaho area.

The great majority of resources provided by the grants have been devoted to two parts of the proposals; first, establishing and performing field activities including collecting water samples from domestic wells, measuring water table elevations, and processing samples using an ion chromatograph to evaluate concentrations of fluoride, chloride, nitrate, and sulfate; second, working with undergraduate students, training them how to participate in data acquisition and processing of samples.

In addition to funding provided through these grants, BYU-Idaho has and continues to support this program in several ways. While on sabbatical leave, partial salary support was provided to Mark Lovell. In addition, approximately $20,000 dollars worth of lab & field equipment were purchased and additional lab consumables, leveraging the supplies and equipment provided through these two grants. Major equipment purchased through BYU-Idaho includes a bench top ion chromatograph (Dionex IC-90) with manual injection, a Hach multi-probe (Quanta) to monitor discharge water to allow verification of pumping fresh formation waters prior to collecting water samples, and an electric tape for measuring depth to water table.

In the Idaho Department of Environmental Quality's (IDEQ) ranking of Nitrate Priority (Neely, 2005) the Ashton, Drummond, and Teton area was identified to rank #8 on the State of Idaho's top twenty-five Nitrate Priority Areas. Located approximately 30 miles north of Rexburg, Idaho home for the campus of BYU-Idaho, this seemed to be an ideal area to establish a groundwater study focused on nitrate contamination (figure 1). The regional setting of the Ashton area consists primarily of agricultural activities growing grains, alfalfa, potatoes, and some canola, in addition to a few cattle operations where herds are fed through the winter and then transported to summer pastures. There are also a growing number of residential sites with septic systems including the small town of Marysville which is located up gradient to the direction of ground water flow that provides drinking water for the town of Ashton. This combination of potential sources for nitrates makes it difficult to identify a unique source for the observed contamination problems.

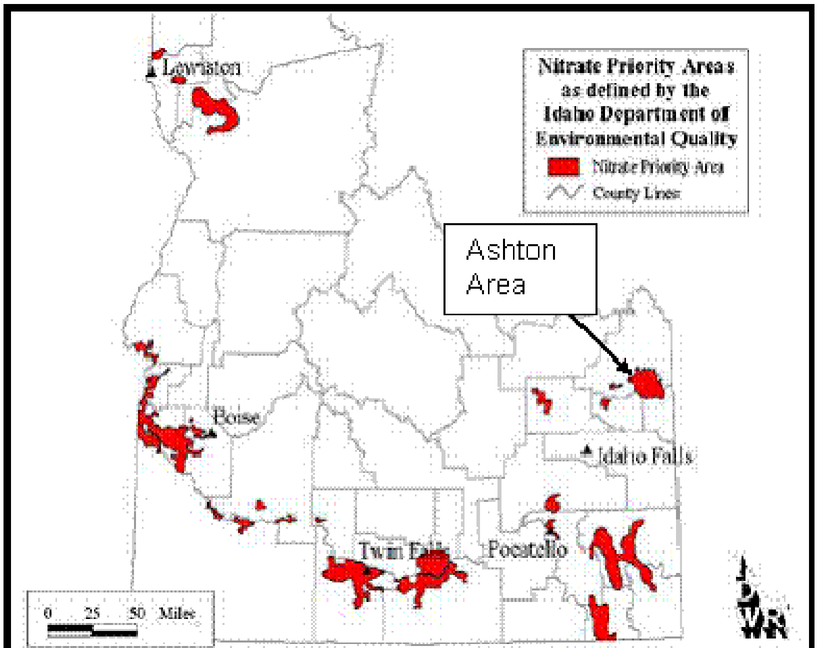


Figure 1. Nitrate Priority Areas modified from Neely 2005.

Funding was used to purchase two Hach Hydrolab-5 down-hole multi-probes, each with data-loggers, and probes for measuring nitrate, pH, specific conductance, and pressure transducers. The nitrate probes were known to have lower sensitivity (+/- 2 mg/l N as total Nitrogen) and a tendency to drift which required weekly calibration efforts. After deploying one of the probes in an abandoned well bore located approximately 10 feet from a small irrigation well, the data looked suspect (figure 2)

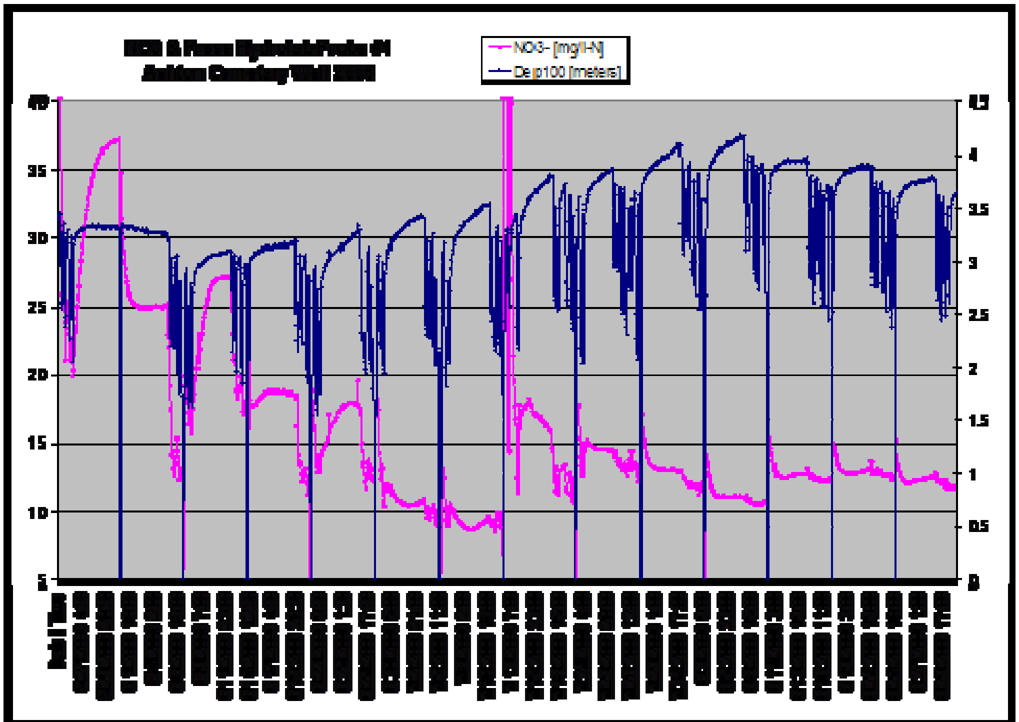


Figure 2. Nitrate and pressure data collected from probe #1.

In figure 2 we see the pressure response indicating water column thickness above the probe allowing identification of pumping events due to the associated drawdown. A zero value was added to the pressure data each time the probe was removed from the well for calibration. The observed nitrate concentrations appear to be diminished each time a pumping cycle occurs. This observation could possibly represent a type of mixing where shallow contaminated waters are being mixed with fresher water drawn in during the pumping cycle. Other observations of the data indicate that overall, nitrate concentrations were seen to decline throughout the year with the exception of the nitrate spike that occurred in mid July. In the small building which encloses the open well there is a sack of lawn fertilizer that is open. The spike may represent an inadvertent spill of some of the fertilizer on the floor that found its way into the well.

A second observation made possible from the data in figure 2 is the seasonal variation of the water table. The lowest observed water table is indicated to have occurred in early-June while the highest occurred in mid-August. It is interesting to note that maximum water-table elevation only persisted for about one week before beginning to decline.

To try and validate the nitrate response as seen by probe #1, the second Hydrolab was also deployed in the same well. Efforts were made to calibrate the probes on different days to allow one probe to be in the well monitoring when the second probe was pulled out, calibrated, data-downloaded, and then re-deployed. Figure 3 shows the data accumulated using probe #2 for nitrate concentration and for pressure/water table.

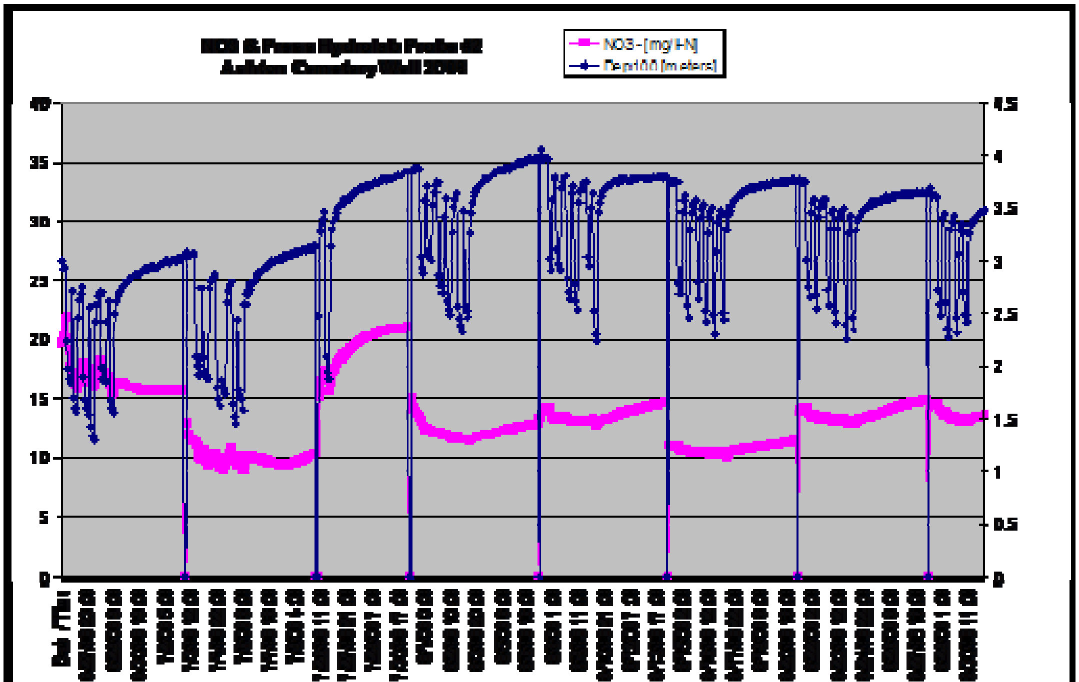


Figure 3. Nitrate and pressure data collected from probe #2.

Unfortunately, probe #2 experienced a mechanical (electronics) failure and several weeks worth of data were lost due to inability to communicate with the probe to download data and for the time lost while the probe was sent to the manufacturer for repairs. Figure 4 shows the nitrogen values for both probes compared on one chart. With the exceptions of the first week that probe #2 was used and the first week of use after probe #2 was repaired, the concentration of nitrates observed by the two probes is similar but there are differences in the shape of the responses that still needs to be evaluated.

The specific conductance of the water as measured by the Hydrolabs over the season showed a continuous trend to fresher waters from the start of measurements until about the end of July. Measurements by probe #1 show a step-wise patter because the wrong scale was selected for recording the data allowing the instrument to record 600 or 700 µS/cm (see figure. 5).

In addition to work related to using the down-hole Hydrolabs, water samples were also collected during the 2006 field season. Over 90 samples were collected from 21 sites using the Hach multi-probe to monitor water parameters at the time of pumping. Titrations using sulfuric acid were performed in the field to establish concentration of $CaCO_3$, and all samples were analyzed within 48 hours using the ion chromatograph (IC) to establish concentrations of fluoride, chloride, nitrate, and sulfate. The IC runs also analyzed samples for nitrite, bromide, and phosphate but these compounds were not detected.

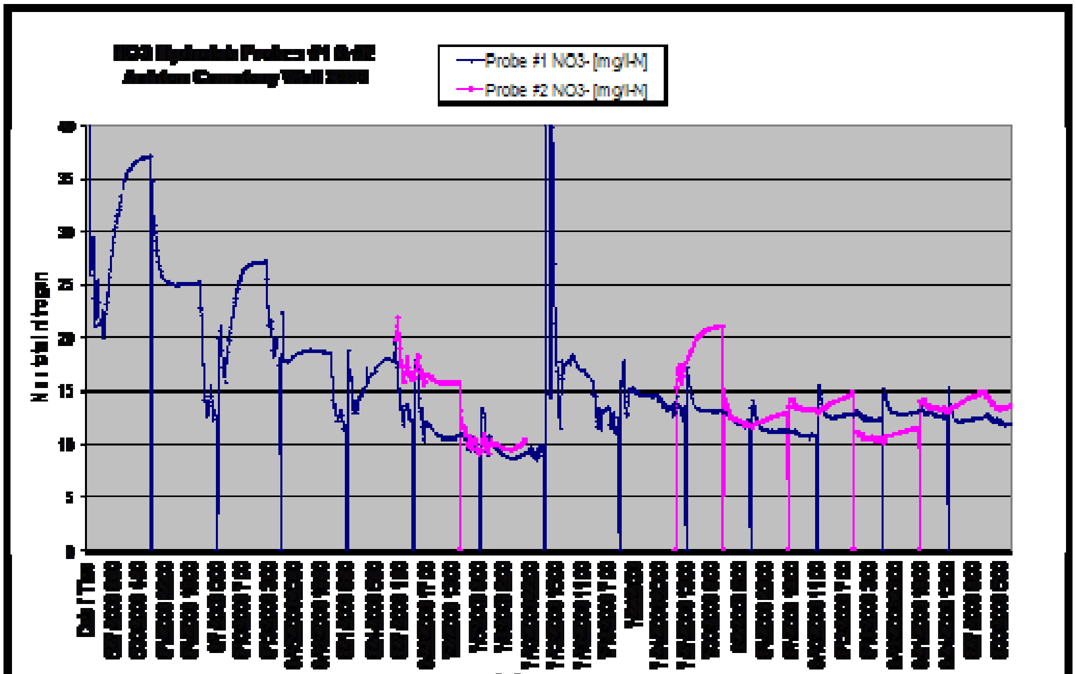


Figure 4 Nitrate values compared for both probes #1 and #2.

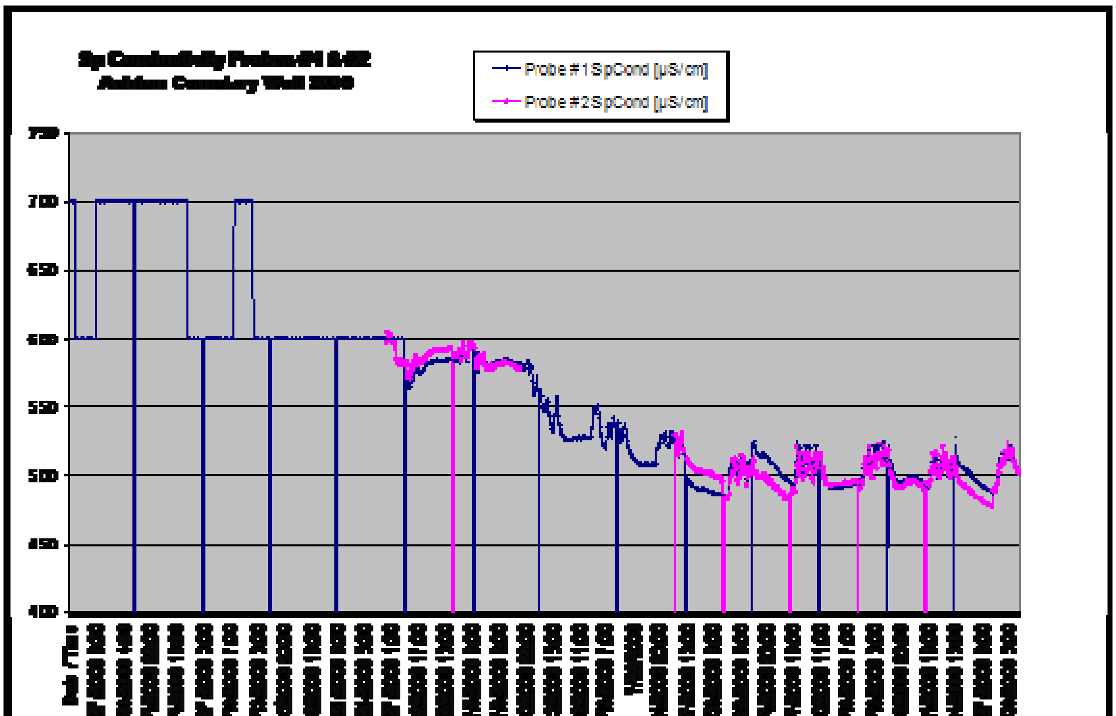


Figure 5. Probes #1 and #2 showing values for specific conductance.

After the first couple of weeks of sampling it became apparent that water table elevation information was highly desirable causing the abandonment of monitoring in some wells in favor of other wells which could be accessed for measuring water table elevations. Thirteen of the twenty-one sites sampled provided access to measure water table elevations. Work continues creating maps of the water table trying to represent the changes of elevation through time for the 2006 water season. The water table appears to act somewhat like a trap door, hinged along the Henrys Fork of the Snake River where the river has downcut into the aquifer. Numerous springs located along the south side of the river and projected elevations of the water table to the canyon wall based upon well measurements support this interpretation. To the south side of the valley, closer to Fall River, changes in water table elevation throughout the summer varied by nearly 10 feet while wells closer to the Henrys Fork showed only two-three feet of seasonal change.

Publications Resulting from the Project

None to date

Undergraduate and Graduate Student Researchers Supported

One PhD graduate student at the University of Idaho, Mark Lovell, has been funded by and participated in this research. Mr. Lovell has served as advisor and directed the work of multiple BYU-Idaho undergraduates in this project.

Undergraduate student participation has been one of the highlights of the project. For the 2006 sampling season, three undergraduate students at BYU-Idaho participated. One student graduated in geology in Dec. 2006. A second student, majoring in geology with a minor in chemistry will graduate Dec. 2007. The third student of the 2006 group is an agriculture major who was working part-time for the US Soil Conservation District in Fremont County.

These students help plan which wells to sample, contacted well owners asking permission, collected and processed samples. Water table and results from the IC analyses were also used in classes during the 2006/2007 school year. Equipment was used by the BYU-Idaho Geol 435 (Hydrology) course to collect samples from wells within the Ashton program as part of major projects for the class. Other students in the hydrology class also worked with the water table data trying to determine the extent of change through time and possible implications for direction of water flow in the subsurface and how it might change throughout the water season. Figure 6 shows one of the students who worked to process samples using the IC machine located in the George S. Romney Science building at BYU-Idaho.

Three additional students have been participating in the Ashton project in 2007.

Figure 6. BYU-Idaho student using the IC

Notable Achievements or Awards

None

Award No. 04HQAG0205 Initial Model Development of the Spokane Valley Rathdrum Prairie Aquifer Project

Basic Information

Title:	Award No. 04HQAG0205 Initial Model Development of the Spokane Valley Rathdrum Prairie Aquifer Project
Project Number:	2005ID71S
Start Date:	7/20/2004
End Date:	8/31/2006
Funding Source:	Supplemental
Congressional District:	
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	

Publication

Synopsis
Idaho Water Resources Research Institute 104b Project
March 1 2005 - February 28 2006

1. Title: INITIAL MODEL DEVELOPMENT FOR THE SPOKANE VALLEY –RATHDRUM PRAIRIE AQUIFER PROJECT

2. Project Number: 2005ID71S

3. Start Date: March 2005

4. End Date: September 2006

5. Funding Source: Supplemental.

6. Research Category: Ground Water Flow and Transport

7. Focus Categories: Groundwater
   Models
   Water Quantity

8. Descriptors:

9. Primary PI: Gary Johnson, :Professor, University of Idaho, johnson@if.uidaho.edu

10. Other PI:

11. Project Class: Research

Project Summary:

This Cooperative Agreement was established to provide the Idaho Water Resources Research Institute with funding to become involved in initial efforts on the Spokane Valley – Rathdrum Prairie Modeling Project. This project is a collaborative effort of the USGS, the states of Idaho and Washington, and others. This initial stage was comprised of largely a planning effort, and the overall project is not scheduled for completion until 2008.

There were three specified tasks in the Cooperative Agreement. The following discussion provides a summary of how these tasks were addressed and potentially evolved in the project period. These tasks are intimately connected,

so a complete separation of activities is not possible. Also provided are estimates of the funding expended on each of the tasks.

TASK A

Compile and review existing ground water/surface water models for the study area: conduct preliminary model runs using existing ground water/surface water models to evaluate model conceptual elements (boundary conditions, recharge and discharge, etc.); and identify additional data requirements.

A complete set of documents describing existing models in the Spokane Valley and Rathdrum Prairie has been assembled and reviewed. The Buchanan (1999) model has been the focus of our work because the model extent is similar to the scale of the present investigation. The Buchanan model has been run by all partners in the effort including IWRRI. This model has been selected as the basis from which the new model will evolve. Several steps in that evolution have already occurred in the partnership. Those steps include: a) conversion to operate in MODFLOW 2000, b) extension of the model domain to cover all areas of interest, c) refinement of the model grid, d) distribution of Buchanan aquifer properties and recharge and discharge to the new grid, e) conversion of lakes from fixed head to "river" cells, f) adjustment of aquifer thickness to represent present estimates. In the process of performing initial model runs, the modeling team (including IWRRI) has made assessments and recommendations of additional data requirements.

This task was also amended to include initiation of a review of the interconnection and flux between the aquifer and 9 lakes along the perimeter. A graduate student has been assigned to conduct the evaluation. Pressure transducers have been deployed in most of the lakes and in nearby wells. The program procedures have been reviewed by the Modeling Team and some existing data analysis is underway.

Estimated Expenditures on Task: $27000

TASK B

Work with project partners to help to determine data requirements for numerical model development. Data requirements will include the collection of historical data and the collection of new field data. These data requirements will be meant to serve the needs of the ground water modeling task as well as more general project needs.

The IWRRI researchers have been working with the rest of the modeling team to identify future data requirements. Part of this effort is associated with performing preliminary model runs to gain an improved understanding of data deficiencies, consequently there is overlap between this task and the first task. Data deficiencies have been discussed in video and phone meetings with the rest of the Modeling Team and have been transmitted to the Program Technical

Leadership Team(PTLT) in writing. The PTLT has been responsive and has also requested Modeling Team input on other data collection suggestions. The Modeling Team (including IWRRI) has responded.

Estimated Expenditures on Task: $7840

TASK C
Work with project partners to develop an FY05-07 work plan for developing a ground water/surface water model for the SVRP study area. This task will include meeting with project partners and interested constituents to determine modeling requirements and to determine what questions are to be addressed via ground water modeling so that the planned ground water/surface water modeling effort addresses project needs to the fullest extent possible. The SVRP Modeling Team will select the modeling code(s) to be used, and the modeling work plan will address both steady state and transient versions of the ground water/surface water model.

There have been multiple iterations on a modeling work plan within the modeling team. Within the process the roles of team members has become more refined. A draft work plan was submitted to the PTLT for comment. Those comments were subsequently addressed by the Modeling Team. The work plan continues to evolve as the project progresses. It has been developed such that modeling efforts will be complete in December 2006. It has been determined within the Modeling Team that MODFLOW 2000 will be used and that PEST will be applied to parameterize the model. The steady state model is under active development, efforts on the transient model (1995-2005 calibration period) will follow.

Estimated Expenditures on Taskt: $7839

Assessment of Impacts of Population Growth on Ground Water Nitrate Loading in Teton County, Idaho

Basic Information

Title:	Assessment of Impacts of Population Growth on Ground Water Nitrate Loading in Teton County, Idaho
Project Number:	2006ID57B
Start Date:	3/1/2006
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	Second
Research Category:	Ground-water Flow and Transport
Focus Category:	Nitrate Contamination, Groundwater, Water Quality
Descriptors:	None
Principal Investigators:	Donna Cosgrove

Publication

Synopsis of Research

Project Title
Assessment of Impacts of Population Growth on Ground Water Nitrate Loading in Teton County, Idaho

Principal Investigators
Donna M. Cosgrove and Joanna L. Taylor, University of Idaho, Idaho Water Resources Research Institute, Idaho Falls, 83402.

Students Supported on the Project
Ms. Cami Johnson, a summer IWRRI intern, who assisted with sampling and Mr. Gary Billman, a summer IWRRI intern, who prepared GIS maps of Teton County.

Statement of the Problem and Research Objectives
Nitrate levels have become a concern in Teton as well as Ada, Canyon, and Madison Counties in Idaho due to the rapid changes in land use from agricultural to housing developments. This rapid influx of septic systems from the increased housing developments has raised concern both within Idaho Department of Environmental Quality (IDEQ) and among citizen's groups over potential nitrate contamination of the ground water. The Idaho Water Resources Research Institute (IWRRI) was approached by IDEQ and two Teton Valley citizen groups, the Valley Advocates for Responsible Development (VARD) and the Friends of the Teton River, requesting that IWRRI assist in assessing the potential for future water quality degradation due to this rapid population growth in Teton County, Idaho.

The objective of the study was to establish nitrate levels throughout Teton County, Idaho for 2006 and determine whether nitrate concentrations have changed significantly since 2002 USGS water quality sampling.

Well Selection
Forty-nine wells were selected for ground-water sampling. We attempted to sample as many of the 2002 wells as possible. Of the 49 wells sampled in 2006, 17 were sampled in the 2002 study. The rest of the wells were selected to a) provide good spatial coverage of the valley and b) provide a higher sample density in sensitive areas such as wetlands or areas close to the Teton River. In addition to sampling groundwater in the valley, 11 surface water sites were sampled.

Water Chemistry Analysis
The groundwater samples where analyzed for dissolved oxygen (D.O.), pH, specific conductance, temperature, oxidation reduction potential (ORP), and alkalinity in the field. Groundwater samples and 11 surface water samples were collected and brought back to the lab for analysis of major cations and anions (Na, Ca, Mg, K, NH_4, F, Cl, SO_4, NO_3, and PO_4) using an Ion Chromatography (IC).

Results

Water Chemistry

The groundwater chemistries of Teton County were plotted on a Piper diagram. The diagram indicated that the groundwater in Teton County is very uniform and predominantly Ca-Mg-HCO3 water with the exception of one sample, which had high levels of NaCl. The well is located near a highway maintenance facility, so the high levels of NaCl may reflect road salt leeching into the ground in the vicinity of the facility.

Nitrate Concentrations in Teton County

The nitrate concentrations in all 49 ground-water samples and 11 surface-water samples were below the EPA regulatory limit of 10 mg/L NO_3-N. The highest nitrate concentration measured in Teton Valley was at 8.17 mg/L NO_3-N and only 10% of the ground-water samples were greater than 5.0 mg/L NO_3-N. All other ground-water samples were below 5.0 mg/L NO_3-N. One surface-water sample had a slightly elevated nitrate level (7.64 mg/L NO_3-N); however, all other surface water samples were below 5.0 mg/L NO_3-N. The six highest nitrate samples which where greater than 5.0 mg/L NO_3-N, are spatially distributed throughout the study area. One is located west of the river and the other four ground-water samples and the single surface-water sample are located east of the river and evenly distributed north to south.

Nitrate Concentrations in 2002 and 2006

As mentioned earlier, the USGS conducted previous sampling of ground water in the Teton Valley in 2002 for 17 of the 49 wells sampled for this study. We compared previous and current nitrate concentrations for those 17 wells. We observed both increases and decreases in nitrate concentrations from 3 mg/L to less than 1 mg/L NO_3-N from 2002 to 2006. Two wells sampled showed a decrease of 1.65 and 2.63 mg/L NO_3-N, while three other wells sampled showed increase of 1.69, 1.09, and 1.09 mg/L NO_3-N. The other twelve wells exhibited slight increase or degrease of less than 1 mg/L NO_3-N, four wells had an increase, while the other eight wells had a decrease. Wells in the Fox Creek and Victor, Idaho area exhibited a decrease in nitrate concentrations while the wells north of Driggs exhibited both increases and decreases. Overall, there has been little change in nitrate concentrations between 2002 and 2006, with no apparent spatial trends.

Discussion and Conclusions

The water quality investigation in Teton County does not show any alarming results. Even wells with the highest concentrations of nitrate levels are well below the EPA regulatory limit of 10 mg/L NO_3-N, indicating no immediate problem. Wells with higher nitrate concentrations were not located within a specific region in Teton County, but were distributed throughout the county. However, care should be taken to limit the permitted density of onsite wastewater systems and not permit onsite waste water systems in or near ecologically fragile wetlands. Future work should be done to monitor the seasonal fluctuations of nitrate in groundwater. With the rapid growth in the region and the corresponding increase in the number of onsite wastewater and drain fields, nitrate concentrations should be regularly monitored to ensure safe drinking water for private well owners and to avoid contamination of the aquifer or river.

Publications

Cosgrove, D.M. and J.Taylor. 2007. Preliminary Assessment of Hydrogeology and Water Quality in Ground Water in Teton, County, Idaho. Idaho Water Resource Research Institute Technical Report 07-002.

A geochemical investigation of groundwater sources in the Blackfoot River and Snake River floodplain

Basic Information

Title:	A geochemical investigation of groundwater sources in the Blackfoot River and Snake River floodplain
Project Number:	2006ID60B
Start Date:	3/1/2006
End Date:	5/15/2007
Funding Source:	104B
Congressional District:	First and Second
Research Category:	Ground-water Flow and Transport
Focus Category:	Groundwater, Water Supply, Hydrology
Descriptors:	None
Principal Investigators:	J. P Mcnamara, J. P Mcnamara

Publication

Blackfoot River
Groundwater-Surface Water
Interface Investigation
Blackfoot, ID

Preliminary Data and Report
6/25/07

Groundwater-Surface Water Interface Investigation – Blackfoot, ID

I. Introduction

The Eastern Snake River Plain Aquifer (ESPA) is a Sole Source Aquifer (EPA, 1990) and vital to over 400,000 people as a source of irrigation and drinking water. The Snake River is equally vital for irrigators who pump from its aquifers for crops and stock water. Recent drought has caused concern for upper Snake River tributaries which are dependent on recharge from the aquifer. Land managers note that water being pumped from the ESPA for agricultural and domestic use may impact flow of the Blackfoot River at Blackfoot, Idaho. Knowledge of the hydraulic connection of groundwater to the river channel is critical to floodplain management of the Blackfoot River. While considerable work has been done to evaluate how agricultural practices impact flows in the Snake River, little is know how these practices impact tributaries. The Blackfoot River is particularly sensitive because it runs parallel and close to the Snake River for approximately 30 miles, and intensive agriculture exists in the floodplain between the two rivers. Further, the boundary for the heavily used ESPA groundwater model used by numerous agencies does not include the upper Blackfoot River watershed. Consequently, the impacts of agricultural practices on flows in the Blackfoot River are not well understood. Flow levels in the Blackfoot River are of interest to numerous agencies and stakeholders. For example, seventeen segments of the Blackfoot River are listed as impaired on the Federal Clean Water Act 303(d) list. Currently, an interagency effort is being organized to evaluate the water resources in the Blackfoot River watershed. This proposal outlines an initiative to bring Boise State University into this working group.

A key first order problem from a water management perspective is simply delineating the watershed boundary through the shared floodplain between the Snake and Blackfoot rivers (SBR). Are groundwater withdrawals from specific wells coming from the Snake River watershed, the Blackfoot River watershed, or a mixture of both? We propose to evaluate relative proportions of Blackfoot River water and Snake River water in wells across the Snake/Blackfoot floodplain and to map hydraulic heterogeneities due aquifer withdrawal using geochemical tracer techniques.

Objectives:

1. Conduct a reconnaissance investigation of surface water and groundwater in the Snake and Blackfoot watersheds upstream of the SBR floodplain to identify isotopic and geochemical signatures.
2. Sample groundwater wells in the SBR floodplain for isotopes and apply mixing models to determine relative proportions of Snake River and Blackfoot River water.

II. Discussion

Geochemical tracers

Over the past decade, radiogenic isotopes have been increasingly applied to studies of catchment hydrology, water-rock reaction and weathering (Bullen and Kendall, 1998). These solute isotopes contribute to the study of surface and groundwaters through their potentially distinctive fingerprints derived by mineral-fluid reaction, which in turn may distinguish water flowpaths through different hydrogeological units. When combined with O and H isotopic compositions of waters, these stable and radiogenic isotopes become powerful tools to constrain or test the validity of theoretical hydrogeological models of water sources, reaction paths and fluid flowpaths in catchments and aquifers.

Sr is soluble in most surface and groundwaters during the chemical weathering of mineral surfaces. Leaching of Sr derived from minerals with contrasting time-integrated Rb/Sr will lead to the inheritance of distinct isotopic compositions in reacting waters dependent upon the matrix flowpath and the reaction rates of the constituent minerals. These Sr isotope signatures can be used to determine the source and mixing of isotopically distinct water masses, and the degree and extent of mineral-specific water-rock reactions. (McNamara, 2006).

Groundwater Recharge

Long term hydrologic drought has affected Idaho agricultural regions, particularly areas that depend on groundwater allocations. This drought has had a negative effect on recharge to the ESPA and, in combination with pumping from the aquifer, has had a negative effect on groundwater discharge to local river channels. Peters et al. (2001) analyzed initiation of drought timing from groundwater recharge to groundwater discharge. A confounding factor was lack of understanding of how physical aquifer characteristics influence propagation of surface water drought through groundwater discharge near streams.

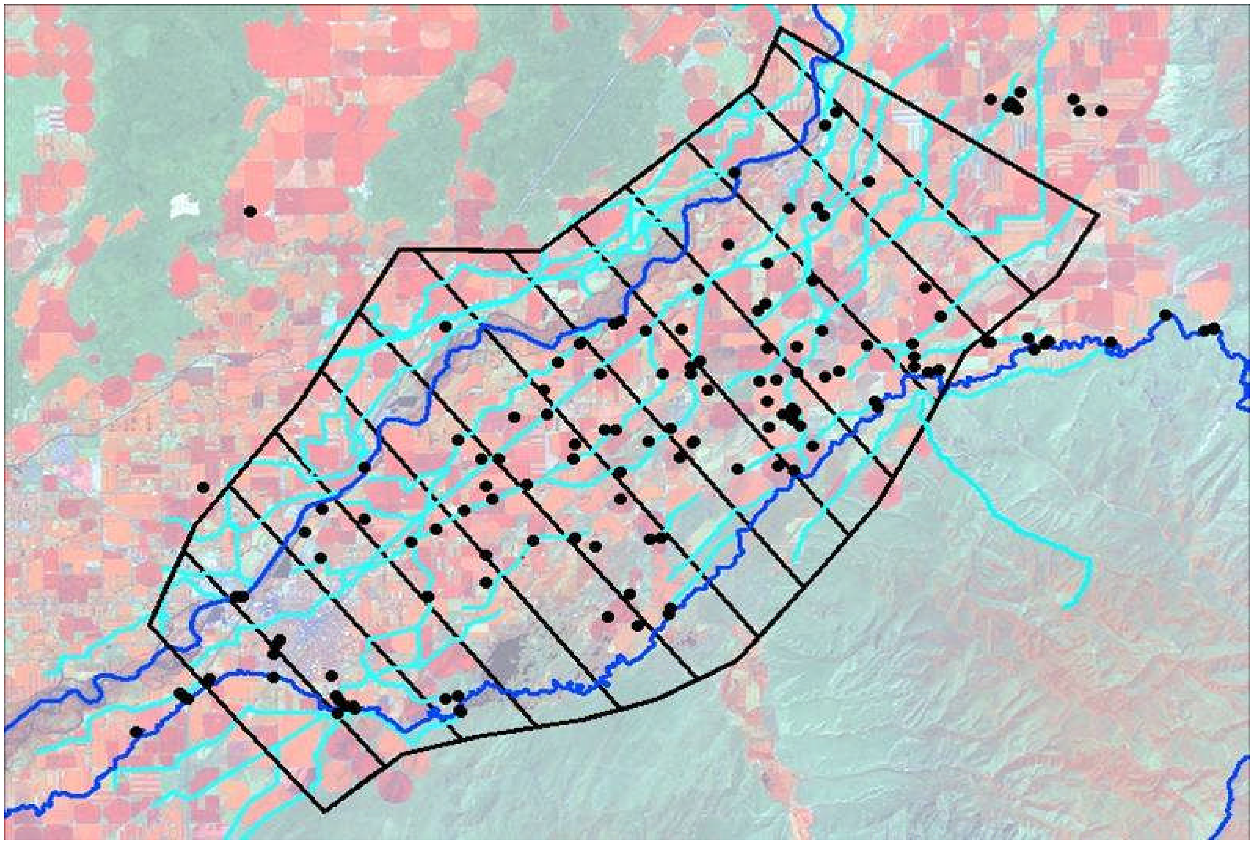
Peters et al. (2003) studied systematically how droughts are propagated from recharge to groundwater heads and discharge regions, and evaluated how aquifer characteristics affect propagation. A synthetic recharge function was defined and the groundwater system was simulated as a linear reservoir with a reservoir coefficient representing the aquifer characteristics. This work enabled derivation of analytical expressions, which express the drought duration and deficit in terms of the decrease in recharge, change in discharge and calculation of a reservoir coefficient.

Groundwater Connectivity to Surface Water

Understanding the spatial variability in hydraulic connection of aquifer to river channel is critical to floodplain management. Lamontagne et al. (2005) studied isotopic signatures within riparian zones where aquifer-surface water exchange was thought to occur on a time scale commensurate with stream hydrograph variations. The resulting patterns in environmental tracers suggest that groundwater in one floodplain had varied origins, including bank recharge, diffuse rainfall recharge, and vertical recharge in the floodplain. Similar isotopic signatures from wells at the bank were found in adjacent stream locations. Lamontagne (2004) found that groundwater in a floodplain has several origins including lateral bank recharge, diffuse vertical rainfall recharge, floodplain close to the river (<100 m). Simpson and Herzog (1991) found that bank recharge could be characterized by low Cl^- and high H^2 and that similar isotopic compositions of cold water wells were observed in surface water less than 75m away.

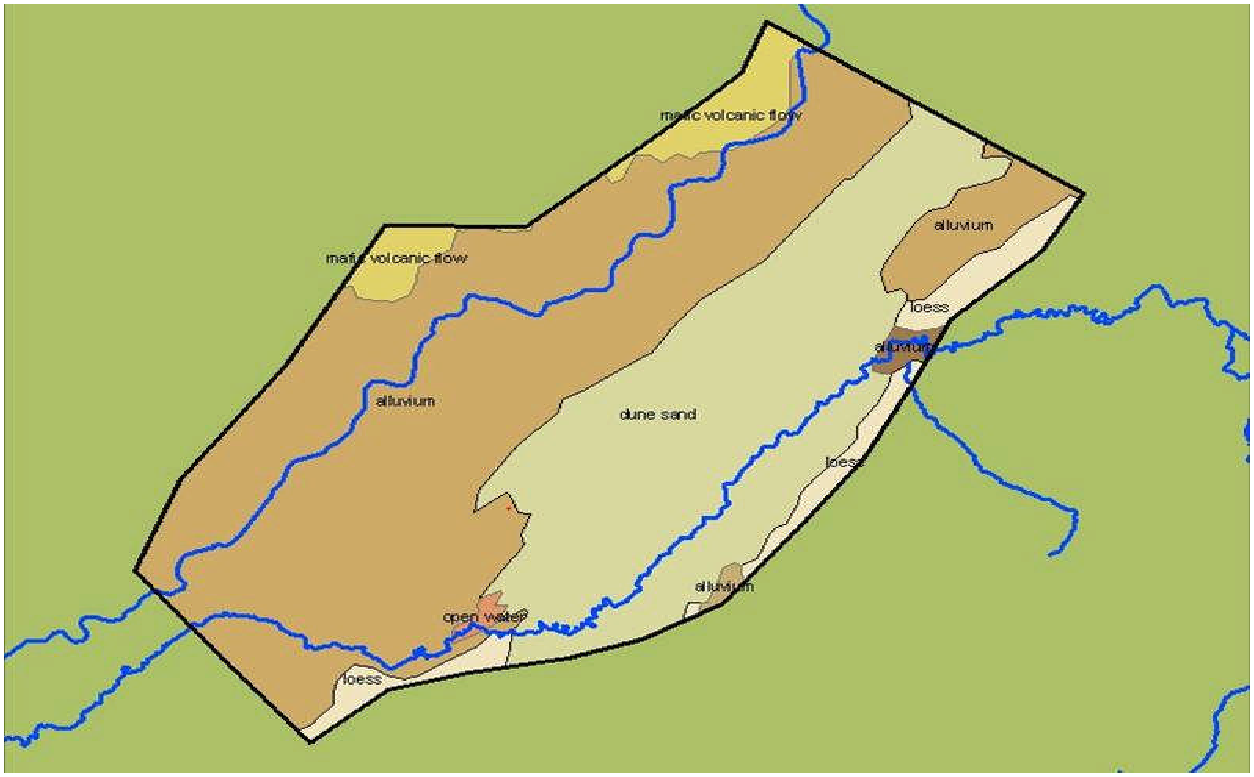
III. Blackfoot Geochemical Tracer Project

The Blackfoot Watershed is roughly 700,000 ac., 130 mi. in length, with annual average flows of 2,140 cfs (USGS). The Blackfoot Valley is roughly 50 sq. mi. in size. The last 30 mi. of the Blackfoot River are included in the study site. Ten transects between the Blackfoot River and Snake River have been constructed such that each transect is roughly 5-7 mi. in length. Forty-five wells were sampled from June-October 2006 within the same range as all ten transects. Canals which run through this area were also sampled. Both the Snake River and Blackfoot River were sampled during this same time period.



IV. Basin Lithology

The study area is mainly alluvium, a mix of clay, fine sands and gravels. Mafic outcrops were observed north of the Snake River.



Site geology, IDWR.

Well logs for the study area suggest an alluvial horizon roughly 100-150 ft deep with deeper wells containing basalt at 200+ ft. River and canal banks contain sandy clay, and sandy gravels. No basalt outcropping was observed near the Blackfoot River (south side of study area).

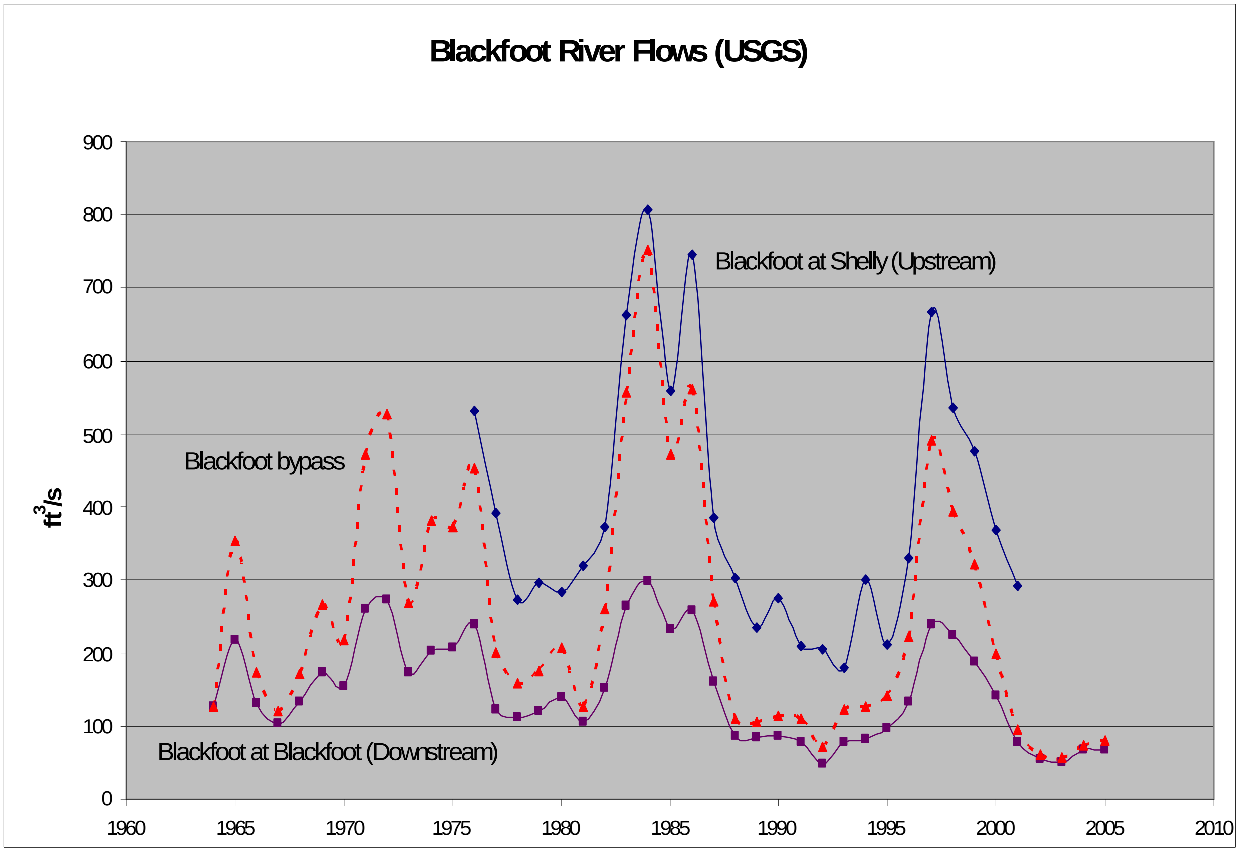
Little geologic information exists for the Blackfoot River Basin. The Portneuf Basin south of the study area contains similar overlapping alluvial flows from the Bonneville Flood. Sedimentary sands, sandy gravels and clays can be observed in this basin as well. The Portneuf aquifer has been characterized as an unconfined, leaky, sandy-clay aquifer and overlies a deep, confined aquifer with known depth of 950 ft. Like the Portneuf, the unconfined shallow Blackfoot aquifer overlies a deep aquifer of unknown depth.

This aquifer system is mainly silty gravel, and sands up to 300-500 feet thick. These sediments are very permeable, unconfined gravels and may be comprised of silty gravels of low permeability below 150 ft. (Welhan et al., 2002). Basalt inclusions are found in many of the wells logs at depths below 100 ft. The hydraulic response of the sand and gravels to extraction infers that vertical hydraulic conductivity is much lower than horizontal hydraulic conductivity. High permeability and anisotropy are characteristic of the horizontal flow in the formation (CH2M-Hill, 1994).


Upper Blackfoot River (August, 2006).

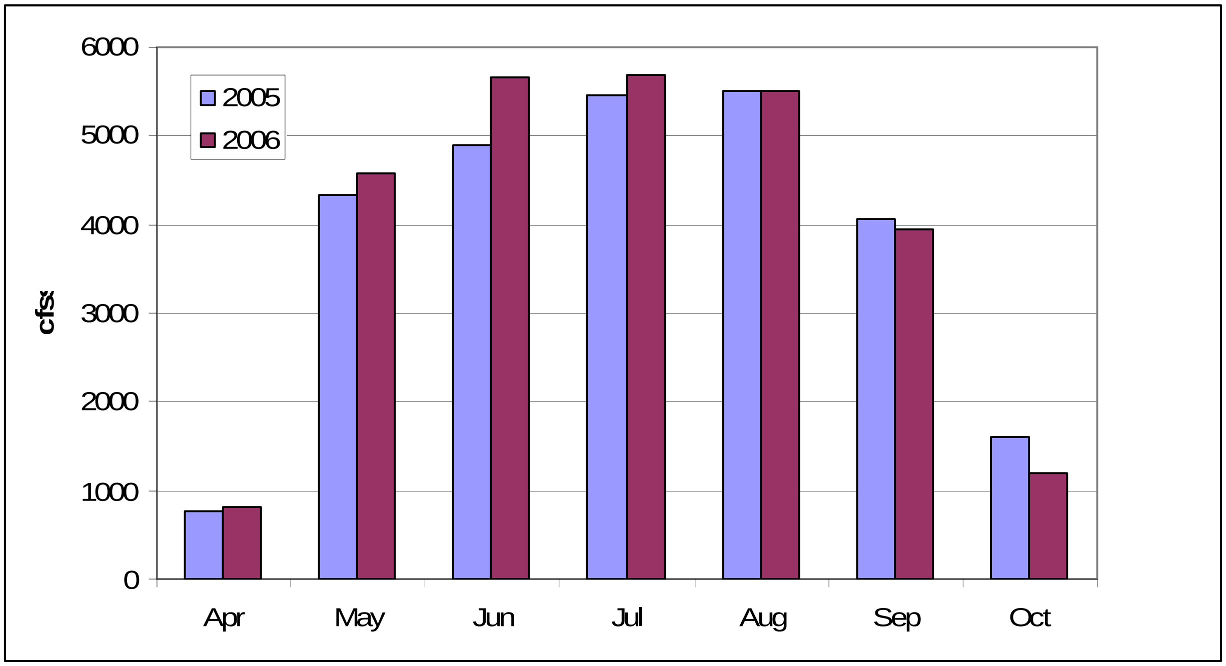
V. Flow Data

Flow data currently exists for 2005, 2006 IDWR monitored diversions to both the Blackfoot and Snake Rivers. IDWR does not monitor flow in the rivers. USGS data is currently available for 2005. Preliminary USGS flow data for 2006 has been received, and is currently being analyzed along with geochemical data to calculate mass balance in irrigation wells and rivers.



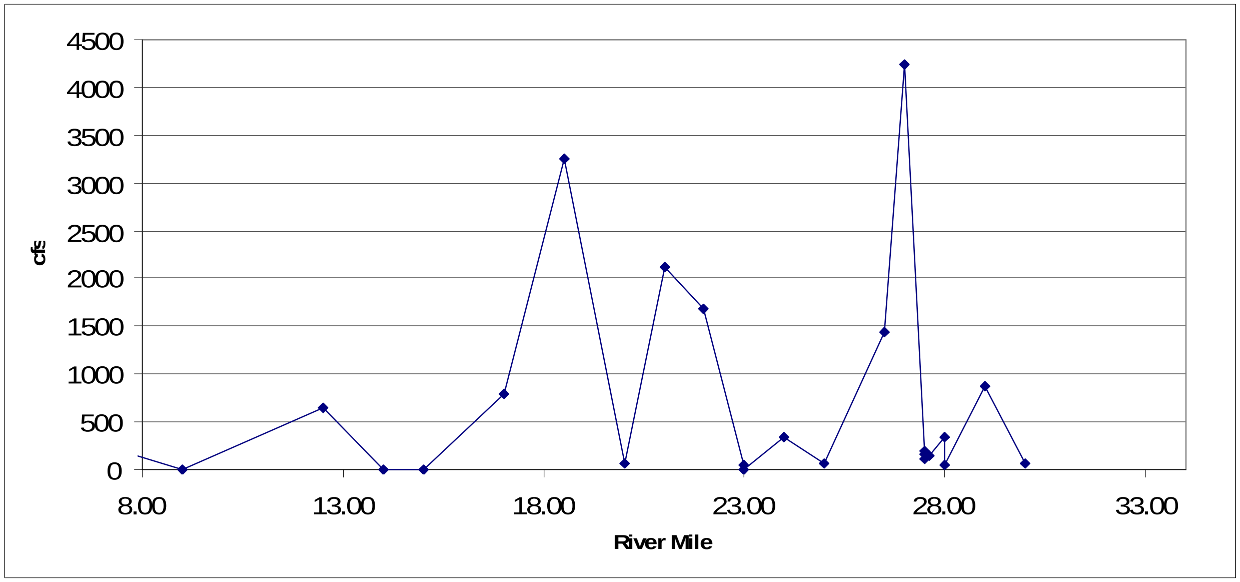
USGS Ave. yearly flows (1964-2005).

Blackfoot River Diversions - Flow totals

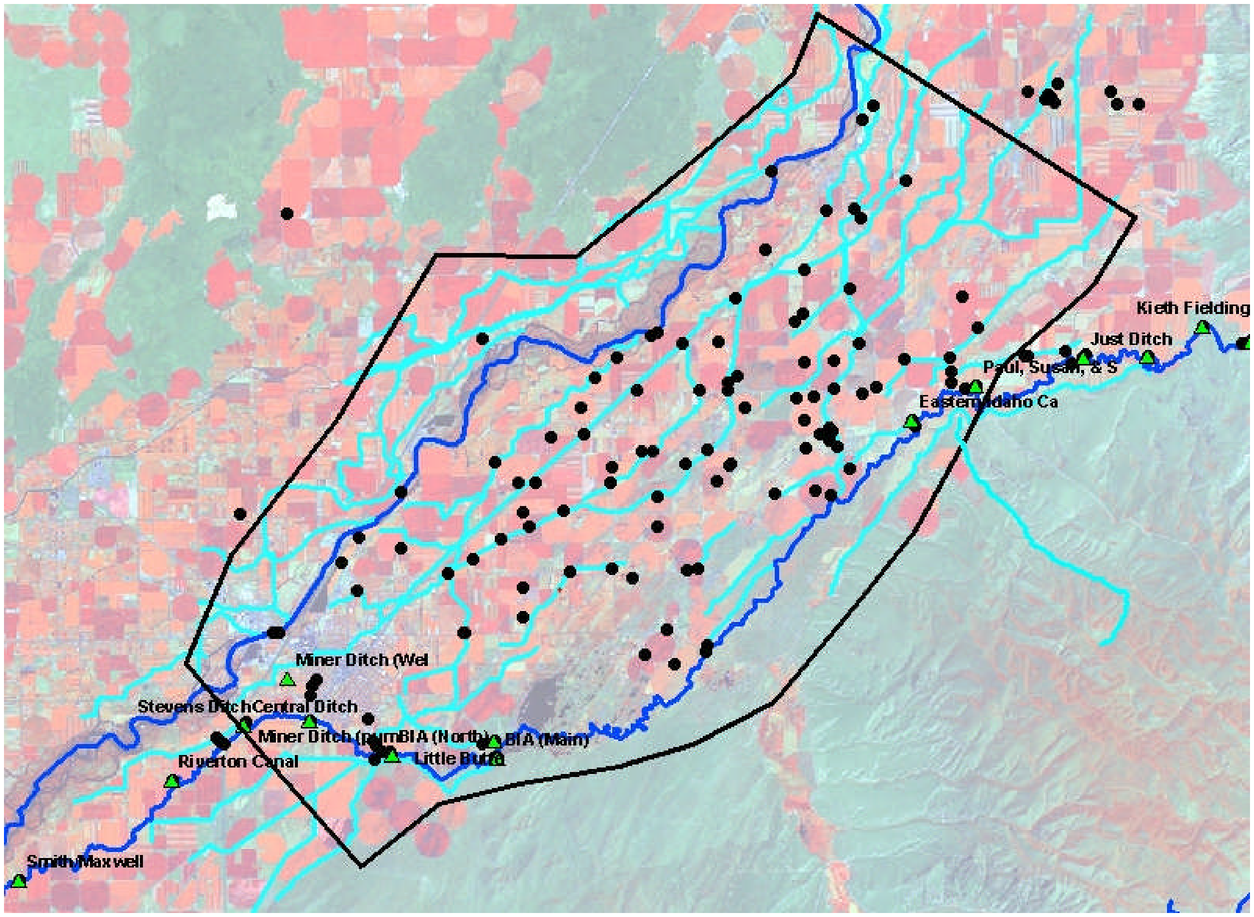


Blackfoot River – monthly diversion rate (cfs) 2005, 2006.

Data is currently availalble for IDWR-monitored returns to the Blackfoot River for 2005, 2006, Reservation Canal, Sand Creek, Willow Creek all return to the Blackfoot River in the northern side of the study area.   Return data for 2006 has not been acquired yet.



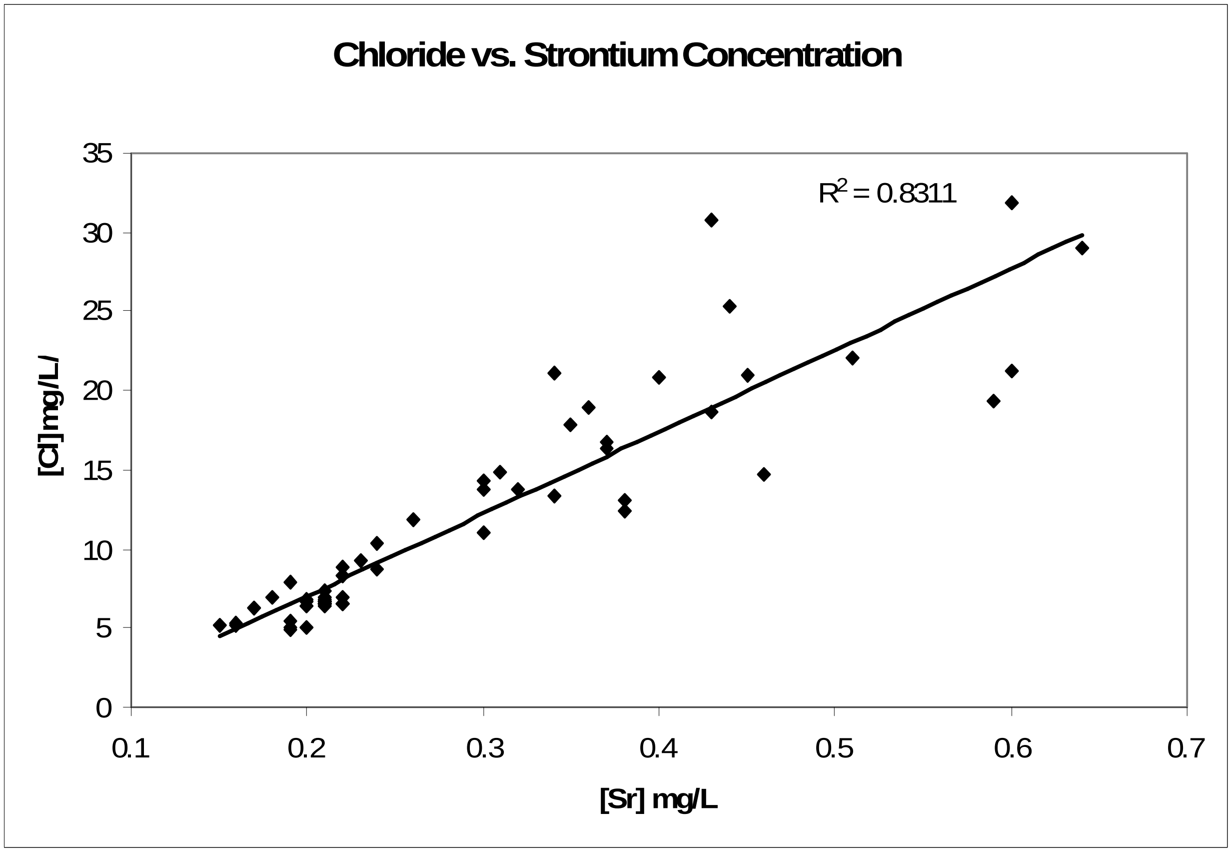
Blackfoot River diversions (June, July, Aug., 2006) from river mile 0 of the last 30 miles.

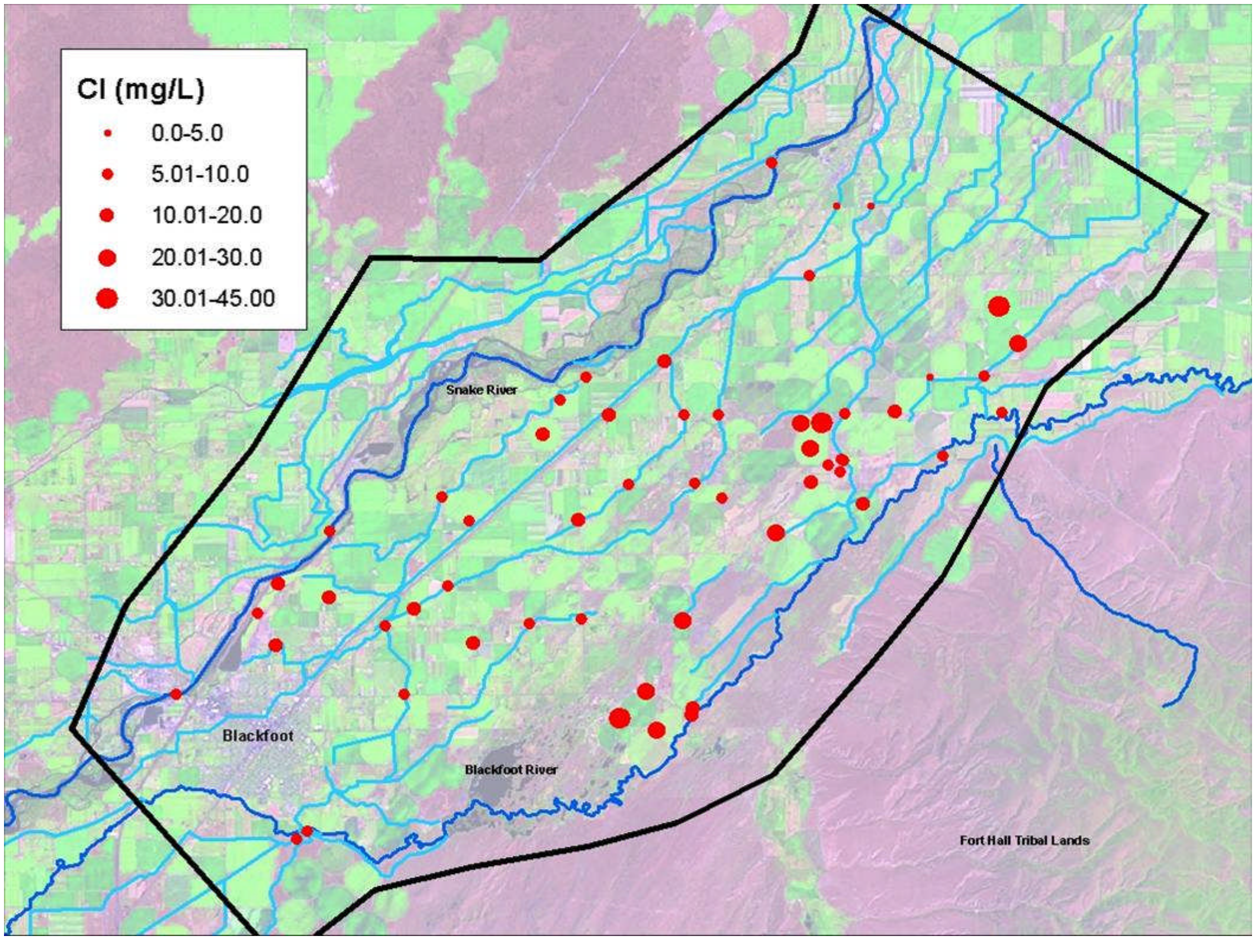


IDWR Diversion Monitoring Sites, 2006.

VI. Water Chemistry

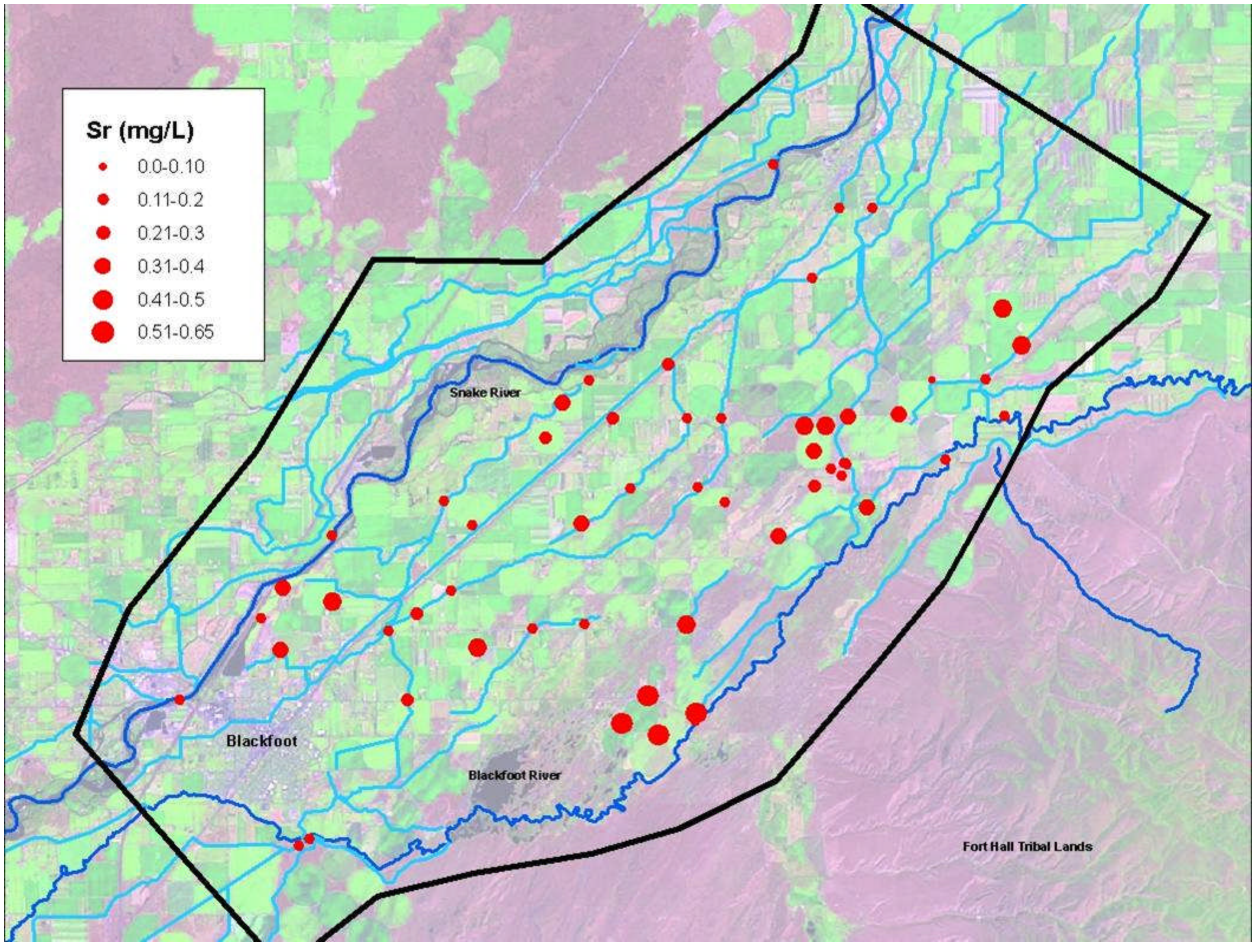
During the 2006 irrigation season, river, canal water and irrigation well samples were collected at 70 sites. The sites were analyzed for total Sr, Pb, U and Cl. The first 32 well samples have been analyzed for major cations and anions. Five river samples (those upstream and downstream of study area) have been analyzed for major cations and anions, ph and alkalinity (CaCO3). Irrigation well, Blackfoot and Snake River samples are currently being analyzed for Sr and U isotope ratios.



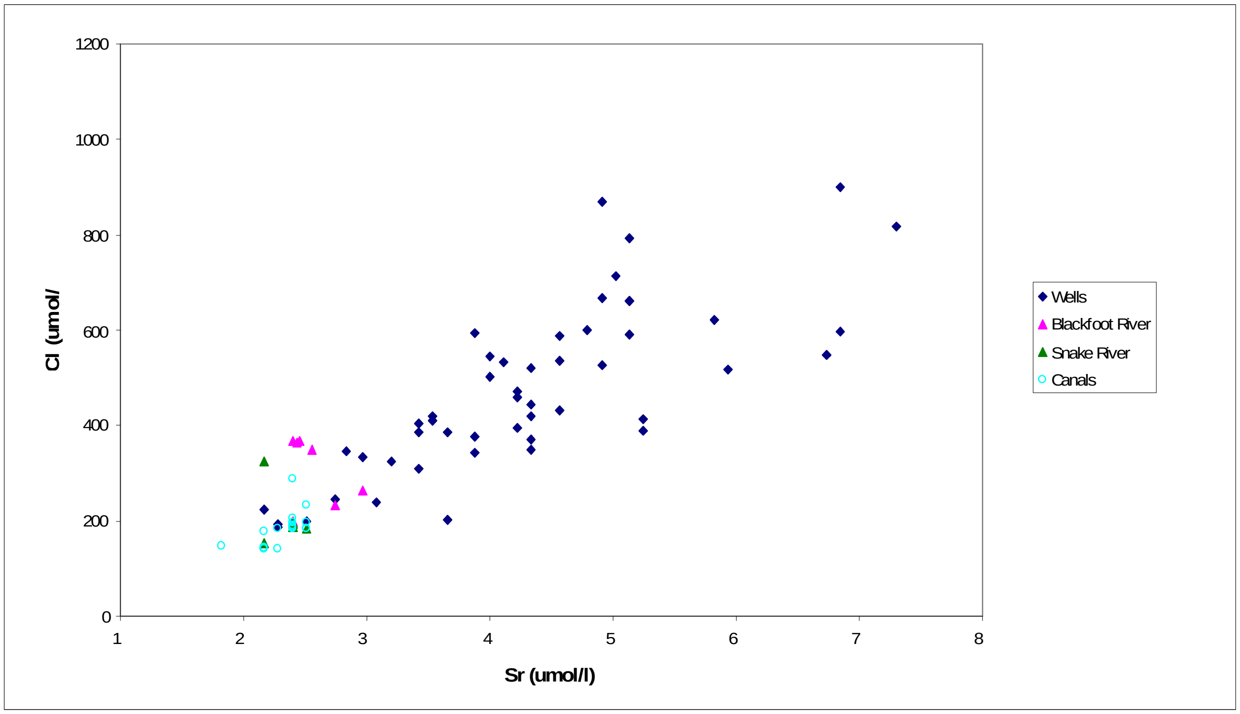


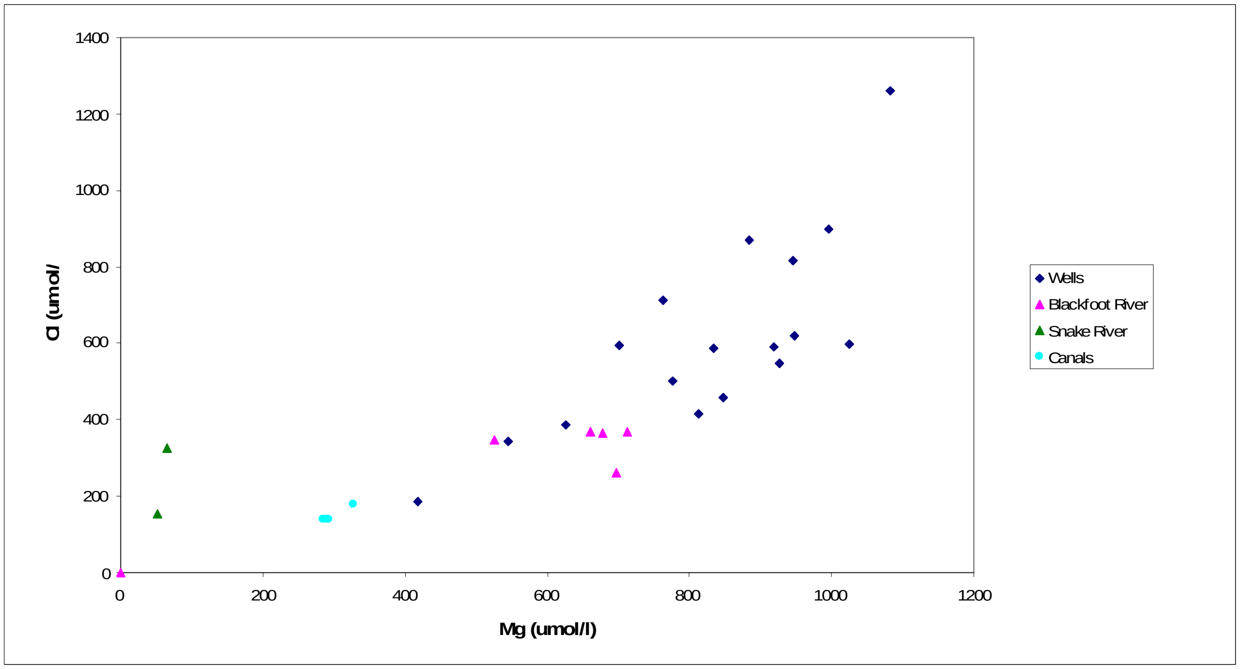
Chloride concentrations appear to be greater in wells near the base of the Blackfoot Mountains, and closer to the border with the Blackfoot River. Chloride well concentrations closer to the Snake River floodplain appear to be lower by 0.2 mg/L on average. Canal concentrations appear to be lower as well, though do not vary much from the Snake River water concentrations.

Canal water levels for 2006 may be higher due to the increase in flows during the 2006 irrigation season (April 15-November 1). Canal substrate is mainly sandy clay, and clayey sand. Major canals throughout the Blackfoot Valley are roughly 20 ft. wide and 10-15 ft. at mid-channel. The canals mainly filled to capacity during the irrigation season. Increased flows most-likely diluted species concentrations at these location.



Of interest is the difference between upstream and downstream water chemistry within the study site. Upstream Blackfoot River water appears have lower concentrations than downstream sites (by ~0.2mg/L) for Sr, Ca, Na, SO4, and higher levels (by 0.1mg/L) of Br, K, Mg, Cl. Well concentrations are much higher than all river samples in SO4, Sr, Ca, NO3 and lower in Br, K, Mg, Cl. The higher NO3 concentrations could be due to slow moving waters which are accumulating fertilizer leachates. Lower Br, Cl ratios in well vs. surface water were found to be similar to those in a similar Arizona study suggesting the effect of evapo-concentration on irrigation well water (Phillips et al, 1998).

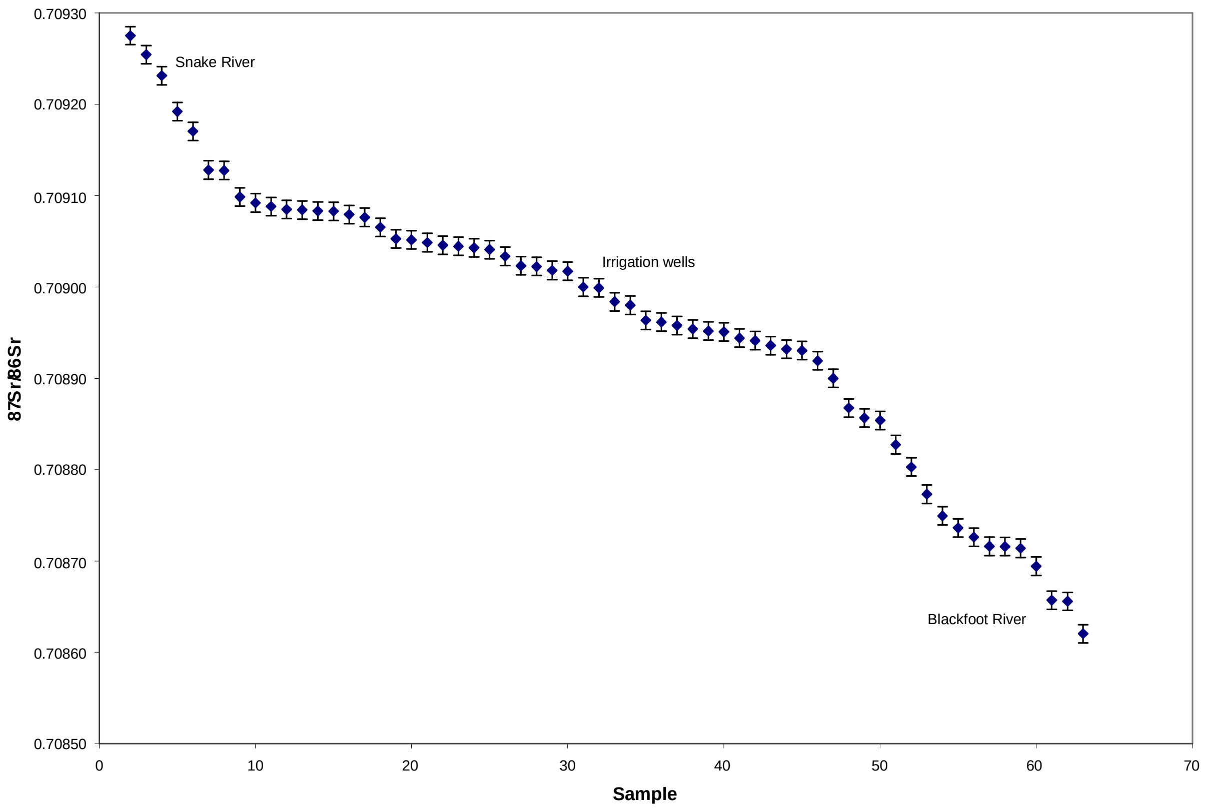




Plotting Cl vs. Mg, we find that there is a clear difference between the Mg concentrations in Snake River water vs. Blackfoot River water, and that wells are more influenced by Blackfoot River water. Canal water is clearly a mixture, of both, and this is expected due to the lengthy canal network associated with both rivers. The Cl vs. Sr plot shows this relationship as well, Although it shows wells and canals are clearly influenced by both rivers. In comparison, the Cl, Mg plot shows a more definitive break between river end members and mixing potentials.

Strontium Isotopes

Currently surface water and well samples are being analyzed for Sr isotope signatures. Total Sr concentrations are higher for Snake River water and irrigation wells, where water most-likely comes from a source higher in ^{87}Sr. Many of the irrigation wells also have a higher than expected Sr isotope ratio. Slower-moving well water has had significant time to accumulate Sr from surrounding sands and gravels high in Sr and Ca. Well mixing is influenced more by Snake River water closer to this source, whereas well mixing near the Blackfoot River is more influenced by this source.



Sr isotope ratio data for the Blackfoot Valley. Samples collected 2006-2007.

VII. Projected Timeline

Currently, no further data collection is planned. Laboratory and statistical analysis is expected to be completed by August, 2007.

Reference

Lamontagne, S. ,Fred W. Leaney and Andrew L. Herczeg 2005 Groundwater–surface water interactions in a large semi-arid floodplain: implications for salinity management *Hydrol. Process.* 19, 3063–3080.

Peters, E., P J. Torfs, H. van Lanen and G. Bier (2003) Published Propagation of drought through groundwater—a new approach using linear reservoir theory *Hydrol. Process.* 17, 3023–3040.

Phillips, F. M., Mills, S., Hendrickx, M. H., Hogan, J. 1998. Environmental tracers applied to quantifying causes of salinity in arid-region rivers: results from the Rio Grande Basin, Southwestern USA. Earth & Environmental Science Department, New Mexico Tech, Socorro, NM

Welhan, J. and Meehan, C. 1994. Hydrogeology of the Pocatello aquifer: implications for well head protection strategies; Proc., 30th Eng. Geology and Geological Engineering Symposium, Boise, March 23-25, 1994.

Welhan, J.A., Meehan, C. and Reid, T.V. 1996. The lower Portneuf River valley aquifer: a geologic and hydrologic model, and implications for wellhead protection strategies; Final Report, EPA Wellhead Protection Demonstration Project and City of Pocatello Aquifer Geologic Characterization Project.

	pH	Alk CaCO3 mg/L	Fl mg/L	Cl mg/L	Nitrite as N mg/L	Sulfate mg/L	NO3- N	Phos. as P mg/L	Na mg/L	Mg mg/L	K mg/L	Ca mg/L	Br ug/L
BFR-14	7.79	144.00	n.a.	13.02	n.a.	25.41	n.a.	n.a.	9.89	16.06	3.29	35.74	38.73
BRF-15	7.94	140.00	0.24	12.97	n.a.	25.37	0.01	n.a.	9.95	16.48	3.35	36.11	38.44
BFR-16	7.94	160.00	n.a.	13.03	0.01	25.39	0.01	n.a.	10.12	17.30	3.36	39.55	36.07
BFR-17	7.87	140.00	n.a.	12.32	0.01	31.21	0.03	0.16	11.30	12.77	3.05	39.02	32.84
SNAKE9	8.02	139.00	0.97	11.53	0.01	29.75	0.07	n.a.	11.82	9.87	2.60	35.70	29.14
LOWSNAKE	8.12	140.32	n.a.	6.80	n.a.	30.13	n.a.	n.a.	11.43	10.55	2.03	34.19	29.50
PJENSEN	7.30	150.00	0.68	12.22	n.a.	38.72	1.58	n.a.	11.65	13.24	3.30	55.25	33.37

Blackfoot River Upstream samples = BFR14, BFR15, BFR 16
Blackfoot River Downstream sample = BFR17
Snake River Upstream = Snake9
Snake River Downstream = LowSnake
sample Pjensen is an irrigation well with Oct. 2006 water level = 18.4 ft.

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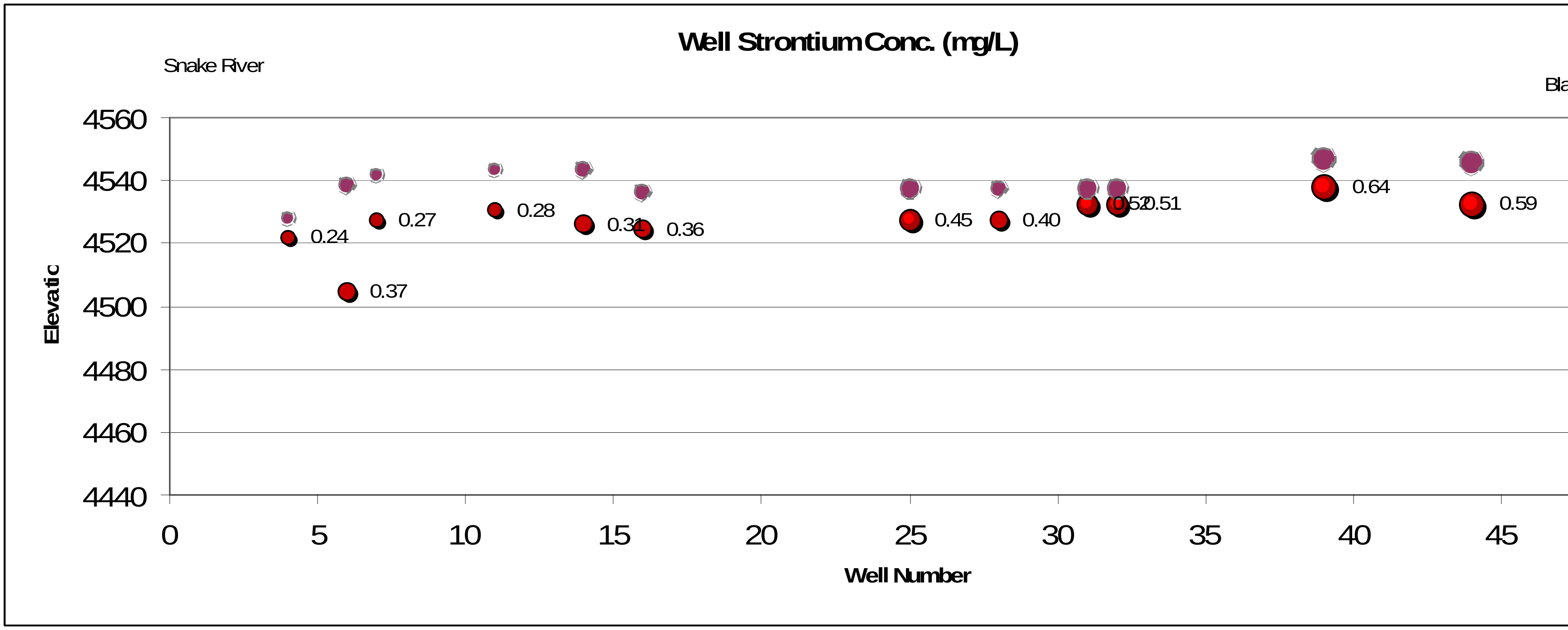
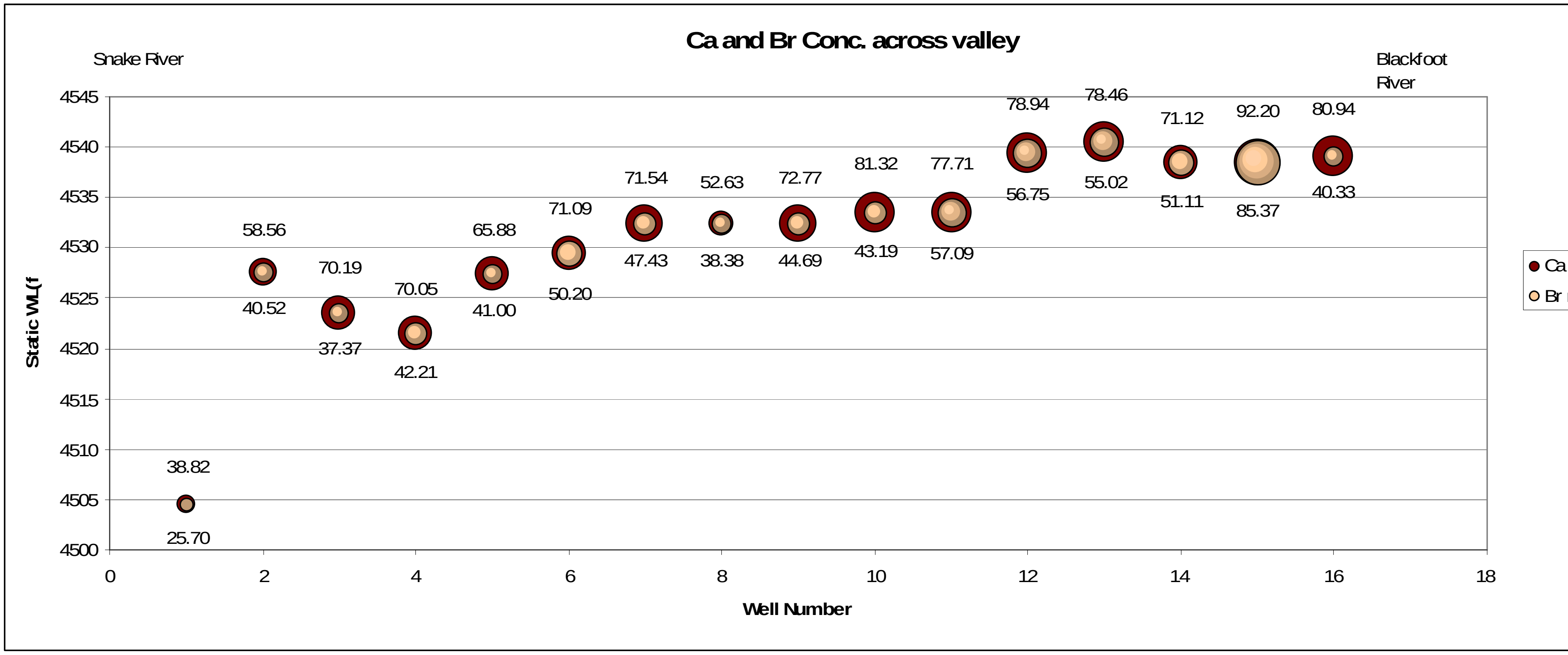
SampleID	Fl mg/L	SO4 mg/L	Br ug/L	Na mg/L	Mg mg/L	K mg/L	Ca mg/L	HCO3 mg/L	Cl mg/L	Sr mg/L	Sample Location	Owner Name
606-356	0.49	18.73						234.00			Blackfoot River	
606-359	0.47	20.05	22.09	7.07	8.47	1.76	34.50	245.00	5.21	0.16	Blackfoot River #1	
606-360	0.45	19.44	22.25	6.94	8.40	1.80	34.10	300.00	5.25	0.16	Blackfoot River #2	
606-361	0.45	20.01	23.45	6.89	12.34	1.97	36.67	203.00	10.3	0.24	Blackfoot River #3	
606-362	n.a.	22.42	28.99	9.35	16.94	2.73	60.32	254.00	9.3	0.23	Blackfoot River #4	
606-363	0.44	21.18	24.89	7.96	11.96	2.19	47.79	278.00	7.01	0.18	Blackfoot River #5	
606-364	0.43	19.59	24.12	7.52	10.28	2.00	39.58	245.00	6.29	0.17	Blackfoot River #6	
606-365	0.31	22.54	29.82	8.26	14.31	2.65	52.54	235.00	8.86	0.22	Blackfoot River #7	
606-366	0.30	21.23	21.28	7.01	7.91	1.71	32.20	231.00	5.12	0.15	Blackfoot River #8	
606-685	0.37	22.08	24.15	6.72	8.51	1.92	36.11	243.00	4.95	0.19	BFR9	
606-686	0.38	22.22	22.73	6.66	8.58	1.83	36.39	213.00	4.95	0.19	BFR10	
606-687	0.37	22.88	23.63	6.55	8.53	1.82	36.49	217.00	5	0.2	BFR11	
606-687	0.37	22.88						215.00	5	0.22	BFR12	
606-687	0.38	23.32	23.63	6.55	8.53	1.82	36.49	213.00	5	0.19	BFR13	
606-688	0.40	22.85	26.41	7.59	9.63	2.03	40.11	234.00	5.43	0.19	Snake1	

SampleID	Fl mg/L	SO4 mg/L	Br ug/L	Na mg/L	Mg mg/L	K mg/L	Ca mg/L	HCO3 mg/L	Cl mg/L	Sr mg/L	Sample Location	Owner Name
606-669	0.59	22.41	25.70	9.59	10.18	2.36	38.82	205.00	6.61	0.2	Groundwater	DSheiss
606-679	0.60	66.84	40.52	19.85	17.04	3.59	58.56	245.00	21.1	0.34	Groundwater	Mickelsen4
606-673	0.42	38.26	37.37	14.55	19.75	4.02	70.19	265.00	14.7	0.46	Groundwater	Wassia1
606-676	0.27	42.12	42.21	12.28	20.60	3.84	70.05	234.00	16.3	0.37	Groundwater	Mickelsen1
606-682	0.34	54.70	41.00	13.61	18.85	3.68	65.88	202.00	17.8	0.35	Groundwater	MClausen3
606-677	0.55	89.42	50.20	26.29	21.50	4.47	71.09	273.00	30.8	0.43	Groundwater	Mickelsen2
606-670	0.28	48.99	47.43	15.65	23.05	4.55	71.54	222.00	22	0.51	Groundwater	LButler1
606-684	0.43	38.68	38.38	14.46	15.23	3.46	52.63	223.00	13.7	0.3	Groundwater	GPratt2
606-683	0.34	56.60	44.69	16.64	20.27	4.67	72.77	194.00	20.8	0.4	Groundwater	GPratt1
606-678	0.55	71.77	43.19	16.20	18.54	4.11	81.32	275.00	25.3	0.44	Groundwater	Mickelsen3
606-671	0.48	64.73	57.09	22.53	24.90	5.23	77.71	238.00	21.2	0.6	Groundwater	Goleson1
606-675	0.27	68.97	56.75	19.54	24.22	4.76	78.94	267.00	31.9	0.6	Groundwater	BShoemaker1
606-674	0.32	67.53	55.02	16.52	22.98	5.02	78.46	276.00	29	0.64	Groundwater	BRamey1
606-672	0.42	56.63	51.11	19.50	22.52	4.77	71.12	213.00	19.4	0.59	Groundwater	RBradley1
606-680	0.35	70.08	85.37	14.75	26.29	4.43	92.20	235.00	44.7	0.5	Groundwater	MClausen1
606-681	0.27	54.86	40.33	13.55	22.35	4.07	80.94	212.00	21	0.45	Groundwater	MClausen2


Well Strontium Conc. (mg/L)
Snake River
Bla
4560
4540
4520
4500
4480
4460
4440
Elevatic
0.24
0.37
0.27
0.28
0.31
0.36
0.45
0.40
0.52
0.51
0.64
0.59
0
5
10
15
20
25
30
35
40
45
Well Number



Ca and Br Conc. across valley
Snake River
Blackfoot River
Static WL(f
Well Number
4545
4540
4535
4530
4525
4520
4515
4510
4505
4500
0
2
4
6
8
10
12
14
16
18
38.82
25.70
58.56
40.52
70.19
37.37
70.05
42.21
65.88
41.00
71.09
50.20
71.54
47.43
52.63
38.38
72.77
44.69
81.32
43.19
77.71
57.09
78.94
56.75
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85.37
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Ca
Br

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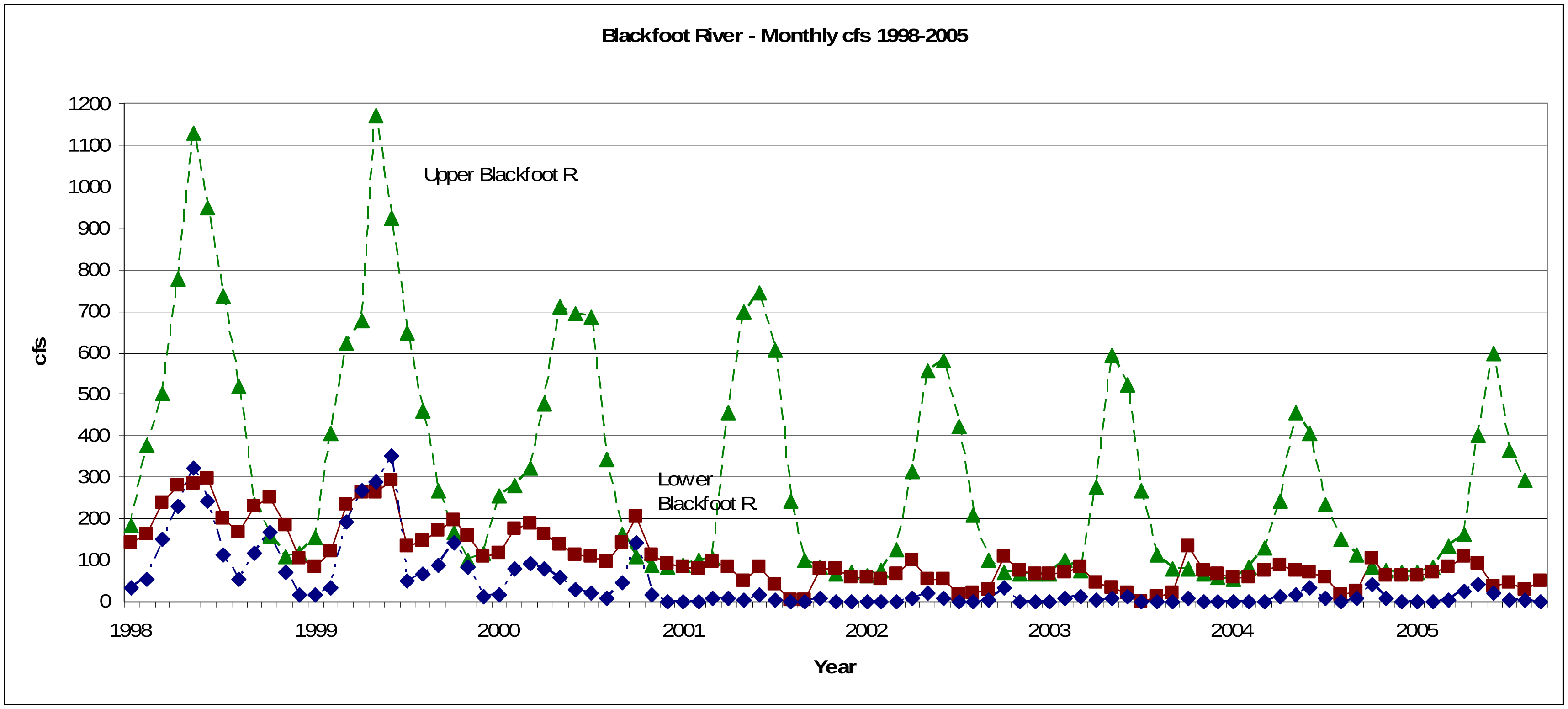
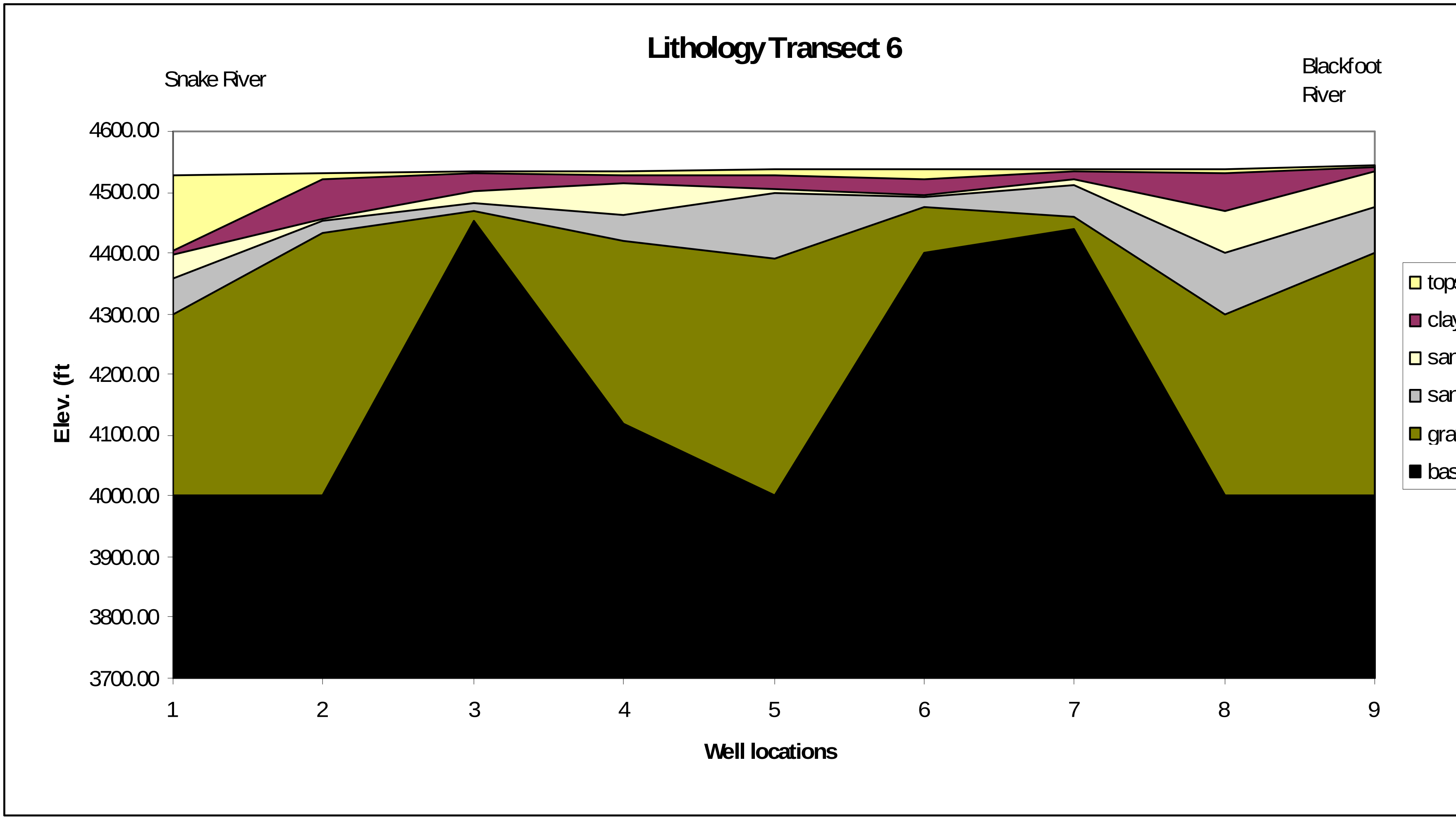


Monthly flows for 3 USGS gages, Blackfoot River (1998-2005).



Lithology Transect 6
Snake River
Blackfoot River
4600.00
4500.00
4400.00
4300.00
4200.00
4100.00
4000.00
3900.00
3800.00
3700.00
Elev. (ft
1
2
3
4
5
6
7
8
9
Well locations
top
clay
san
san
gra
bas

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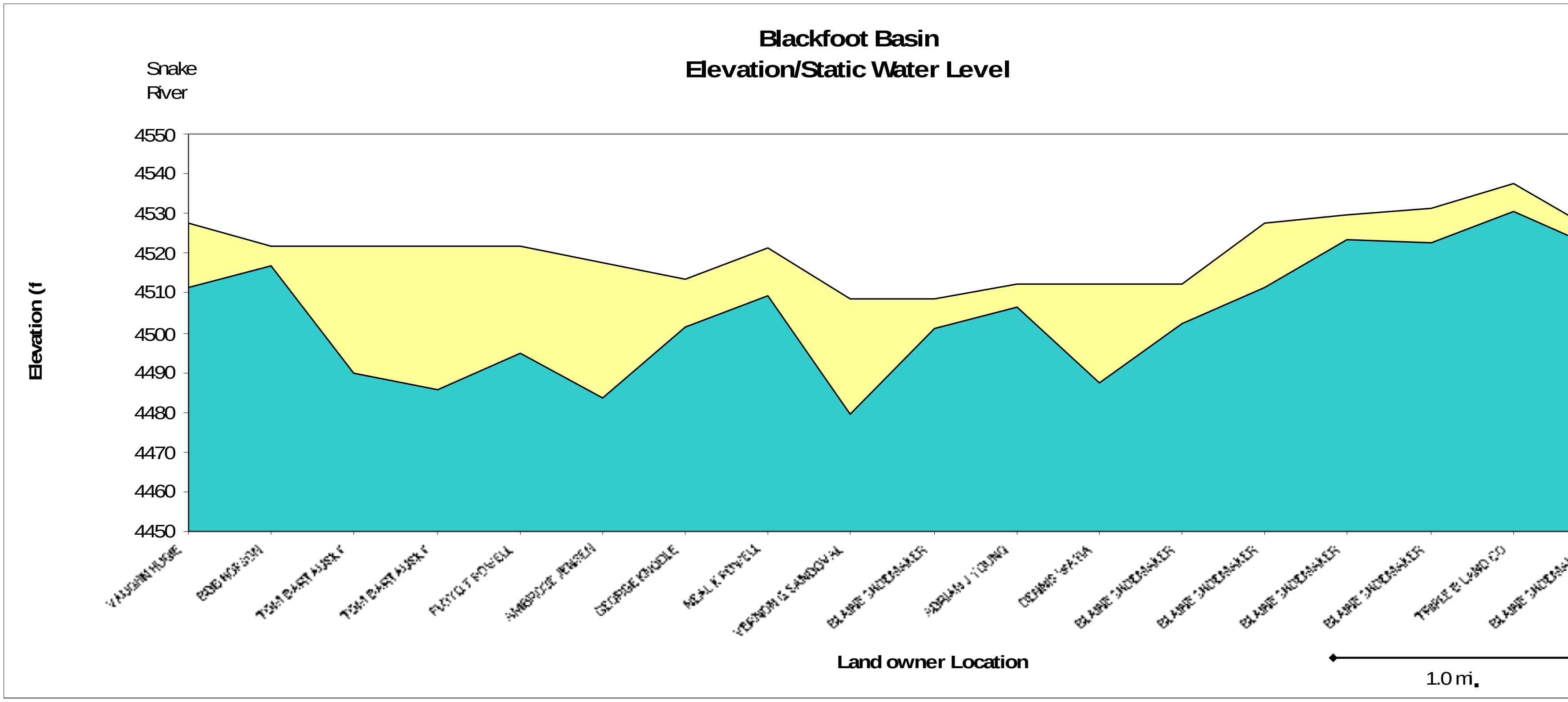
Transect 5



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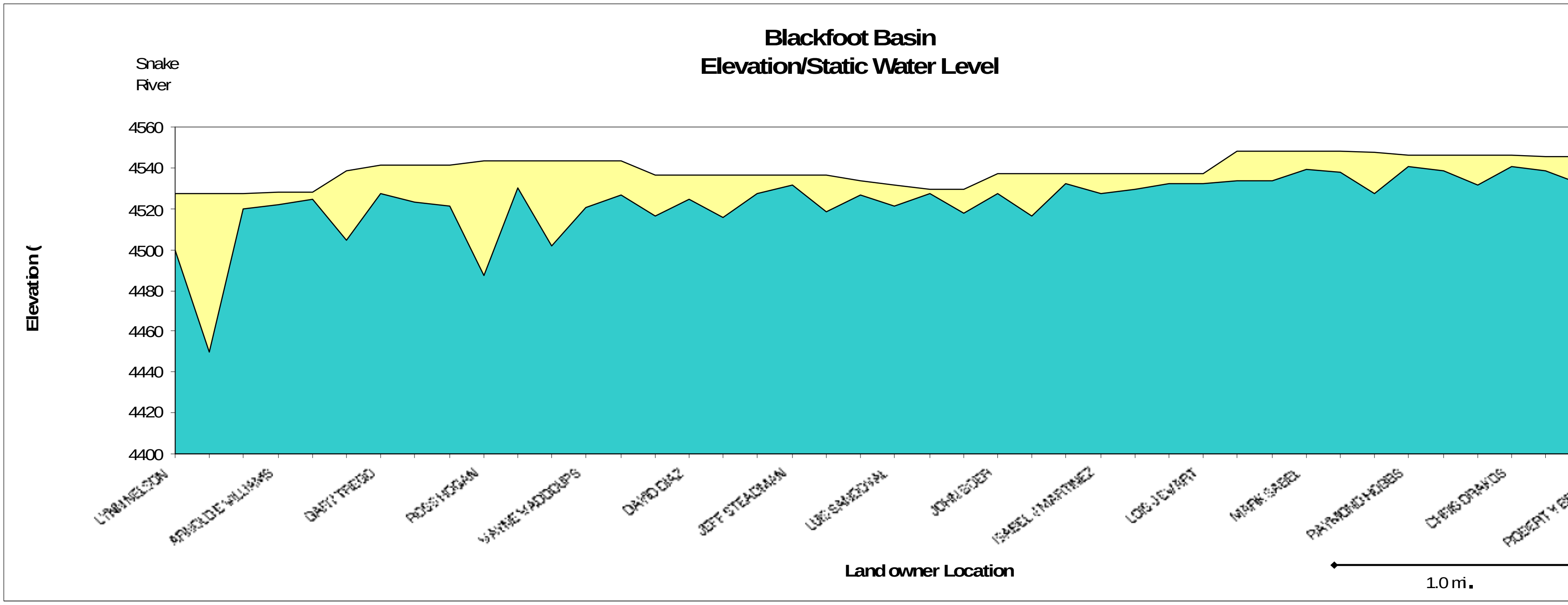
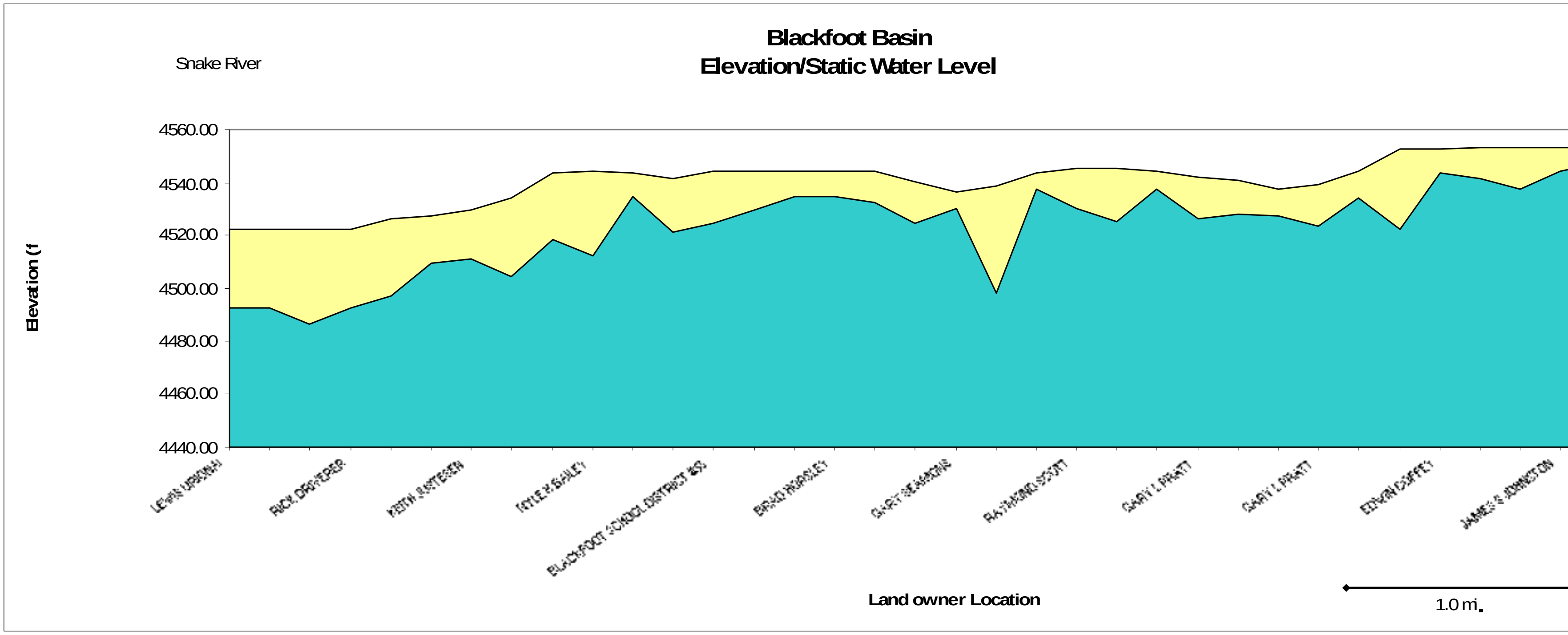
Transect 6


Blackfoot Basin
Elevation/Static Water Level
Snake
River
4560
4540
4520
4500
4480
4460
4440
4420
4400
Elevation (
DAVID DIAZ
JEFF STEADMAN
Land owner Location
1.0 mi.

Transect 7


Blackfoot Basin
Elevation/Static Water Level
Snake River
4560.00
4540.00
4520.00
4500.00
4480.00
4460.00
4440.00
Elevation (f
Land owner Location
1.0 mi.

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Evaluation of levels of success of diagnostic and remediation efforts for nitrate contaminated ground waters with application to the Ashton, ID area.

Basic Information

Title:	Evaluation of levels of success of diagnostic and remediation efforts for nitrate contaminated ground waters with application to the Ashton, ID area.
Project Number:	2006ID65B
Start Date:	3/1/2006
End Date:	4/30/2007
Funding Source:	104B
Congressional District:	First
Research Category:	Water Quality
Focus Category:	Nitrate Contamination, Non Point Pollution, Groundwater
Descriptors:	
Principal Investigators:	Gary Steven Johnson, Mark Lovell

Publication

ANNUAL REPORT: U.S. Geological Survey 104b Program
2005ID 55B and 55B(S): *Evaluation of temporal variation of the nitrate concentrations in ground-water of the Ashton, Idaho area and potential causative factors*
And
2006ID 65B: *Evaluation of levels of success of diagnostic and remediation efforts for nitrate contaminated ground waters with application to the Ashton, ID area*.

Project Summary

The two projects, *Evaluation of temporal variation of the nitrate concentrations in ground-water of the Ashton, Idaho area and potential causative factors* and *Evaluation of levels of success of diagnostic and remediation efforts for nitrate contaminated ground waters with application to the Ashton, ID area* are linked, and the status and progress of these two projects are therefore provided in this single report.

Beginning fall 2005, Mark Lovell received partial funding in support of a sabbatical leave from Brigham Young University-Idaho (BYU-Idaho). This leave provided the opportunity for Lovell to attend the University of Idaho, Idaho Falls campus full time for two semesters. In addition to completing course work, research time was focused on three main topics:

- Procedures and techniques used to identify ground water contamination problems caused by excess nitrates and associated mitigation efforts to remediate the contaminated aquifers.
- The successful components of developing an undergraduate research experience (URE) and the adaptation and development of an ongoing research hydrologic field study for undergraduates.
- Application of case studies for nitrate contamination and remediation to the Ashton, Idaho area.

The great majority of resources provided by the grants have been devoted to two parts of the proposals; first, establishing and performing field activities including collecting water samples from domestic wells, measuring water table elevations, and processing samples using an ion chromatograph to evaluate concentrations of fluoride, chloride, nitrate, and sulfate; second, working with undergraduate students, training them how to participate in data acquisition and processing of samples.

In addition to funding provided through these grants, BYU-Idaho has and continues to support this program in several ways. While on sabbatical leave, partial salary support was provided to Mark Lovell. In addition, approximately $20,000 dollars worth of lab & field equipment were purchased and additional lab consumables, leveraging the supplies and equipment provided through these two grants. Major equipment purchased through BYU-Idaho includes a bench top ion chromatograph (Dionex IC-90) with manual injection, a Hach multi-probe (Quanta) to monitor discharge water to allow verification of pumping fresh formation waters prior to collecting water samples, and an electric tape for measuring depth to water table.

In the Idaho Department of Environmental Quality's (IDEQ) ranking of Nitrate Priority (Neely, 2005) the Ashton, Drummond, and Teton area was identified to rank #8 on the State of Idaho's top twenty-five Nitrate Priority Areas. Located approximately 30 miles north of Rexburg, Idaho home for the campus of BYU-Idaho, this seemed to be an ideal area to establish a groundwater study focused on nitrate contamination (figure 1). The regional setting of the Ashton area consists primarily of agricultural activities growing grains, alfalfa, potatoes, and some canola, in addition to a few cattle operations where herds are fed through the winter and then transported to summer pastures. There are also a growing number of residential sites with septic systems including the small town of Marysville which is located up gradient to the direction of ground water flow that provides drinking water for the town of Ashton. This combination of potential sources for nitrates makes it difficult to identify a unique source for the observed contamination problems.

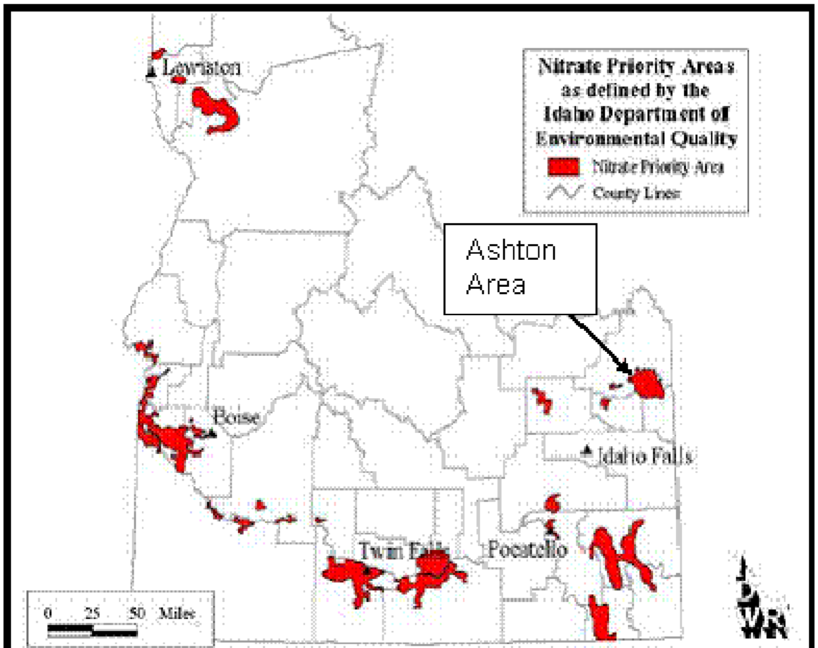

Figure 1. Nitrate Priority Areas modified from Neely 2005.

Funding was used to purchase two Hach Hydrolab-5 down-hole multi-probes, each with data-loggers, and probes for measuring nitrate, pH, specific conductance, and pressure transducers. The nitrate probes were known to have lower sensitivity (+/- 2 mg/l N as total Nitrogen) and a tendency to drift which required weekly calibration efforts. After deploying one of the probes in an abandoned well bore located approximately 10 feet from a small irrigation well, the data looked suspect (figure 2)

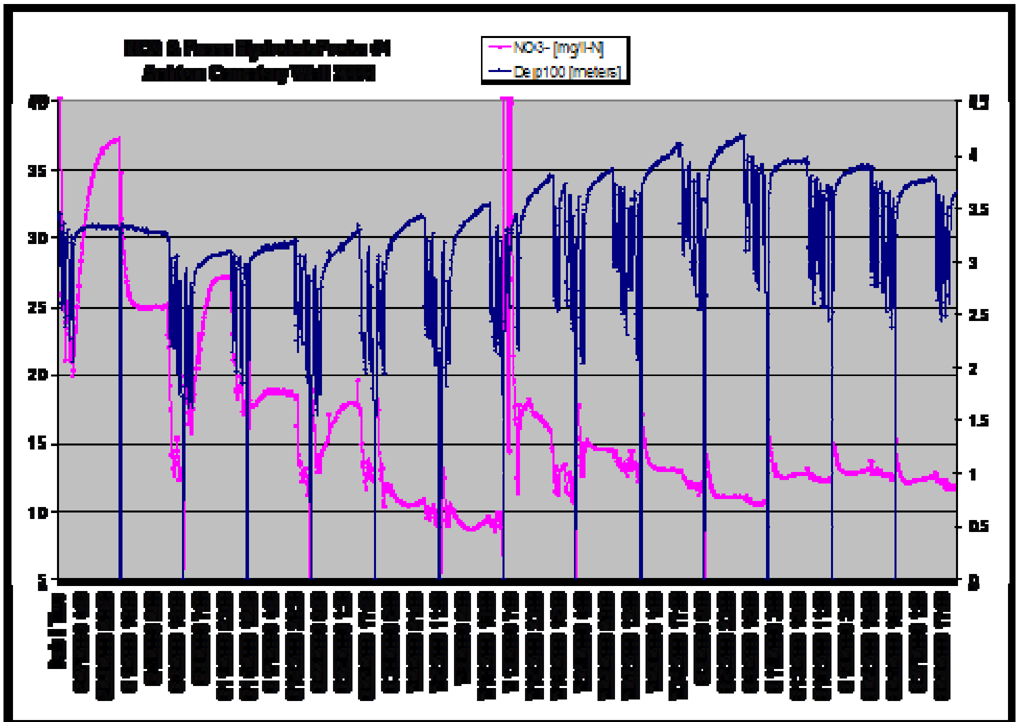

Figure 2. Nitrate and pressure data collected from probe #1.

In figure 2 we see the pressure response indicating water column thickness above the probe allowing identification of pumping events due to the associated drawdown. A zero value was added to the pressure data each time the probe was removed from the well for calibration. The observed nitrate concentrations appear to be diminished each time a pumping cycle occurs. This observation could possibly represent a type of mixing where shallow contaminated waters are being mixed with fresher water drawn in during the pumping cycle. Other observations of the data indicate that overall, nitrate concentrations were seen to decline throughout the year with the exception of the nitrate spike that occurred in mid July. In the small building which encloses the open well there is a sack of lawn fertilizer that is open. The spike may represent an inadvertent spill of some of the fertilizer on the floor that found its way into the well.

A second observation made possible from the data in figure 2 is the seasonal variation of the water table. The lowest observed water table is indicated to have occurred in early-June while the highest occurred in mid-August. It is interesting to note that maximum water-table elevation only persisted for about one week before beginning to decline.

To try and validate the nitrate response as seen by probe #1, the second Hydrolab was also deployed in the same well. Efforts were made to calibrate the probes on different days to allow one probe to be in the well monitoring when the second probe was pulled out, calibrated, data-downloaded, and then re-deployed. Figure 3 shows the data accumulated using probe #2 for nitrate concentration and for pressure/water table.

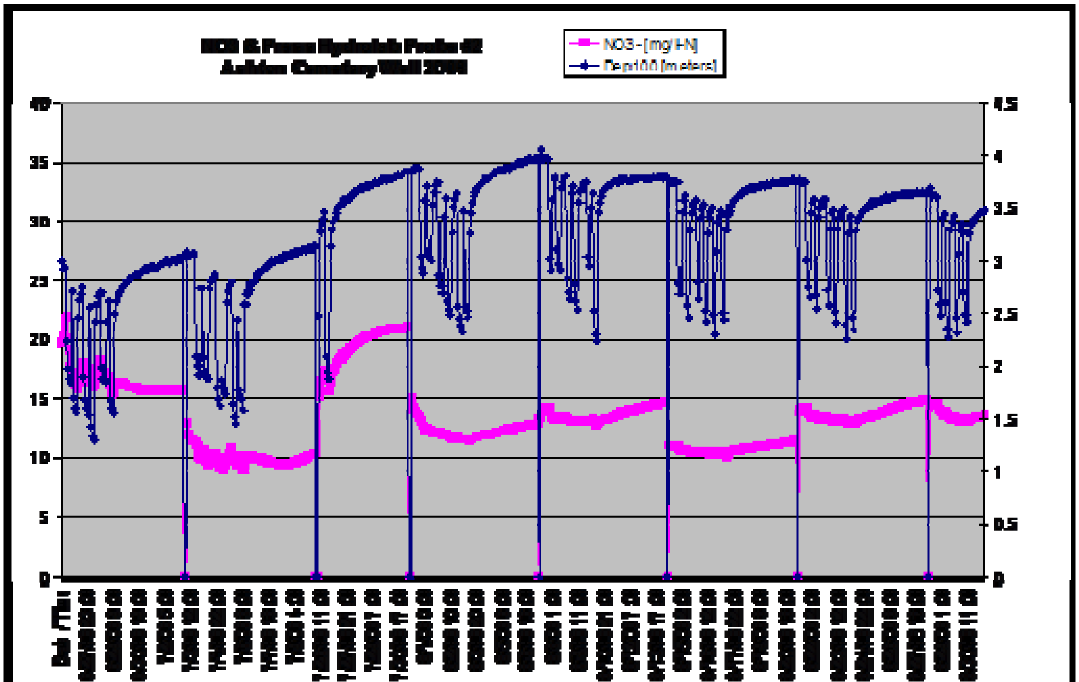

Figure 3. Nitrate and pressure data collected from probe #2.

Unfortunately, probe #2 experienced a mechanical (electronics) failure and several weeks worth of data were lost due to inability to communicate with the probe to download data and for the time lost while the probe was sent to the manufacturer for repairs. Figure 4 shows the nitrogen values for both probes compared on one chart. With the exceptions of the first week that probe #2 was used and the first week of use after probe #2 was repaired, the concentration of nitrates observed by the two probes is similar but there are differences in the shape of the responses that still needs to be evaluated.

The specific conductance of the water as measured by the Hydrolabs over the season showed a continuous trend to fresher waters from the start of measurements until about the end of July. Measurements by probe #1 show a step-wise patter because the wrong scale was selected for recording the data allowing the instrument to record 600 or 700 µS/cm (see figure. 5).

In addition to work related to using the down-hole Hydrolabs, water samples were also collected during the 2006 field season. Over 90 samples were collected from 21 sites using the Hach multi-probe to monitor water parameters at the time of pumping. Titrations using sulfuric acid were performed in the field to establish concentration of $CaCO_3$, and all samples were analyzed within 48 hours using the ion chromatograph (IC) to establish concentrations of fluoride, chloride, nitrate, and sulfate. The IC runs also analyzed samples for nitrite, bromide, and phosphate but these compounds were not detected.

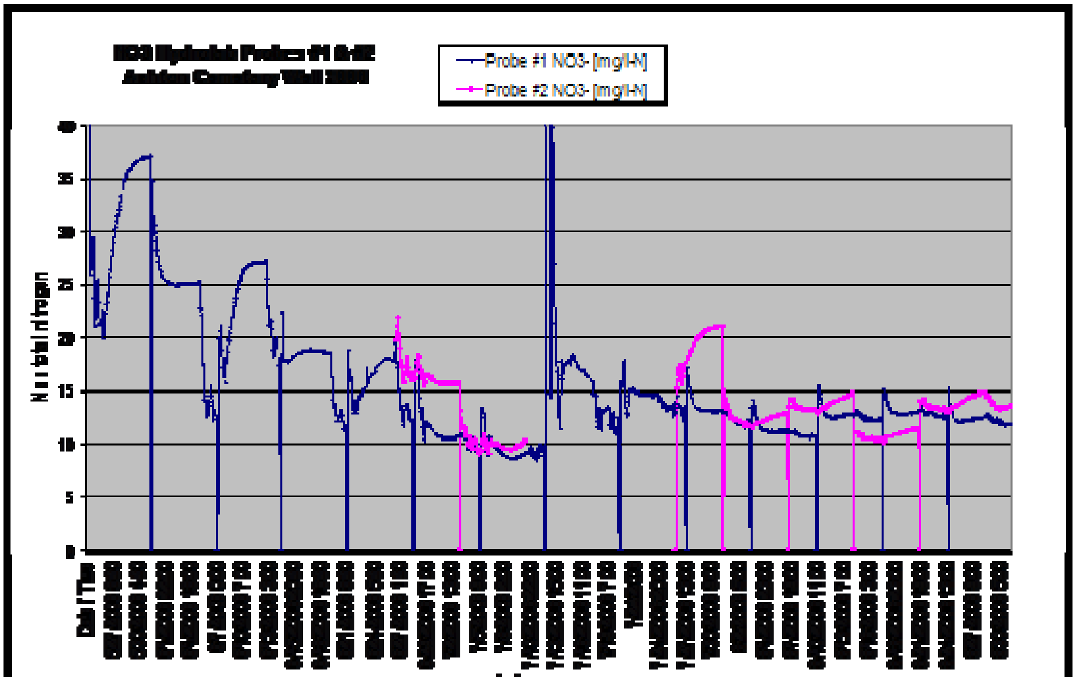

Figure 4. Nitrate values compared for both probes #1 and #2.

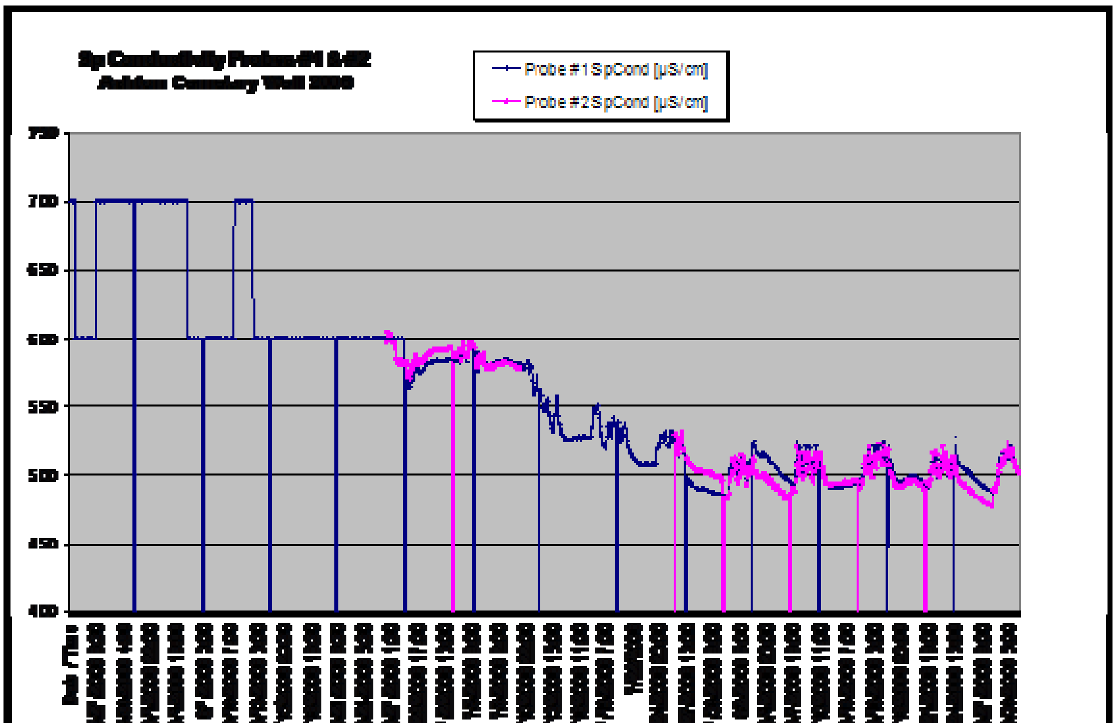

Figure 5. Probes #1 and #2 showing values for specific conductance.

After the first couple of weeks of sampling it became apparent that water table elevation information was highly desirable causing the abandonment of monitoring in some wells in favor of other wells which could be accessed for measuring water table elevations. Thirteen of the twenty-one sites sampled provided access to measure water table elevations. Work continues creating maps of the water table trying to represent the changes of elevation through time for the 2006 water season. The water table appears to act somewhat like a trap door, hinged along the Henrys Fork of the Snake River where the river has downcut into the aquifer. Numerous springs located along the south side of the river and projected elevations of the water table to the canyon wall based upon well measurements support this interpretation. To the south side of the valley, closer to Fall River, changes in water table elevation throughout the summer varied by nearly 10 feet while wells closer to the Henrys Fork showed only two-three feet of seasonal change.

Publications Resulting from the Project

None to date

Undergraduate and Graduate Student Researchers Supported

One PhD graduate student at the University of Idaho, Mark Lovell, has been funded by and participated in this research. Mr. Lovell has served as advisor and directed the work of multiple BYU-Idaho undergraduates in this project.

Undergraduate student participation has been one of the highlights of the project. For the 2006 sampling season, three undergraduate students at BYU-Idaho participated. One student graduated in geology in Dec. 2006. A second student, majoring in geology with a minor in chemistry will graduate Dec. 2007. The third student of the 2006 group is an agriculture major who was working part-time for the US Soil Conservation District in Fremont County.

These students help plan which wells to sample, contacted well owners asking permission, collected and processed samples. Water table and results from the IC analyses were also used in classes during the 2006/2007 school year. Equipment was used by the BYU-Idaho Geol 435 (Hydrology) course to collect samples from wells within the Ashton program as part of major projects for the class. Other students in the hydrology class also worked with the water table data trying to determine the extent of change through time and possible implications for direction of water flow in the subsurface and how it might change throughout the water season. Figure 6 shows one of the students who worked to process samples using the IC machine located in the George S. Romney Science building at BYU-Idaho.

Three additional students have been participating in the Ashton project in 2007.

Figure 6. BYU-Idaho student using the IC

Notable Achievements or Awards

None

Information Transfer Program

During the 2006 Fiscal Year, 104B program and state funds were used to support the Idaho Water Resources Research Institute Information and Technology Transfer Program. This program includes efforts to reach all water resource stakeholders in the state, from K to Grave. These efforts include; Water Education Workshops for Teachers (285 teachers were trained in 13 workshops across Idaho); Youth events across the state which include Water Awareness week (14,000 attendees), Youth Water Festivals in Moscow, Lewiston, Elk River, and Weiser (577 attendees) and Salmon and Steelhead Days (840 attendees); a state wide water resources seminar series delivered via a compressed video system to Boise, Moscow, Pocatello and Idaho Falls (20 seminars during the year); and six water resources workshops or conferences focusing on specific water resources issues of interest across the state. The workshop titles are given below: The Columbia Drainage Energy-Water Nexus Workshop Boise, ID June 2007. The Palouse Water Summit Moscow, ID September 2006. The Idaho Water Resources Research Symposia Boise, ID November 2006. Idaho Environmental Education Summit Salmon, ID March 2007. Idaho Water Users Conference Boise, ID January 2007. Rathdrum Aquifer Conference Spokane Valley, WA May 2007.

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	3	0	0	0	3
Masters	4	0	0	0	4
Ph.D.	2	0	0	0	2
Post-Doc.	0	0	0	0	0
Total	9	0	0	0	9

Notable Awards and Achievements

Publications from Prior Projects