Water and Environmental Research Center
Annual Technical Report
FY 2010

Introduction

The Center continues to address water resource problems at the state level. Clearly, some of our research has application to a much larger audience, particularly in the circumpolar Arctic. Presently, fifteen faculty work in the Water and Environmental Research Center; about twenty graduate students, one post-doctoral researcher and ten technical support people are involved in the research. The funding received from the USGS goes primarily to graduate student support in the form of a stipend, tuition or cost associated with student's research.

The Water and Environmental Research Center recently constructed a new website (http://ine.uaf.edu/werc/) where many of the activities of the Center are described. The "Current Data" link on that website is frequently used by stakeholders within and outside of our organization to get archived or near real time site data. We are currently developing a new searchable database to allow easier access to our site data.

Research Program Introduction

WERC research activities are driven primarily by issues related to resource development, municipal supplies, ecosystem management, and climate change. In many instances, two or more of these broad categories inform the rationale behind a specific research effort. Alaska is a vast state with a comparatively sparse population and limited infrastructure. Consequently, much of the research is dedicated to understanding hydrologic processes in regions that are understudied and/or undeveloped. Moreover, the arctic and subarctic climate found in much of Alaska presents hydrologic conditions not found elsewhere in the US, and requires dedicated expertise and study.

Although hydrologic research in Alaska is technically and logistically challenging, it is crucial not only for the benefit of the state, but also for the benefit of the nation. Alaska represents the nation's single toehold in the Arctic, with coastlines along the Beaufort, Chukchi, and Bering Seas. With the reduction in Arctic Ocean sea ice accompanying a warming climate, shipping activity as well as resource development in the Arctic Ocean are certain to increase. The United States has a stake in this development, and Alaska is the base from which US arctic activities will be conducted. Gaining a better understanding of lake water availability, river discharge, permafrost-groundwater interactions, remote water/wastewater treatment options, climate-related transformations, and a host of related issues is a necessary precursor to increased development in America's Arctic.

The WERC is an interdisciplinary team with the expertise and the inclination to take on a wide variety of research topics in order to meet the needs of the State and the Nation. While the research performed under the WRRA 104(b) program is an important component of our research portfolio, this work represents only a fraction of the varied topics investigated at our Center. Nonetheless, the 104(b) projects elicit 2:1 matching funds from the State, which constitute a significant portion of the WERC's base funding. Consequently, while the topics studied in our 104(b) projects represent only a small sampling of the topics studied at WERC, these projects are crucial to the continued functioning of the Center.

Contribution of Permafrost Degradation to Shrub Expansion in Arctic Alaska

Basic Information

Title:	Contribution of Permafrost Degradation to Shrub Expansion in Arctic Alaska
Project Number:	2010AK86B
Start Date:	3/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	AK-001
Research Category:	Climate and Hydrologic Processes
Focus Category:	Hydrology, Climatological Processes, Ecology
Descriptors:	
Principal Investigators:	Matthew A Nolan, Ken Tape

Publications

1. Tape, Ken, 2011, Mechanisms and Implications of Shrub Expansion in Arctic Alaska, Ph.D. Dissertation, University of Alaska Fairbanks
2. Tape, Ken, D. Verbyla, and J. Welker, 2010, 20th century erosion in Arctic Alaska foothills: the influence of shrubs, runoff, and permafrost, at American Geophysical Union Fall Meeting, San Francisco, CA Dec 8-14
3. Brennan, Sean and M. Wooller, 2010, Working towards a high resolution map of Sr-isotope variation of Western Alaska rivers: tracking salmon migrations of the Nushagak River, AK, at 7th International Conference on Applications of Stable Isotope Techniques to Ecological Studies, Fairbanks, AK, Aug 9-13
4. Chatterjee, Abhijit and Silke Schiewer, 2010, Biosorption of Cadmium(II) ions by citrus peels in a packed bed column, at 5th INternational Conference on Environmental Science and Technology, American Academy of Science, Houston, TX, July 12-16
5. Chatterjee, Abhijit and Silke Schiewer, 2010, Biosorption of Cadmium(II) ions by citrus peels in a packed bed column, at 5th INternational Conference on Environmental Science and Technology, American Academy of Science, Houston, TX, July 12-16

USGS Final Report

Title: 20th century erosion in Arctic Alaska foothills: the influence of shrubs, runoff, and permafrost

Start date: March 1, 2010
End date: February 28, 2011

Topic: Erosion, permafrost stability, Arctic landscape, climate change

PI: Ken D. Tape

Products of Project

Conference Oral Presentation:

Tape, KD, Verbyla, D, Welker, J. 20th century erosion in Arctic Alaska foothills: the influence of shrubs, runoff, and permafrost. *American Geophysical Union Fall Meeting*, San Francisco, CA, December 8-14, 2010.

Journal Publications:

Tape, KD, Verbyla, D, Welker, J (submitted) 20th century erosion in Arctic Alaska foothills: the influence of shrubs, runoff, and permafrost.

PhD Thesis

Tape, KD (submitted) Mechanisms and Implications of Shrub Expansion in Arctic Alaska.

Justification

The general stability of the Arctic landscape, including the fate of the carbon stored in the permafrost, is subject to interactions between permafrost, vegetation, and climate. To predict future states, we therefore need to understand the complex interactions between these components. Warmer air temperatures in Arctic Alaska since the 1970's have led to warmer permafrost temperatures, an increase in vegetation productivity, and a decline in peak runoff events. The outcome of these interactions dictates how the Arctic ecosystem will respond to climate warming, and this outcome can be illuminated by obtaining erosion records for the 20th century.

Objective

The goal of this study was to determine 20th century trends in the erosion regime and identify potential explanatory factors.

Methods

In this study, we cored and analyzed lake sediments from four watersheds where shrub expansion is occurring to compare 20th century temporal trends between shrub expansion, erosion, and runoff. NIWR support was indispensable and was used specifically to conduct Pb^{210} and Cs^{137} analysis on the cores, which allowed us to establish the 20th century depositional chronology.

The Chandler River is located in the central North Slope and flows into the Colville River. We selected the Chandler River corridor for lake coring because it contains abundant shrubs (known to affect erosion), and because repeat photography shows a large increase in shrub cover since 1950. The section of the Chandler River basin with abundant shrubs has never been glaciated , but sediment inputs from weathering Ca-rich rock outcrops provide continual disturbance that prevent peat development near outcrops and along stream channels and floodplains. The primary deciduous shrubs are alder (height = 1-4 m), willow (0.25-4 m), and birch (0.25-1.5 m).

Principal Results

Lake sediment cores 1, 3, and 4 show fluctuating or increasing erosion rates until 1980, after which these cores collectively show a decline (cumulative for three lakes: $r = -0.47$, $p < 0.03$), though when lakes are considered individually only the decline in lake 1 is significant (Figure 1). The two lakes located on a river terrace (3 and 4) have similar temporal trends in deposition, showing that between 1904 and 1980 there was a period of increasing erosion ($r^2 = 0.998$, $p < 0.001$ and $r^2 = 0.82$, $p < 0.05$, respectively). The lake 1 record has a higher temporal resolution revealing more fluctuations prior to 1980.

The record of deposition in lake 2 is unlike that in lakes 1, 3, and 4. Lake 2 deposition is highly episodic, showing an order of magnitude difference between relative maximum and minimum sediment deposition rates (~0.3 to ~0.03 $g/cm^2/yr$). Even the lower rates in lake 2 are substantially higher than the deposition rates in the other three lakes (~.008 $g/cm^2/yr$).

Assuming that the lake deposition record can be used to infer average basin erosion rates, we compute that since 1951 (the shortest record in four lakes), watersheds from lakes 1 and 3 were eroded 11.1 and 11.8 $g/m^2/yr$, respectively. The lake 4 watershed, a large area with a small lake and no obvious inputs, eroded 0.25 $g/m^2/yr$. Using the same computational method, and over the same interval, the watershed of lake 2 eroded 51.6 $g/m^2/yr$, more than twice as much erosion per area as the other three lakes combined.

Relevance

Our results indicate a background decline in erosion (collectively, in 3 cores) since 1980, superimposed by episodic erosional events (in 1 core) that dominate the total erosion from all the watersheds. The background decline in erosion is associated with trends of increasing shrubs and declining peak runoff events. In contrast to the positive feedbacks associated with shrub expansion and climate change, our results suggest a negative feedback from shrubs stabilizing soil (including carbon), though this response could be reversed by an increase in permafrost-related erosional events, or an increase in decomposition. Results from lakes 1, 3, and 4 appear counter to the recent reports of increased thaw slump activity, but results from lake 2 are consistent with these recent reports and probably reflect the episodic contribution of thermal erosion to the erosion regime within that watershed. Determining the relative contribution of enhanced vegetation productivity, changes in the hydrologic regime, and permafrost degradation to erosion trends remains a challenging problem that warrants attention in future studies.

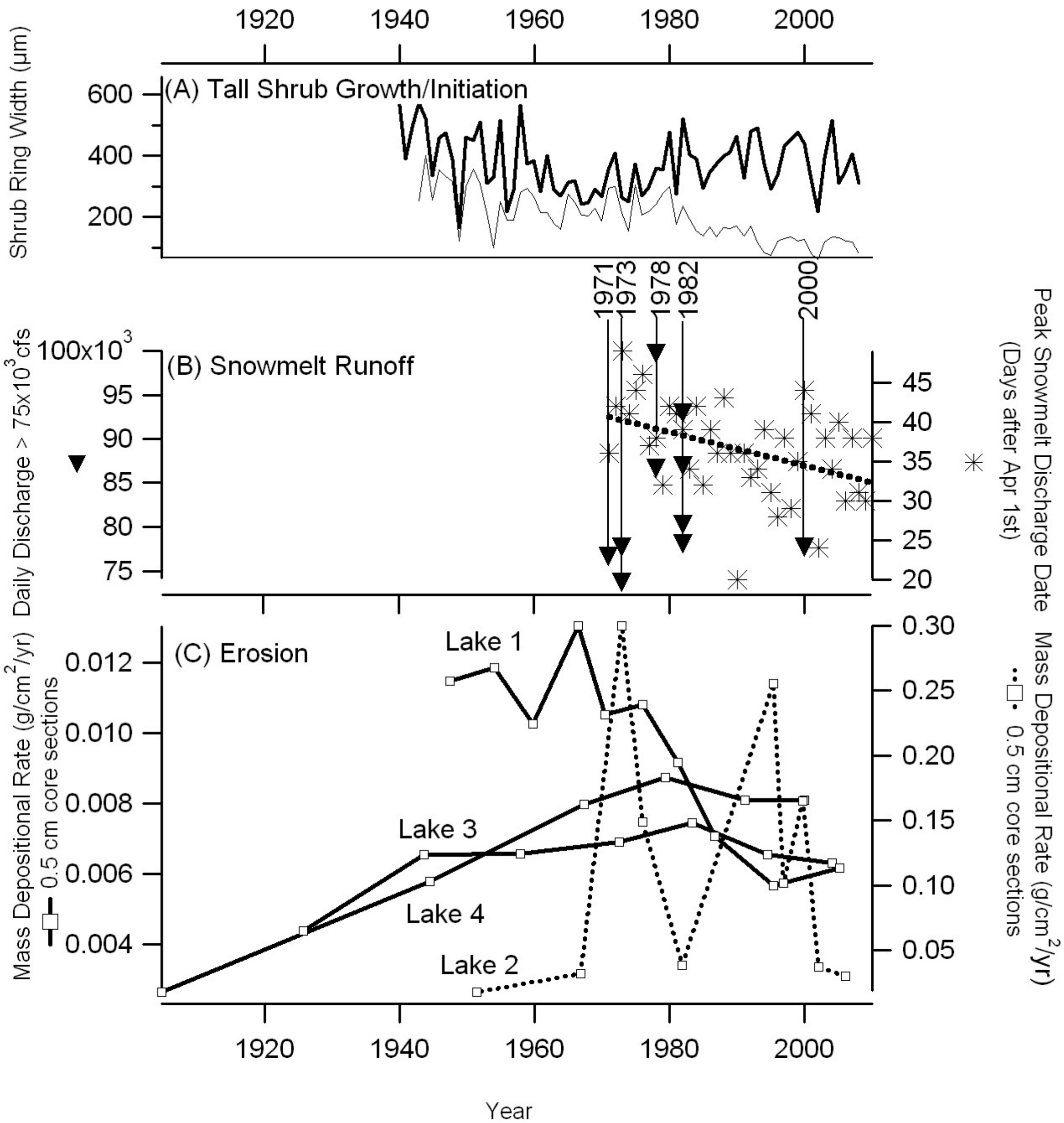


Figure 1. (A) Shrub growth ring widths for expanding (thick line) and stagnant (thin line) shrub patches, indicating increased growth along streams and gullies (expanding shrubs) since 1980. (B) A decline in the number of extreme snowmelt discharge events on the Kuparuk River, and a one-week earlier (0.21 days/decade) peak snowmelt discharge indicative of earlier onset of the growing season ($r^2 = 0.143$, $p < 0.01$, discharge data: USGS Open file reports, 1971-2010). (C) Depositional rate in four lakes over the last century. A decline around 1980 in lakes 1, 3, and 4 reflects a decline in erosion in those watersheds. We speculate that trends in shrub growth (A) and a decline in peak discharge events (B) are contributing to trends in erosion (C), except in lake 2, where the deposition is episodic and seemingly independent of trends in (A) or (B).

The diminishing role of glacier runoff into Eklutna Lake: potential impacts on hydropower and water supply for the Municipality of Anchorage (year 2 renewal)

Basic Information

Title:	The diminishing role of glacier runoff into Eklutna Lake: potential impacts on hydropower and water supply for the Municipality of Anchorage (year 2 renewal)
Project Number:	2010AK87B
Start Date:	3/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	AK-001
Research Category:	Climate and Hydrologic Processes
Focus Category:	Water Supply, Climatological Processes, Sediments
Descriptors:	
Principal Investigators:	Michael Gregg Loso

Publication

1. I note that while the period of the grant is over, and the finances have been closed out by our office, work continues on this project. Both graduate students funded by this work, Ann Marie Larquier and Louis Sass, have done exceptionally well in their work on the project and are well on their way to completion of their theses. Ann Marie Larquier's thesis is in its first draft now and is due for completion by the end of April, 2011. She will submit her thesis to Water Resources Research by summer. Louis Sass' thesis will be two chapters, with one in the first draft now and the second due in the fall 2011. He will submit the first to Water Resources Research and the second to Journal of Glaciology. I am confident that all these works will successfully be published, and I will notify NIWR of this. All data collection and analysis is at this time substantially complete.

2010 NIWR Funded Research Project
Final Report March 2011

Title: The diminishing role of glacier runoff into Eklutna Lake: potential impacts on hydropower and water supply for the Municipality of Anchorage

Start Date: March 1, 2009

End Date: February 28, 2011

Principal Investigator: Michael G. Loso, Associate Professor of Earth Sciences, Alaska Pacific University; mloso@alaskapacific.edu; (907) 564-8263

Congressional District: Alaska

Abstract: I propose to continue an existing study of the impacts of ongoing climatic changes on the glacier runoff contribution to Eklutna Lake. The existing study includes work funded by NIWR in the previous fiscal year and successfully completed by Alaska Pacific University faculty, graduate students, and undergraduates (see companion progress report: Loso 2009). Anchorage, the largest city in Alaska, is critically dependent upon the waters of Eklutna Lake for both drinking water (~80% of the city's supply) and hydropower generation (10-15% of the city's supply). Eklutna Lake is glacier-fed and has retreated dramatically over the last 50 years, losing approximately 1.5 km^3 of ice. Impacts of this ongoing glacier retreat include the short-term provision of additional meltwater to the Eklutna Lake, but over the longer term will likely include a reduced contribution of meltwater during the mid-summer when Municipal demand for water and power peaks. Additional glacier-mediated changes to the temperature and sediment load of the lake's inlet stream appear to have already altered the density-driven stratification of the lake with implications for water treatment and reservoir volume. The work proposed here will be led by the same two graduate students who worked on this project last year. Both are scheduled to complete their theses during the performance period of this grant, and a virtue of funding their continued work on this project (aside from the obvious benefit of gaining an additional year of data) is the ability it provides them to incorporate their experience with this logistically difficult work into improved field techniques that will benefit our research over the long-term. One student, focused on the glacier, will continue the mass balance and velocity measurement program. The second student, focused on hydrology, will continue a time-series of water and sediment discharge on East and West Forks of Eklutna River. Support is requested primarily for graduate student salary and logistical expenses; mentoring will be provided by research collaborators from Alaska Pacific University, US Geological Survey, the Anchorage Water and Wastewater Utility, and Municipal Light and Power.

Summary of Results to Date

This final report updates a progress report submitted December 2009. A brief description of activities to date (March 28, 2011) is provided below, and corresponds numerically to the five tasks outlined in our original proposal. An additional task completed, but not included in the original proposal, is included as task 6.

I note that while the period of the grant is over, and the finances have been closed out by our office, work continues on this project. Both graduate students funded by this work, Ann Marie Larquier and Louis Sass, have done exceptionally well in their work on the project and are well on their way to completion of their theses. Ann Marie's thesis is in its first draft now and is due for completion by the end of April, 2011. She will submit her thesis to *Water Resources Research* by summer. Louis's thesis will be two chapters, with one in the first draft now and the second due in the fall 2011. He will submit the first to *Water Resources Research* and the second to *Journal of Glaciology*. I am confident that all these works will successfully be published, and I will notify NIWR of this. All data collection and analysis is at this time substantially complete.

1. **Complete automated hourly melt-season (May – September) measurements of water temperature, river stage, and turbidity on both the West and East Forks of the Eklutna River**

   Monitoring stations were established at two locations in the Eklutna Basin in the spring, and removed in the late fall (May 19th through October 24th, 2010) by graduate student Ann Marie Larquier with assistance from undergraduate field assistant Janelle Eklund and new graduate student Nathan Bosch. The East Fork Eklutna River gage was installed at a stable cross section where a bridge crosses the river at mile 10.2 of the Eklutna Lakeside trail (61◦17'51.9''N, 148◦58'23.7''W). The West Fork Eklutna River gaging station was established in a stable reach of unbraided proglacial channel approximately 2 km below the terminus of the glacier, approximately 150 meters downstream of a bridge crossing (61◦17'47.2''N, 148◦58'37.3''W). Onset HOBO U20 water level data loggers recorded water pressure at 10 second intervals and 15 minute averages were recorded internally, while barometric pressure was recorded with a HOBO Barometric Pressure Smart Sensor and used to convert raw pressure data recorded by the water level logger to water levels and compensate for barometric pressure changes, recorded at the same interval as the water level data logger. Gaging stations were also equipped with an in situ Campbell Scientific OBS-3+ turbidity sensor mounted in a protective housing which recorded turbidity in real time at 10 second intervals and 15 minute averages (2010) were recorded using a Campbell CR800 data logger. For the first time in our three year history of this gaging effort, all automated gages survived summer high flow events and recorded complete data during the entire melt season. Discharge data from both forks of the creek are shown in figure 1, with 2009 data for comparison (turbidity data not shown).

2. **A minimum of ten measurements of water discharge and suspended sediment concentration on both Forks to establish rating curves**

   In conjunction with the automated data collection described under task 1, above, during each field visit river discharge was measured using the area-velocity method and dip samples of water were collected to determine the suspended sediment concentration in the water column. These dip samples were later analyzed in the laboratory using standard vacuum-assisted filtering equipment. Results of these measurements were used to create rating curves relating stage and turbidity to discharge and suspended concentration, respectively. Direct results of these measurements are shown in the tables collected by figure 2. The discharge rating curve was constructed using Aquarius GRMAT software under the supervision of USGS hydrologist Dave Meyers and this curve was used to create the continuous discharge record shown in figure 1. We note that the number of measurements were less than the ideal target, 10, but were judged sufficient to create robust rating curves nonetheless.

3. **Complete melt-season (May – September) measurements of accumulation, ablation, and velocity at a minimum of three sites on the Eklutna Glacier**

   In 2010 we expanded our mass balance program to include 6 sites: we measured both winter accumulation and summer ablation at three sites on the main eastern branch of the glacier and supplemented that program with three additional ablation monitoring sites on the previously unmonitored west branch. Spring measurements were made between May 21 and 24, 2010 and final fall measurements were made between September 21 and 22, 2010. The resulting calculated mass balance is shown in figure 3 as a function of mapped elevation, with 2008 and 2009 results for comparison. Velocities were also measured (not shown) and were consistent with previous year's measurements. In summary, the glacier-wide annual balance for the years 2008, 2009, 2010 was +0.53 meters water equivalent, -1.45 mweq, and -0.15 mweq respectively.

4. **Complete hourly melt-season (May – September) measurements of air temperature at an expanded network of sites (minimum 3) on the Eklutna Glacier to complement the existing complete meteorological measurements carried out at mid-glacier**

   A complete met station was again installed at mid-glacier by APU students during the May field course. As in previous years, this station monitored air temperature, RH, wind speed and direction, incident and reflected shortwave radiation, and snow melt during the entire melt season. In addition to this station, air temperature was measured with shielded Hobo dataloggers at an additional four sites during the melt season: the upper glacier, near the ELA, below the ablation zone near the terminus, and at the Eklutna River bridge downstream of the terminus.

5. **Detailed, ground-based measurements (using kinematic differential GPS) of the surficial geometry of the Eklutna Glacier surface and margin**

   This work was completed primarily by graduate student Louis Sass, in conjunction with a number of field assistants including the PI, students from the May field course, undergraduate John Sykes, and others. But in a huge boon to our research program, we were able to convince the USGS and Army Corps of Engineers to fly LIDAR over the entire Eklutna Glacier in October of 2010, providing us (at no cost to APU or to the NIWR grant) a complete, high accuracy, high resolution digital elevation model of the glacier surface. This result is shown in figure 5.

6. **Additional task: Bathymetric surveying**

   In order to complete a hydrologic model of the Eklutna Watershed, it is necessary to account for changes in storage in Eklutna Lake. Knowledge of the volumetric change in storage as a function of time allows us to compare inputs (gaged streams) with outputs (evaporation and usage by power and water utilities) to estimate the nature and magnitude of unconstrained variables in the basin (chiefly input by other small streams, loss to groundwater, and unknown errors). USGS gages the lake but we needed to conduct a bathymetric survey of Eklutna Lake to convert stage to volume. The survey was conducted by Ann Marie Larquier and other students in October 2010 using a 210 kHz single beam survey grade echosounder. Horizontal position was measured synchronously with a GPS mounted directly above the echo sounder. Depth measurements collected at a frequency of 7 points per second were averaged to a corresponding GPS position. Depth measurements have a manufacturer reported accuracy of +/- 0.01m or +/- 0.02%, with positional data accuracy of +/-4m.

Data were collected from a moving boat; surveying equipment was fitted to a canoe powered by an electric motor because outboard engines are not allowed on Eklutna Lake. Data were processed using Environmental Systems Research Institute's (ESRI) ArcGIS software version 9.3 and the bathymetric surface was interpolated from 71,256 measured points using spherical kriging. A digital elevation model of Eklutna Lake created from 71,256 measured depth points using a spherical kriging technique. The model is shown in figure 6.

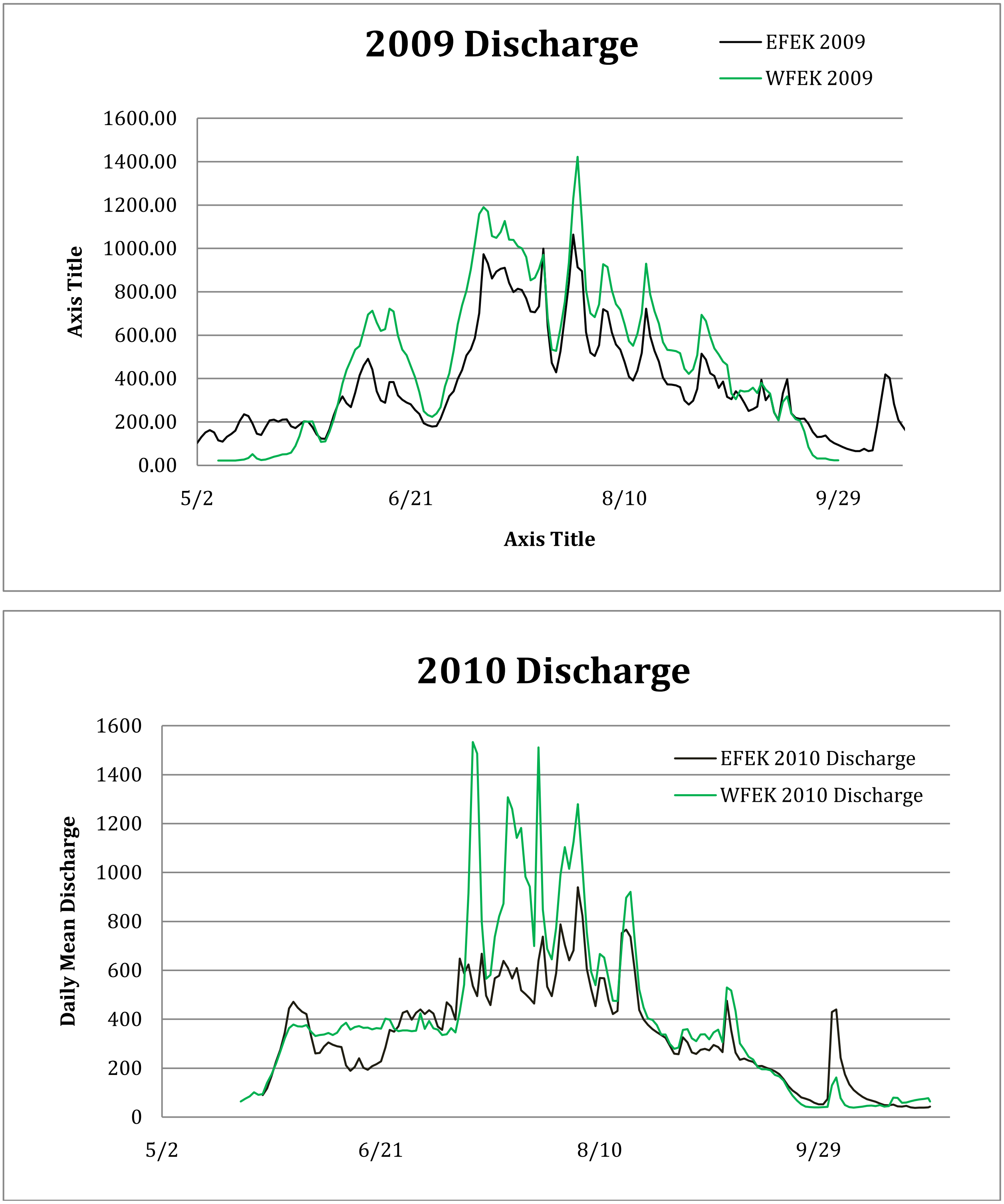


Figure 1. Continuous melt season discharge measurements from the West Fork and East Fork of the Eklutna River. Upper panel shows 2009 results for comparison with 2010 results collected under the current proposal. Turbidity/SSC data were collected simultaneously but are not shown.

East Fork Eklutna 2010		
Date	DISCHARGE (CFS)	Stage (m)
6/18/2010	263.85	0.2105
7/10/2010	712.31	0.4875
8/29/2010	246.56	0.252667
9/7/2010	511.92	0.416333
10/2/2010	420.63	0.3584
10/10/2010	86.38	0.07375

EAST FORK 2010		
Date	SSC (mg/L)	Turbidity (NTU)
6/12/2010	2.39	37.95
6/18/2010	6.67	43.16
7/10/2010	44.69	86.10
7/24/2010	6.60	50.04
8/10/2010	14.90	51.14
8/29/2010	3.26	42.56
10/24/2010	12.76	16.25

West Fork Eklutna 2010		
Date	DISCHARGE (CFS)	Stage (m)
6/12/2010	211.29	0.7018
6/18/2010	158.1	0.6786
7/10/2010	737.49	0.8650
8/10/2010	819.38	0.8488
8/29/2010	435.81	0.7201
9/1/2010	284.01	0.6672
9/7/2010	538.09	0.7983
10/2/2010	147.35	0.4730
10/10/2010	28.3	0.2094

WEST FORK 2010		
Date	SSC (mg/L)	Turbidity (NTU)
5/23/10	2.55	18.05
6/12/10	176.80	257.30
6/18/10	124.57	136.20
7/10/10	347.55	832.00
7/24/10	197.11	765.90
8/10/10	5.11	180.50
9/1/10	102.67	108.00
9/7/10	860.22	983.00
10/2/10	299.18	282.70

Figure 2. Turbidity and stage measurements from the East Fork (upper tables) and West Fork (lower tables) of the Eklutna River. Measurements are shown with corresponding SSC and discharge measurements from automated equipment.

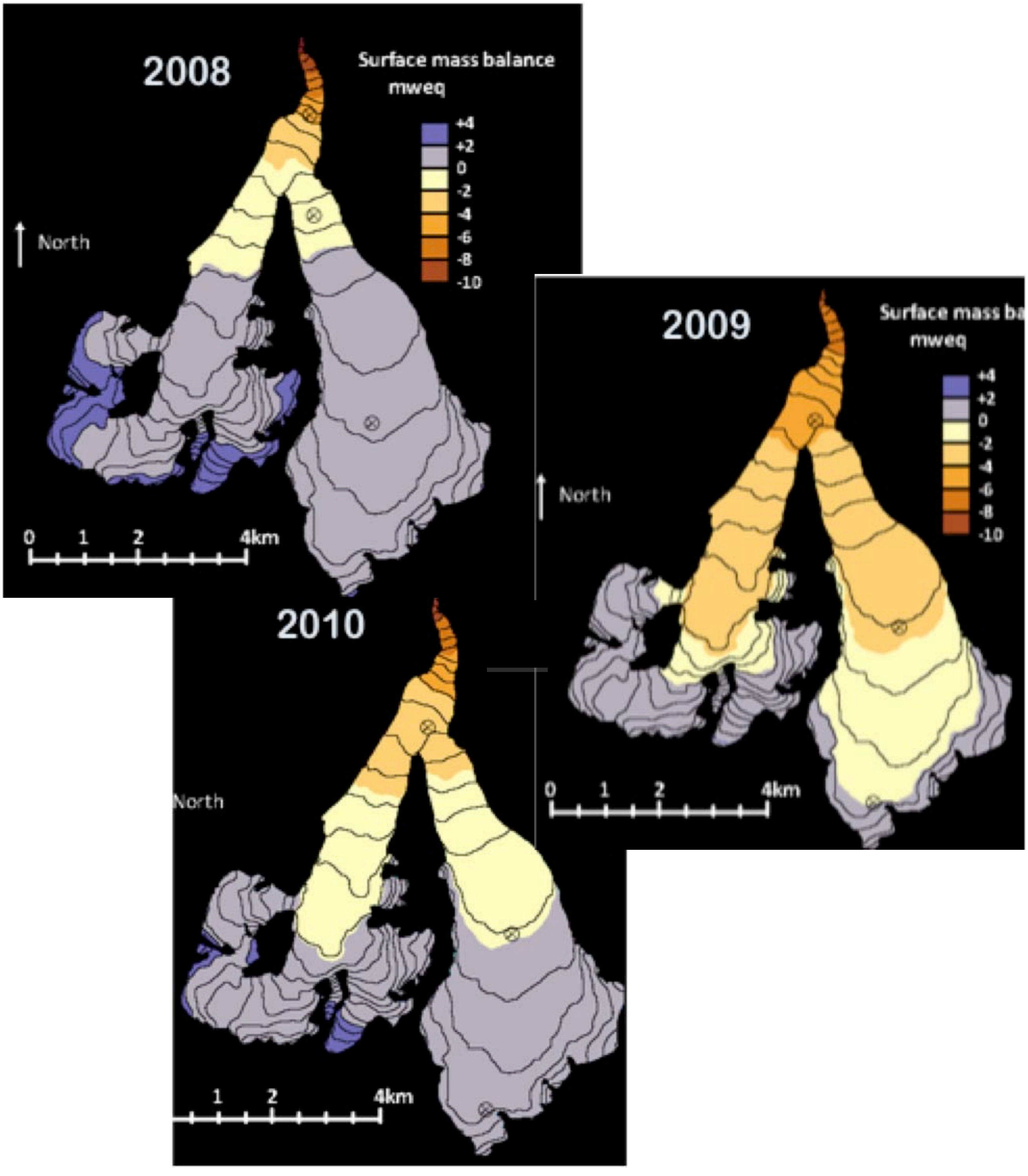


Figure 3. Mass balance for Eklutna Glacier for years 2008-2010, based on 3 primary measurement stations on each glacier. 2010 map reflects the most complete monitoring program yet undertaken: three ablation stations on the west branch and three combined accumulation/ablation stations on the east branch.

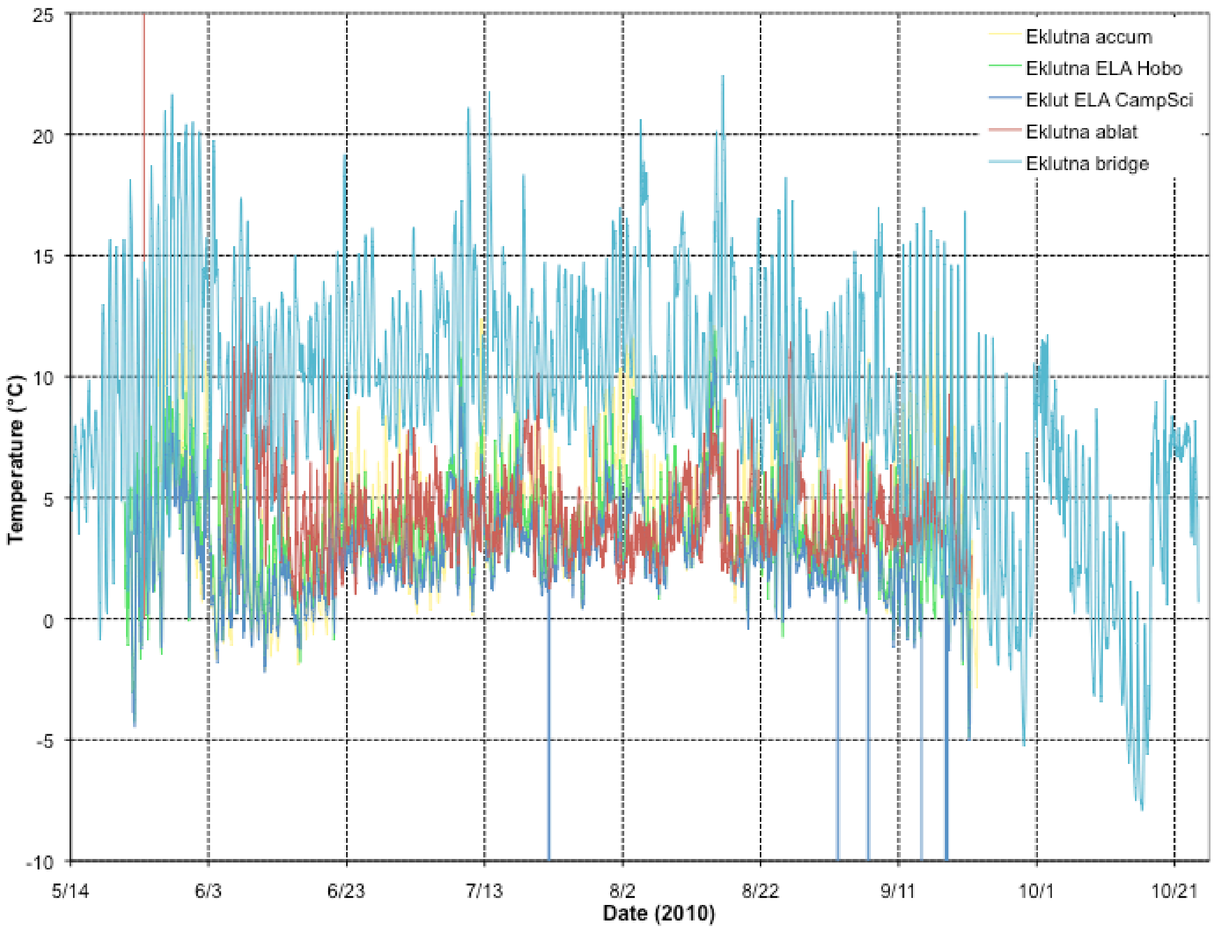

25
20
15
10
5
0
-5
-10
Temperature (°C)
5/14
6/3
6/23
7/13
8/2
8/22
9/11
10/1
10/21
Date (2010)
Eklutna accum
Eklutna ELA Hobo
Eklut ELA CampSci
Eklutna ablat
Eklutna bridge

Figure 4. Air temperatures measured at five sites on and below Eklutna Glacier during melt season 2010.

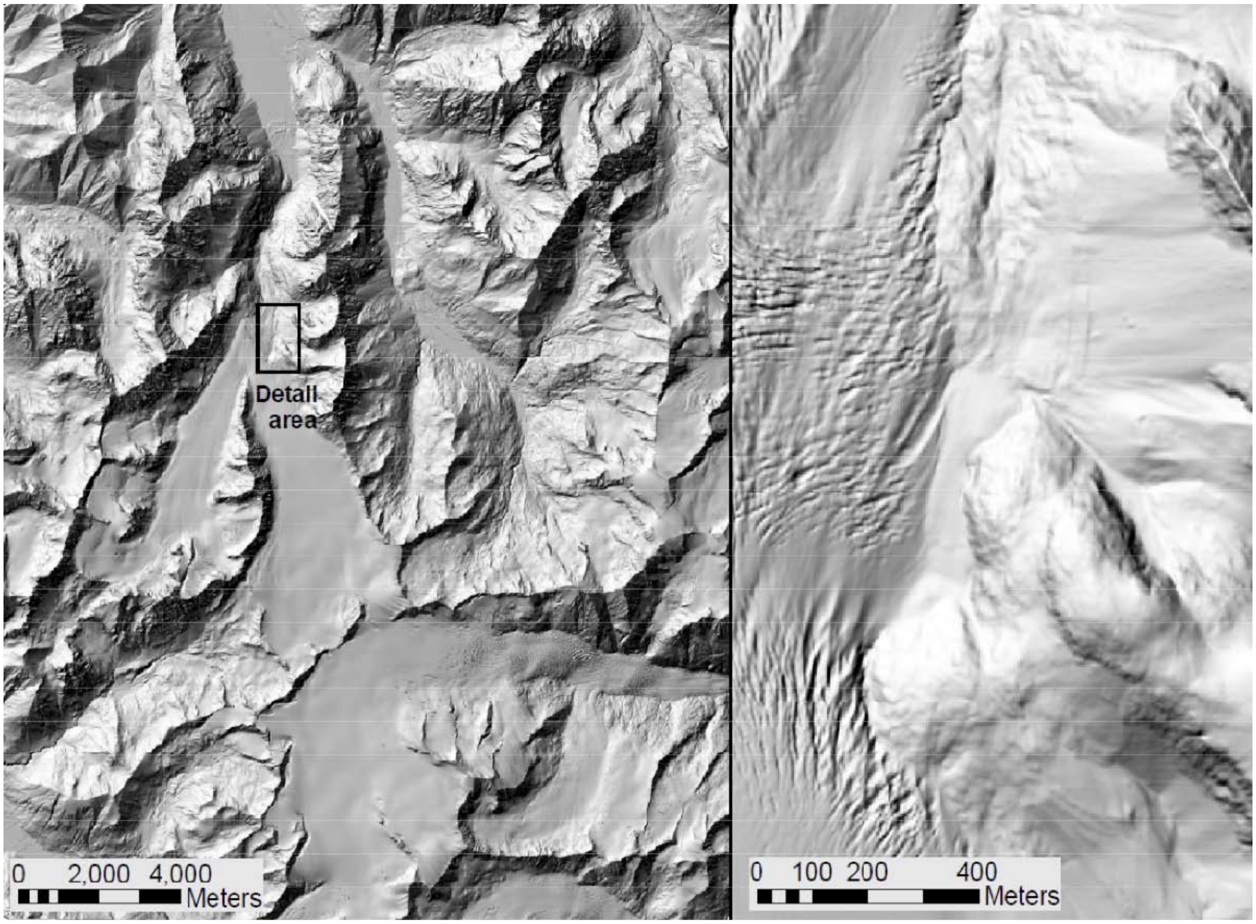


Figure 5. LIDAR derived hillshade map of the Eklutna Glacier (left) and detail from that image (right). This data was collected by Aerometric under a contract with USGS and the Army Corps of Engineers in October 2010 and was made available to APU for this research project at no cost.

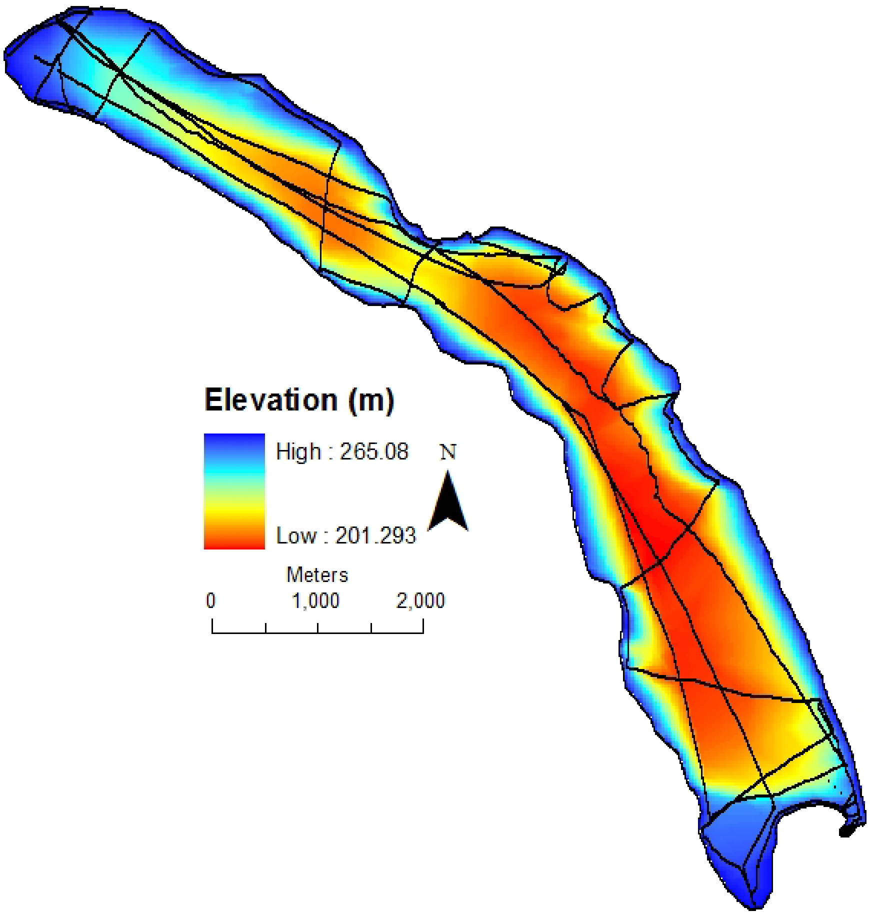


Figure 6.
Bathymetric map of Eklutna Lake constructed using thousands of sonar-soundings collected from a moving boat along transects shown as thick black lines. Elevations are shown in the colorbar legend as meters above sea level.

Hydrogeology and Geochemistry of the Anchorage Aquifer System: Research and Teaching Applications

Basic Information

Title:	Hydrogeology and Geochemistry of the Anchorage Aquifer System: Research and Teaching Applications
Project Number:	2010AK89B
Start Date:	3/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	AK-001
Research Category:	Water Quality
Focus Category:	Groundwater, Water Quality, Education
Descriptors:	None
Principal Investigators:	LeeAnn Munk, Jens Munk, Bryce Willems

Publication

1. Willems, B.A., Munk, L.A., Munk, J., 2010, Training Alaskan Environmental Geologists: installation of a new well field on the campus of UAA, Alaska Section of the American Water Resources Association Annual Conference, May 31st-April 2nd, 2010.

Activities to Date

We have completed the installation of the wellfield, sedimentologic descriptions, static water level monitoring, and slug tests. Collectively, these data have already led to developing collaborative projects between the Department of Geological Sciences and Facilities Management at UAA as well as the Anchorage Water & Wastewater Utility (AWWU). Both parties are particularly interested in understanding the record of head variability at the well field as it may relate to the use of high-yield wells for building cooling.

Wellfield Design

The well field consists of one pumping well and two monitoring wells. All wells reach a depth of 68 ft and are screened over the final 12 ft, which corresponds to the thickness of a basal sand and gravel unit. The 4 in pumping well is cased with PVC pipe and has a 1 GPM pump installed 2 ft from the base of the well. The flow rate for the pump was determined from preliminary pumping tests during wellfield installation. Flow rate can be reduced using a manual lever at the well head and a flow meter allows the determination of well yield during pumping tests. The 2 in diameter, PVC cased, monitoring wells are 20 and 10 ft away from the pumping well at approximately perpendicular angles. The pumping well and one monitoring well has a sand pack around the screened interval with a mud seal. The second monitoring well was slightly deviated from vertical during drilling, which made well construction difficult. This difficulty forced the use of a natural pack around the screened interval.

Stratigraphy

A total of 15 split spoon samples were collected during drilling. Field and lab descriptions of material, along with the drillers notes, indicates that the stratigraphy consists of approximately 41 ft of sandy gravel, 13 ft of gray-blue till, and 12 ft of gravelly-sand. The well depth was based on the occurrence of a hard, gravelly till underlying the lower sand and gravel unit, as evidenced by a split spoon sample with poor recovery. The occurrence of the gray-blue till and basal till was unexpected and not evident from adjacent well logs.

Static Water Levels

Water levels were measured continuously from March through the present. A pressure transducer in each of the monitoring wells automatically records head measurements in two minute intervals. The head data is corrected for changes in barometric pressure using softer provided by the manufacturer. The monitoring wells responds similarly despite the difference in fill material around the two wells. The head levels are greatest in the winter when the water table is within 15 ft of the ground surface. During the summer, the water table fluctuates widely and appears to be strongly influenced by drawdown from nearby wells used for building cooling.

Slug Tests

Six rising head and six falling head tests have been conducted in each of the monitoring wells. Plastic cylindrical slugs that measured 32 5/8 in long and 1.5 in wide were raised and lowered accordingly within the monitoring wells. Head measurements were collected every second by a pressure transducer and corrected for barometer pressure changes. Slug test data were analyzed using a Hvorslev solution. Each test estimated a hydraulic conductivity of approximately 0.01 cm/s, which corresponds to a lithology of well sorted sands and gravels indicative of glacial outwash. It is noted that the values derived values of hydraulic conductivity appear to be nearly identical for each well, which suggests that flow into the wells is being controlled by the formation and not the sand pack.

GPR Profile

A GPR profile was collected over the wellfield in an attempt to image the shallow subsurface and buried utilities. The profile was collected using a pulseEKKO PRO System with a 50 MHz Antenna. A common-offset survey was completed with a 6 m antenna separation and a 0.5 m antenna step size. The profile showed two diffraction hyperbolas that were produced over two buried utilities, yet the presence of clay-rich soil at the ground surface produced extensive attenuation of the radar signal which resulted in penetration only within the upper 1-2 meters of the subsurface.

Student Involvement

Undergraduate students have participated in every phase of our investigation. Students from the Spring 2010 Regional Aquifer Systems course described core in the field during well installation. They also conducted a semester long project that examined the potential physical characteristics of the aquifer throughout Anchorage based off the understanding of the stratigraphy at the wellfield. Clifton Fox completed the geologic description of the core material in lab. Emily Conway and Kyla Choquette conducted slug tests on two separate occasions. Emily Conway also assisted in a preliminary pump-test while Kyla and Megan Cardenas also assisted in the collection of head data from the pressure transducers. Nine students from the Fall 2010 Environmental Geophysics class collected the GPR profile across the wellfield.

UAA Geological Sciences students process aquifer material extracted during drilling of the UAA well field.

UAA Geological Sciences student oversees drilling of the UAA well field.

Characterization of major watersheds draining into Bristol Bay, Alaska using strontium isotopes: a new method for tracking water resources in Alaska

Basic Information

Title:	Characterization of major watersheds draining into Bristol Bay, Alaska using strontium isotopes: a new method for tracking water resources in Alaska
Project Number:	2010AK93B
Start Date:	3/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	AK-001
Research Category:	Not Applicable
Focus Category:	Hydrogeochemistry, Water Use, Methods
Descriptors:	Strontium Isotopes, watersheds, Alaska
Principal Investigators:	Matthew John Wooller

Publications

1. Conference Poster and Abstract: Brennan et al. (2010). Working towards a high-resolution map of Sr-isotope variation of Western Alaska Rivers: tracking salmon migrations of the Nushagak River, AK. 2010. Poster Presentation. ISOECOL, Fairbanks, AK. Oral Conference Presentation: Brennan et al. (2011). The Trans-Alaskan Strontium Isotope Survey (TASIS) – geochemically characterizing Alaskan watersheds to track salmon migrations. Oral Presentation American Water Resources Association, Fairbanks, Alaska
2. Brennan et al. (2011). Tracking the Temporal and Spatial Migration of Salmon Using Strontium Isotopes (87Sr/86Sr) in Otoliths. Oral Presentation Water and Environmental Research Center, UAF. Journal Publications:
3. Brennan et al. (in prep.) The Trans-Alaskan Strontium Isotope Survey: characterizing watersheds of Alaska using 87Sr/86Sr.

USGS Final Report

Title: Trans-Alaskan Strontium Isotope Survey (TASIS): geochemically characterizing Alaskan watersheds to track salmon migrations.

Start date: 1 Mar 2010

End date: 28 Feb 2011

Focus Category: Hydrogeochemistry, Water Use

Descriptors: Strontium Isotopes, Watersheds, Alaska

PI: Matthew Wooller

Products of Project

Conference Poster and Abstract:

Brennan et al. (2010). Working towards a high-resolution map of Sr-isotope variation of Western Alaska Rivers: tracking salmon migrations of the Nushagak River, AK. 2010. *Poster Presentation.* ISOECOL, Fairbanks, AK.

Oral Conference Presentation:

Brennan et al. (2011). The Trans-Alaskan Strontium Isotope Survey (TASIS) – geochemically characterizing Alaskan watersheds to track salmon migrations. *Oral Presentation* American Water Resources Association, Fairbanks, Alaska

Brennan et al. (2011). Tracking the Temporal and Spatial Migration of Salmon Using Strontium Isotopes ($^{87}Sr/^{86}Sr$) in Otoliths. *Oral Presentation* Water and Environmental Research Center, UAF.

Journal Publications:

Brennan et al. (in prep.) The Trans-Alaskan Strontium Isotope Survey: characterizing watersheds of Alaska using $^{87}Sr/^{86}Sr$.

Introduction: problem, objectives, and relevance

Problem

A challenging issue in freshwater ecological conservation is tracking population response to perturbations. This is especially difficult when studying population dynamics of anadromous fish such as, salmon of the North Pacific. Pacific salmon stocks (e.g., Chinook - *Oncorhynchus tshawytscha*) have shown dramatic changes in returns into Western Alaskan Rivers. Salmon not only maintain an important mechanism of nutrient transport between marine, aquatic and terrestrial ecosystems, but are also a valuable resource to humans. The population structure of salmon is hierarchical with a strong geographical relationship. Large-scale changes in the freshwater environment such as mineral development by humans pose real threats to the biodiversity and overall productivity of these species, and to human communities dependent upon sustainable returns of salmon year to year. Thus, there are large efforts to develop tools to track salmon natal sources and habitat use patterns to better conserve salmon biodiversity and productivity, and the natural resource they represent to human communities.

Goal

The long-term goal of this research is to geochemically characterize salmon natal sources and habitats in the rivers of Western Alaska. This information will generate a map of strontium (Sr) isotope ratio ($^{87}Sr/^{86}Sr$) variation within and among Alaskan watersheds to provide an accurate and economical method for tracking natal and rearing habitat use of Pacific salmon. $^{87}Sr/^{86}Sr$ compositions of aqueous environments are recorded in the otoliths (the auditory structure of teleost fish) of salmon incrementally like tree rings, such that variations in the aquatic habitats used by salmon are recorded throughout an individual fish's life span. We aim to use this chemical record to track the lives of Pacific salmon originating and returning to the freshwater habitats of Alaskan Rivers to aid current management efforts to conserve salmon biodiversity and sustain salmon productivity.

Objectives

The objectives of this study were:

1) To document the magnitude of strontium isotopic variation in Alaskan Rivers by conducting the first Trans-Alaskan Strontium Isotope Survey.

2) To continue to develop and evaluate a model in Arc Global Information Systems (GIS) which predicts inter- and intra-watershed variation using rock geochemistry data and geologic maps.

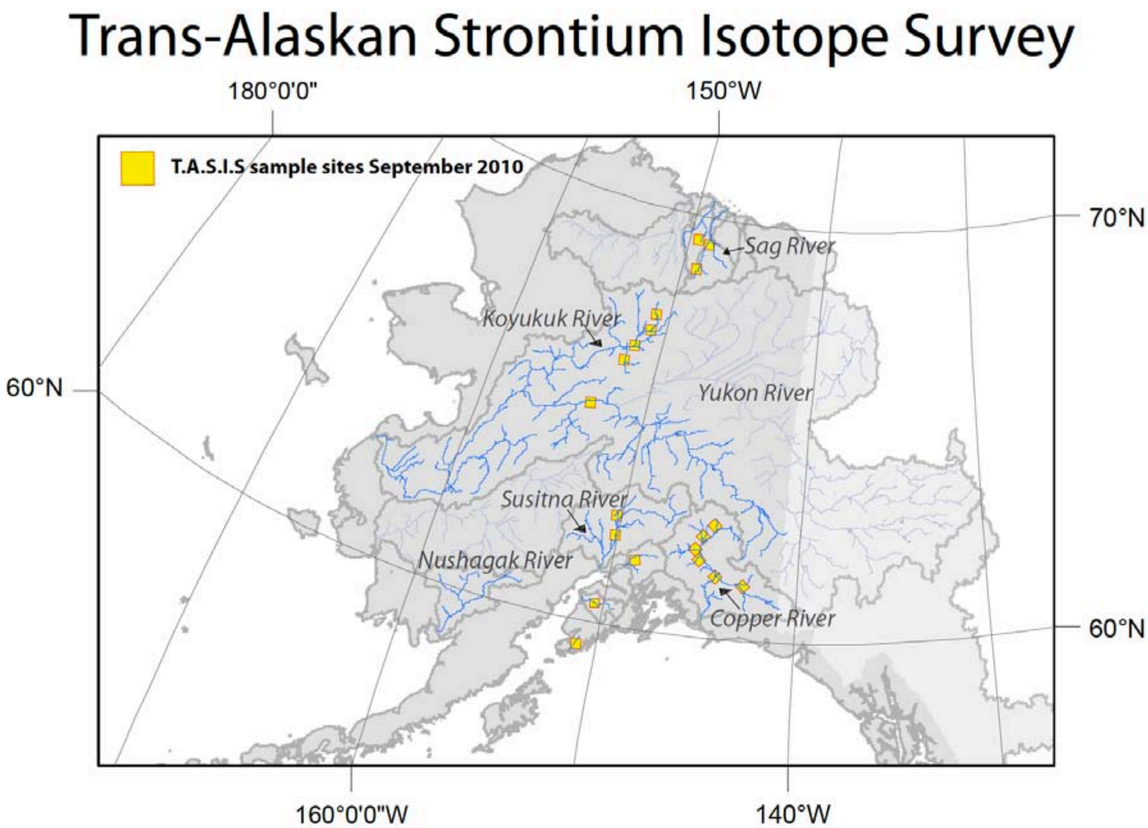


Figure 1: River sampling sites of TASIS along the road system in Alaska.

Main Findings

The main findings of this geochemical survey indicate the large variation of $^{87}Sr/^{87}Sr$ ratios of Alaskan Rivers driven by geologic diversity. This variation has a strong latitudinal gradient, such that the lowest $^{87}Sr/^{87}Sr$ ratios are found in rivers draining the relatively young mountain ranges of South Central Alaska, while the highest ratios are found further north in the much older, compositionally different Brooks Range (Figure 2).

Additionally, our preliminary modeling of the Nushagak River draining into Bristol Bay, Alaska suggests that rock geochemistry data and geologic maps are significant predictors of $^{87}Sr/^{87}Sr$ ratio variations in a watershed (Figure 4). This modeling was done prior to the TASIS field work and analysis. We aim to further develop this model (presented in Figure 4) with the analyses conducted for the TASIS project from this study.

Further, our preliminary analyses on a coho salmon otolith caught in the Tonsina River (tributary to the Copper River in Alaska) indicate that natal sources and habitat use patterns can be discerned with high accuracy using laser ablation $^{87}Sr/^{87}Sr$ ratio analyses in otoliths (Figure 3).

Relevance

This study suggests that characterizing the geospatial strontium isotopic variation within and among Alaskan Rivers is feasible and will be beneficial in helping to resolve fundamental knowledge gaps concerning Pacific salmon population structure and habitat use patterns.

Methods

Water sample collection in the field:
Water samples from 25 rivers in Alaska were collected for isotopic and elemental analysis. Sample inventory is summarized in Table 1. At each sample site three field replicates were collected to evaluate reproducibility of field collection and subsequent filtration methods. Initially, water was collected into acid washed 250 ml LDPE bottles. Bottles were fastened using zipties to an ~ 8' long pole (either wood or plastic) wrapped in Parafilm ® and submerged completely underwater upstream of sampler. Following collection, all samples and replicates were filtered using 0.45 μm syringe filters within 48 hours of collection into acid washed 125 ml LDPE bottles. Samples were acidified with Ultrapure concentrated nitric acid within 16 days of collection and stored until analysis four months later. Up until the point of acidification all samples were kept cold and out of light.

Water isotopic and elemental analyses:
Sr isotopic compositions of waters were determined using a Thermo Scientific NEPTUNE High Resolution multi-collector inductively coupled mass spectrometer (MC-ICP-MS) at the University of Utah ICP-MS Laboratory. Elemental analyses were determined using an Agilent 7500ce inductively coupled mass spectrometer. All samples prepared for elemental and strontium isotopic analysis were prepared in a clean laboratory in laminar flow hoods.

For isotopic analyses the UUGL has developed an automated sampling system to purify the Sr present in aqueous solutions using an inline chromatographic column packed with a crown ether resin (Eichrom's Sr Resin ®). The column is repeatedly used throughout each run (and also multiple runs). A total of two columns were used during the analyses presented in this paper. The initial column was replaced with a new column when signal intensities for ^{88}Sr attenuated consistently below ~ 8 volts. Each sample (and standard) is bracketed with two 4M blanks (one before sample; one after), which act to purge the column of any residual Sr present from the prior analysis. The voltage of Sr measured in the blanks is used to correct the corresponding following sample or standard analysis. The residual voltage of Sr measured in blanks attenuates exponentially, such that our sample to blank signal ratio is consistently ~ 250:1 Volts).

Samples were analyzed in a series of runs (1-8). Prior to isotopic analysis a small sample from each river was analyzed to determine its elemental strontium concentration. For both elemental and isotopic analyses samples were prepared as a 4 molar acid solution using trace metal grade HNO_3. Run sequences were ordered starting with samples containing lowest concentrations of Sr to progressively higher concentrations. By not running a particular sample with a low Sr concentration directly after a sample with high Sr concentration we minimize potential memory effects of the column. The samples with relatively high Sr concentrations were diluted within a range of 40 – 290 ppb.

Otolith strontium isotopic analyses:
Analyses of ^{87}Sr/^{86}Sr ratios in otoliths were done using multicollector-inductively coupled plasma mass-spectrometry (MC-ICP-MS) by Sean Brennan and Co-PIs Drs. Cerling and Fernandez at the University of Utah ICP-MS Laboratory using established laser ablation methods. Otolith analyses targeted a) the region accreted during a salmon's freshwater stage (~250 μm distal of primordia – after yolk absorption, but before outmigration), and the region accreted during the marine stage; and b) produced ^{87}Sr/^{86}Sr time-series of individuals (e.g. see Figure 3).

ArcGIS modeling of strontium isotopic variation in a watershed:
This model uses high- resolution geologic maps and available rock geochemistry data in the literature and databases (e.g., GEOROC - georoc.mpch-mainz.gwdg.de/georoc) to predict spatial variation of $^{87}Sr/^{86}Sr$ values of river waters. Figure 4 is preliminary modeling conducted by Sean Brennan (the PhD student for this proposed project) with Dr. VanLaningham (Co-PI) (2010). For this preliminary work we compiled all available rock geochemistry data ($^{87}Sr/^{86}Sr$ and Sr ppm) available for each geologic unit in the Nushagak River basin and predicted the $^{87}Sr/^{86}Sr$ ratio of water at the mouth of the river based on the weighted contribution of each geological units respective area and average concentration of Sr in the rocks (see Figure 4). This is a simple model, which we aim to improve with the herein reported geochemical analyses from the TASIS.

Principal Results

The geochemical measurements of waters from rivers reported in this study span a great deal of geological diversity. Sample sites ranged from large rivers (i.e., the Yukon River, Copper River and Susitna River) to smaller tributary streams (the Little Tonsina River, tributary to the Tonsina River – a tributary to the Copper River). The $^{87}Sr/^{87}Sr$ values of the 25 Alaskan rivers measured in this study range from 0.70539 – 0.71823 with an average absolute 2σ error of 0.00005.

In general, the lowest $^{87}Sr/^{87}Sr$ water values were found in rivers draining the Chugach Mountains with a successive increase in values from rivers draining (as listed): the Wrangell Mountains, Alaska Range (with the exception of the Gulkana River), Interior Alaska, North Slope and Brooks Range (with the exception of the Kuparuk River) (Figure 2). Detailed interpretation of how these results relate to each watersheds geological setting will be done using corresponding and complimentary elemental data, high-resolution geologic maps and literature rock geochemistry data, and is currently underway to be submitted to a peer-reviewed journal.

Our preliminary modeling of the Nushagak River draining into Bristol Bay predicted a strontium isotopic composition of river water at the river mouth to be 0.7076 using a weighted average of all contributing geologic unit average Sr concentrations and isotopic compositions. The measured value at the river mouth is 0.7073 (Naidu and Ingram, unpublished, 2004) (Figure 4).

Our preliminary otolith analyses of a coho salmon from the Tonsina River (tributary to the Copper River in Alaska) show a time series of $^{87}Sr/^{87}Sr$ variation depicting the anadromous migration of this salmon. These analyses also show high precision (absolute 2σ SD = 0.00013, freshwater; = 0.00006, marine) in $^{87}Sr/^{87}Sr$ values obtained from laser ablation transects (parallel to growth axis) done within a particular period of a fish's life recorded in a 30μm increment in the otolith (5 μm ~ 14 days) (see Figure 3b and c).

Figure 2: There is a strong latitudinal gradient in $^{87}Sr/^{87}Sr$ ratios of Alaskan Rivers

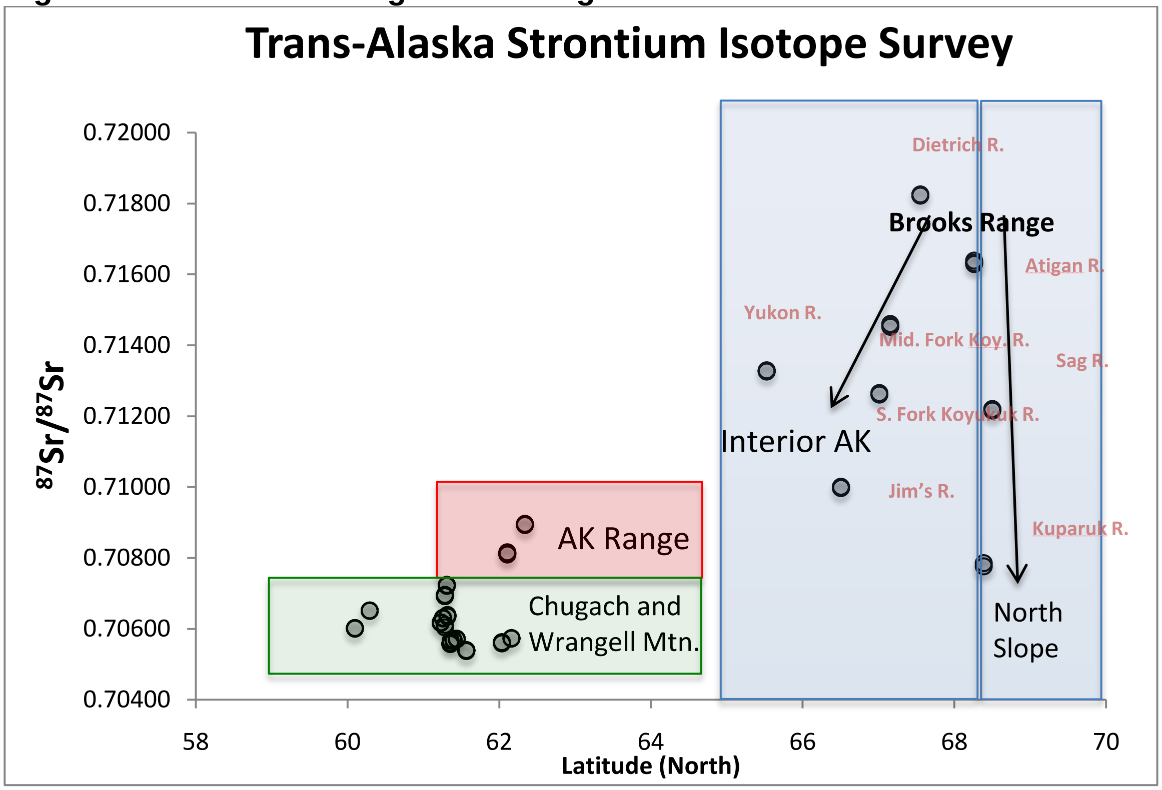


Figure 3: **Adult coho salmon caught in the Tonsina River – tributary of the Copper River in Alaska. Analyses done by Sean Brennan, Fernandez and Cerling at University of Utah ICP-MS Laboratory using laser ablation MC-ICP-MS (laser diameter = 30.4mm). The blue filter lines are calculated using a two-dimensional low pass Hanning filter with window size n=30. A) ablation transect perpendicular to growth axis showing $^{87}Sr/^{86}Sr$ time series of coho salmon – indicating migrations in freshwater, migration to ocean and even migration back into freshwater isotopic signal (Tonsina River – where fish was caught). B) ablation parallel to growth axis during freshwater residence. C) ablation parallel to growth axis during marine residence.**

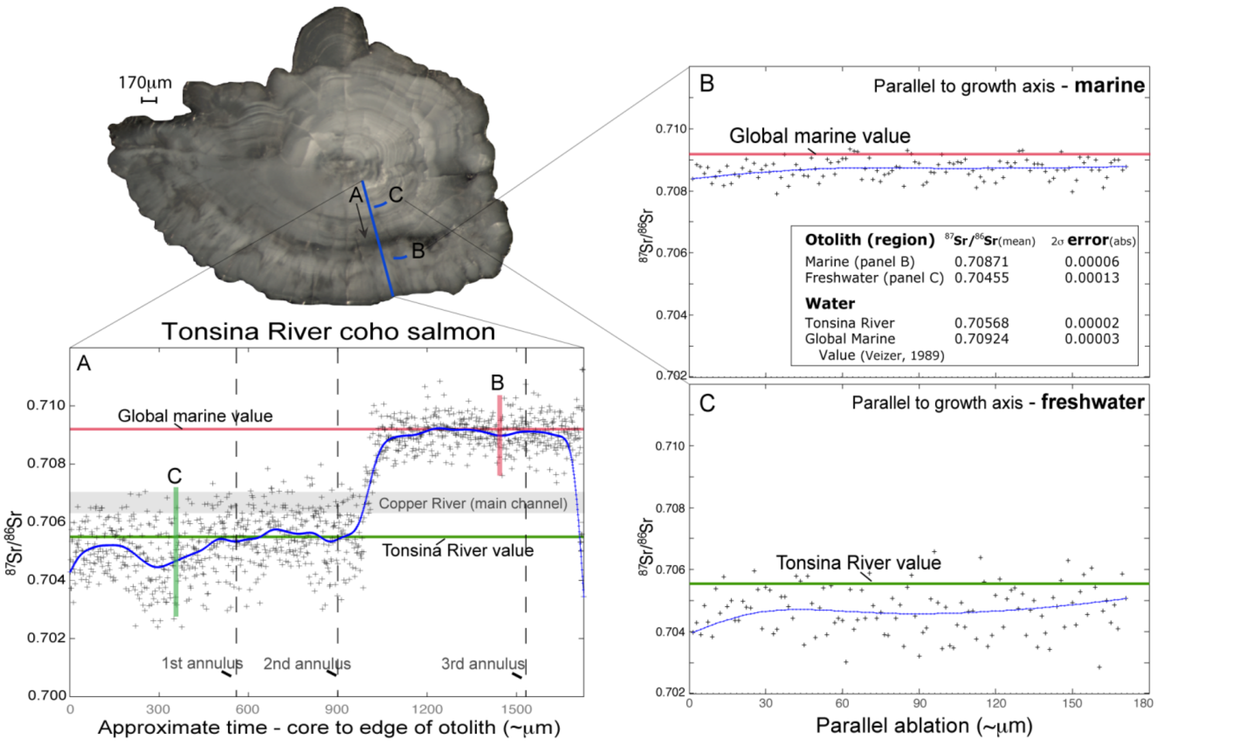
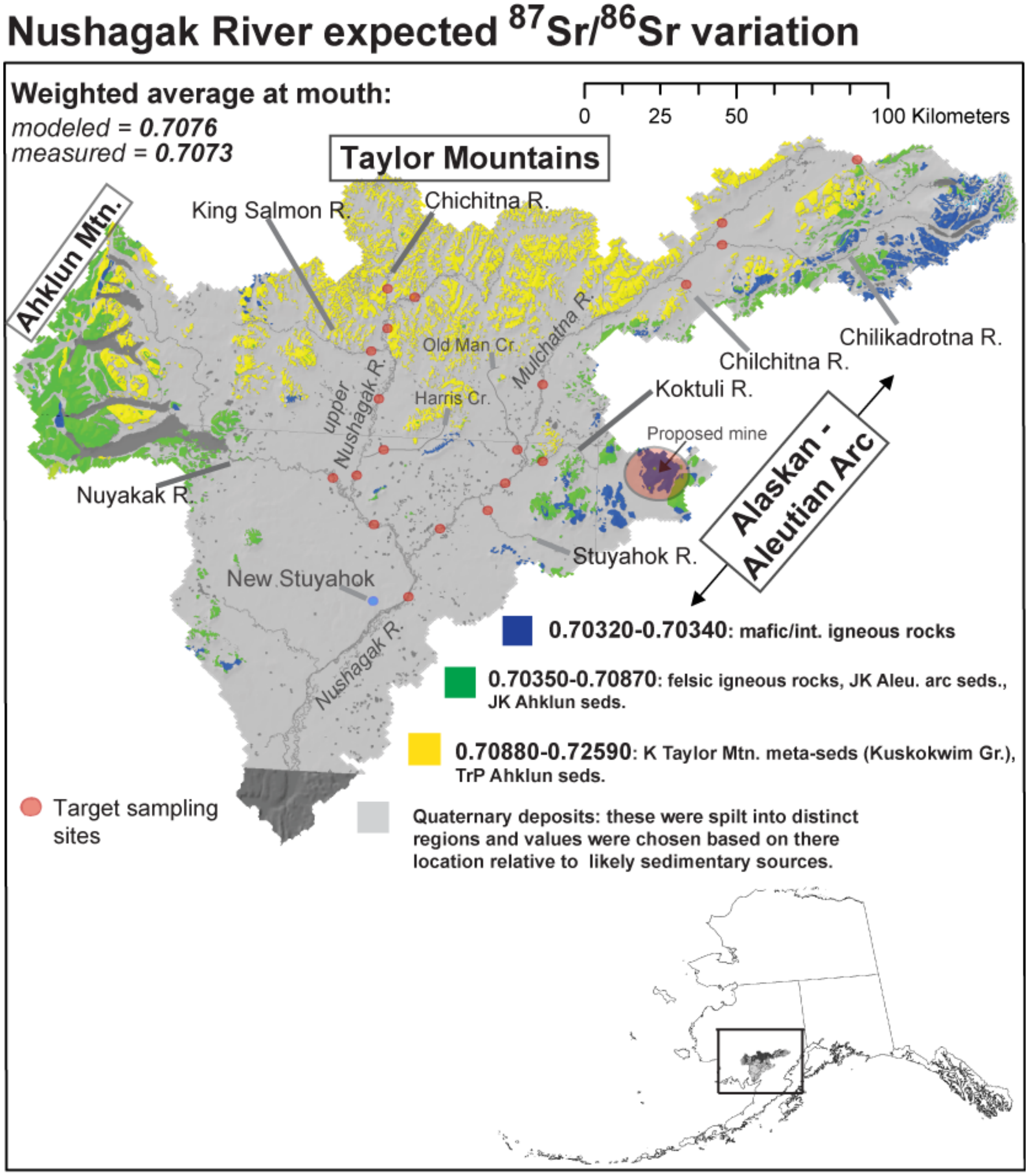


Figure 4: Preliminary modeling in ArcGIS using rock geochemistry data and geologic maps. The measured $^{87}Sr/^{87}Sr$ value at the mouth of the Nushagak River was 0.7073 (Naidu and Ingram, unpublished). The modeled was 0.7076 (Brennan et al., unpublished).



Application of citrus peel biosorbents in repeated adsorption/desorption cycles for removal of heavy metals from waste waters

Basic Information

Title:	Application of citrus peel biosorbents in repeated adsorption/desorption cycles for removal of heavy metals from waste waters
Project Number:	2010AK94B
Start Date:	3/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	Ak-001
Research Category:	Engineering
Focus Category:	Treatment, Models, Wastewater
Descriptors:	None
Principal Investigators:	Silke Schiewer

Publications

1. Chatterjee, A.; Schiewer, S.: Biosorption of Cadmium (II) ions by citrus peels in a packed bed column. 5th International Conference on Environmental Science and Technology, American Academy of Sciences, Houston TX, July 12-16 2010.
2. Chatterjee, A.; Schiewer, S.: Biosorption of cadmium (II) from sinle and binary metal solutions using protonated citrus peels in a fixed bed column reactor. Abstracts of the American Water Resources Association Alaska Section Conference, Anchorage, March 31-April 2 2010
3. E. Njikam, S. Schiewer: Optimization and Kinetic Modeling for Cadmium Desorption from Citrus Peels: a Process for Biosorbent Regeneration. Bioresource Technology (about to be submitted).
4. A. Chatterjee, S. Schiewer: Biosorption of cadmium(II) ions by citrus peels in a packed bed column: application of mathematical models for prediction of breakthrough curve. CLEAN – Soil, Air, Water (revised after review)
5. Student paper award for Abhijit Chatterjee at 5th International Conference on Environmental Science and Technology, American Academy of Sciences, Houston TX, July 12-16 2010. This paper was also one of 20 papers selected (one of only two from the USA) among 200 papers presented at the conference to be considered for publication in a special issue of the peer reviewed journal CLEAN – Soil, Air, and Water.

USGS Annual Report

Title: Application of citrus peel biosorbents in repeated adsorption/desorption cycles for removal of heavy metals from waste waters

Start Date: March 1 2010

End Date: Feb. 28 2011

Focus Category: Treatment (TRT), Models (MOD), Wastewater (WW)

Key Words: biosorption, packed bed columns, breakthrough, desorption

PI: Silke Schiewer, Associate Professor, WERC, UAF, sschiewer@alaska.edu, (907) 474 2620

Products of Project

Peer-reviewed journal publication:

- A. Chatterjee, S. Schiewer: Biosorption of cadmium(II) ions by citrus peels in a packed bed column: application of mathematical models for prediction of breakthrough curve. CLEAN – Soil, Air, Water (revised after review)
- E. Njikam, S. Schiewer: Optimization and Kinetic Modeling for Cadmium Desorption from Citrus Peels: a Process for Biosorbent Regeneration. Bioresource Technology (about to be submitted).
- Several other manuscripts in preparation

Conference Proceeding with Oral Conference Presentation:

- Chatterjee, A.; Schiewer, S.: Biosorption of Cadmium (II) ions by citrus peels in a packed bed column. *5th International Conference on Environmental Science and Technology*, American Academy of Sciences, Houston TX, July 12-16 2010.

Oral Conference Presentation and Abstract:

- Chatterjee, A.; Schiewer, S.: Biosorption of cadmium (II) from sinle and binary metal solutions using protonated citrus peels in a fixed bed column reactor. Abstracts of the ***American Water Resources Association Alaska Section Conference***, Anchorage, March 31-April 2 2010

Awards:

- Student paper award for Abhijit Chatterjee at *5th International Conference on Environmental Science and Technology*, American Academy of Sciences, Houston TX, July 12-16 2010. This paper was also one of 20 papers selected (one of only two from the USA) among 200 papers presented at the conference to be considered for publication in a special issue of the peer reviewed journal CLEAN – Soil, Air, and Water.

Student Support

Two PhD students, Abhijit Chatterjee and Eloh Njikam were supported by this project.

Introduction: problem, objectives, and relevance

Critical Water Quality Problem

Mining is one of Alaska's main industries. Effluent from mine tailings can contaminate surface waters with heavy metals if improperly treated. Heavy metals should be removed at the source of pollution in order to avoid their bioaccumulation in the food chain and resultant toxic effects in aquatic organisms. Compared to conventional metal treatment techniques, biosorption is both efficient and economic if waste materials are used as sorbents for metal removal. Biosorption is particularly suited as a polishing step, after the bulk of heavy metals has been removed by other techniques such as precipitation, to achieve a high effluent quality, which is especially important if the treated wastewater is discharged to environmentally sensitive areas.

Project Objectives

The project goal was to evaluate the feasibility of using citrus peel biosorbents to remove heavy metals in packed bed columns with multiple adsorption-desorption cycles, considering effluent quality, reuse potential, and economic aspects. A laboratory investigation was undertaken to evaluate the stability and performance of citrus peel biosorbents in heavy metal adsorption (for metal removal from wastewater) and desorption (for sorbent regeneration and metal recovery), complemented by mathematical modeling. To facilitate transition to industrial applications, adsorption and desorption were studied not only in batch systems but also in packed bed columns, as commonly used in industrial wastewater treatment systems based on ion exchange. Objectives were to:

- Conduct batch experiments to study desorption equilibrium and kinetics for different desorbing solutions
- Describe batch kinetics with mathematical models based on fundamental chemical principles
- Perform packed bed column experiments for different flow rates, metal concentrations and column length
- Predict breakthrough time by mathematical models
- Regenerate metal-saturated sorbent with dilute mineral acid and study sorbent reuse through several adsorption desorption cycles
- Confirm effectiveness of biosorption for actual mining wastewaters in packed bed columns.
- Evaluate overall effectiveness and feasibility of metal removal using citrus peels

Project Relevance

This investigation shows that citrus peels can be used for heavy metal removal from industrial wastewaters such as mine tailings. In packed bed column applications, high effluent quality with near-zero metal concentrations can be achieved. Citrus peel biosorbents can be efficiently desorbed using dilute mineral acids and be used in multiple adsorption/desorption cycles wherein the biosorbent is regenerated and reused.

Methods

Batch sorption and desorption studies (kinetic and equilibrium) were performed by contacting 0.05 g of the metal-loaded biomass with 50 ml of solution containing different cations and/or desorbing agents at varying concentrations on a rotary shaker. At different contact times (5 min to 24 hours) the samples were immediately filtered on Whatman 40 ashless filter paper, and stored for analysis. Desorption studies at varying concentrations of the target metal in solution were performed to investigate interference from metal in solution. The impact of ubiquitous ions such as Na on Cd adsorption and desorption was studied by varying the concentration of these ions. Samples were analyzed by Atomic Absorption Spectrometry for metal concentrations.

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A packed bed column setup comprised of a polyacrylic column, peristaltic pump, rotameter and programmable sample collection in a fraction collector assembled by PhD student Abhijit Chatterjee was packed with citrus peels and used in adsorption-desorption experiments with feed solutions containing several cations, including actual mining effluent.

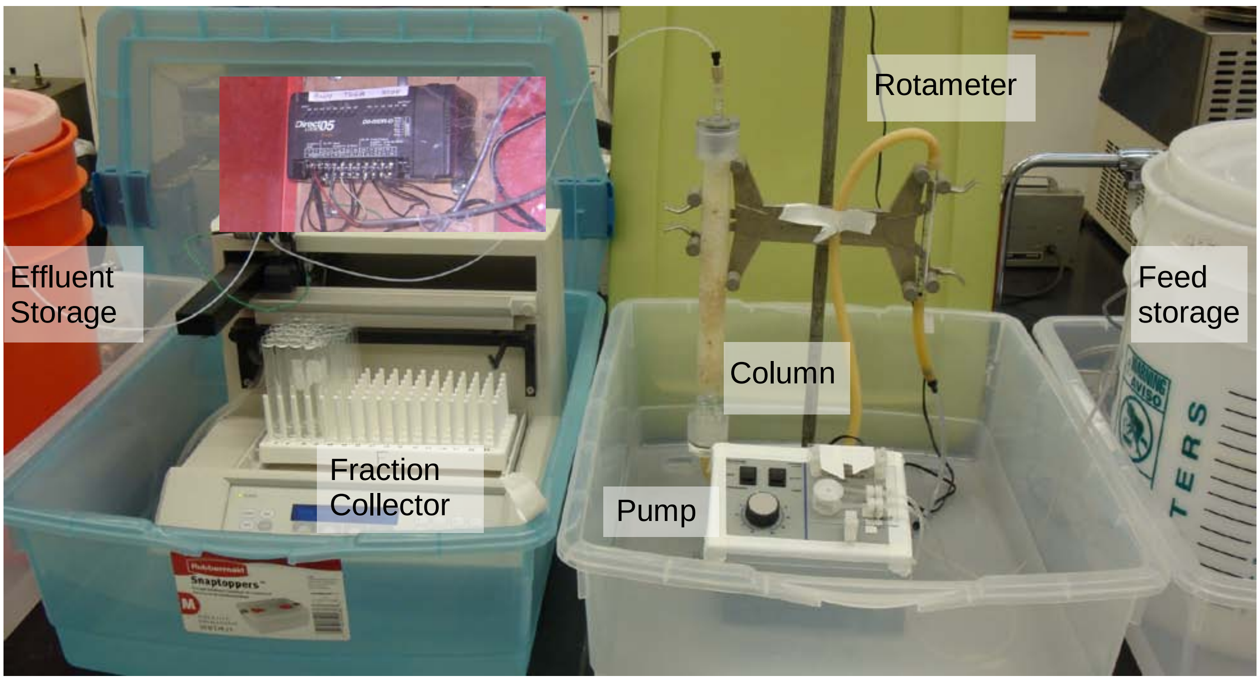


Figure 1: Experimental setup with packed bed column

Principal Results

<u>Optimal desorption conditions</u>

Mineral acids and complexing agents were excellent desorbents for the removal of cadmium from citrus peels, typically achieving 90 % removal in less than one hour. Ca and Na salts showed lower desorption effectiveness than acids at the same molar concentration (**Figure 2**). Based on their cost, effect on the environment, desorption rate, efficiency, and the possibility of sorbent regeneration, 0.1 or 0.01 N acid proved to be the best candidate for Cd desorption from previously loaded peels. While HNO_3 was used as an acidic desorbent in this study, other mineral acids such as HCl could be used for industrial applications.

Models for desorption kinetics

PhD student Eloh Njikam developed models to describe the kinetics of Cd desorption from citrus peels. So far, no published models for biosorbents desorption kinetics are available in the literature. Zero, first and second order models, all with respect to the amount of Cd bound to the peels of the form $r = k_d q^n$, were considered, whereby the first order model with n=1 typically performed best as for example shown in **Figure 3**. In later research, models that also include the effect of cadmium in solution were considered assuming one of the following equations: $r = k_d(q - q_e)$, $r = k_d q - k_a C$ or $r = k_d (q - q_e) - k_a C$ where q=Cd bound, q_e= equilibrium Cd bound, C= Cd concentration in the solution, k_d =desorption constant and k_a =adsorption constant.

Effect of Calcium

Since calcium is a commonly present ion that can interfere with metal binding, a systematic batch study, where Cd and Ca concentrations were varied in a grid, was conducted. **Figure 4** shows the amount of each cation bound in the presence of the other one. Cd had a much stronger effect on the uptake of Ca by the citrus peels than Ca did on the uptake of Cd by the citrus peels. This means though Ca binds more weakly to citrus peels than Cd, the presence of Ca, e.g. from desorbing agents, can to some extend reduce Cd uptake. Therefore, acidic desorption is preferable to desorption using Ca salts.

Effect of Column Operation Parameters

PhD student Abhijit Chatterjee used his packed bed set-up to study the continuous biosorption of cadmium onto native and processed citrus peels. Multiple long-time runs were conducted for a thorough investigation of the effect of process parameters (flow rate Q 2-15 ml/min, inlet concentration Co 5-15 mg/L, bed height Z 24-72 cm) on biosorption characteristics. Effluent concentration vs. time profile (breakthrough) curves were determined experimentally and modeled mathematically. For example, with flow rate decreasing from 15.5 to 9 ml/min, breakthrough time (usable operation time with very low effluent concentrations) increased from 7 h to 19 h. Increasing the inlet concentration from 5 to 15 mg/L lowered the break through time from 36 to 12 h (**Figure 5**).

With increasing residence time (increasing bed height or decreasing flow rate), raw material cost (amount of peels required to produce unit volume of clean water) can be reduced to an optimum level of 0.32 g/L, after which no further reduction occurred when further increasing the residence time (**Figure 6**).

Modeling Breakthrough Curves

Breakthrough curves were successfully modeled by two types of model equations, the Bohart-Adams model and the Dose-Response model (**Figure 5**). The empirical Dose-Response (DR) model, which is common in the field of pharmacology, has the following form

$$\frac{C}{C_0} = 1 - \frac{1}{1 + \left(\frac{t}{\beta}\right)^{\alpha}} \quad (12)$$

where α, β are model parameters, with β being the time when effluent concentration reaches 50% of the influent concentration. The Bohart Adams model assumes irreversible sorption and plug flow

$$\frac{C}{C_0} = \frac{1}{1 + \exp\left(\frac{k_{BA} N_0 Z}{u} - k_{BA} C_0 t\right)}$$

where N_0 is the equilibrium volumetric sorption capacity (mg/L), k_{BA} is Bohart-Adams rate constant (L $h^{-1}mg^{-1}$) and u is the linear flow velocity in cm h^{-1}.

It was found that the commonly used Yoon Nelson model and the Thomas model are mathematically identical to the Bohart Adams model. Use of one of these models renders the use of other models redundant, a fact that is largely unnoticed so far. The Dose Response Model performed somewhat better than the Bohart-Adams model near breakthrough and saturation.

Peel Reuse in Multiple Adsorption/Desorption Cycles

The reusability of protonated peels under optimized hydrodynamic condition was examined, using the most effective desorption agent (0.1 N nitric acid). In the first cycle, 94% of the biosorbed metal was found to be released during desorption. An 8 % weight loss of peels was found after second cycle of desorption. Decrease in the maximum uptake capacity after the first cycle was slightly more than 10% although uptake capacity before breakthrough remains almost unaltered (data not shown).

Characterization of Peels

Abhijit noted that stability and integrity of peels vary from batch to batch. Using SEM/EDX revealed that this variation could be linked to the variation in the surface structure of the peels.

He devised a processing method to stabilize peels by immobilization in agar or alginate gel. Results using processed peels were presented in the 2010 AWRA conference.

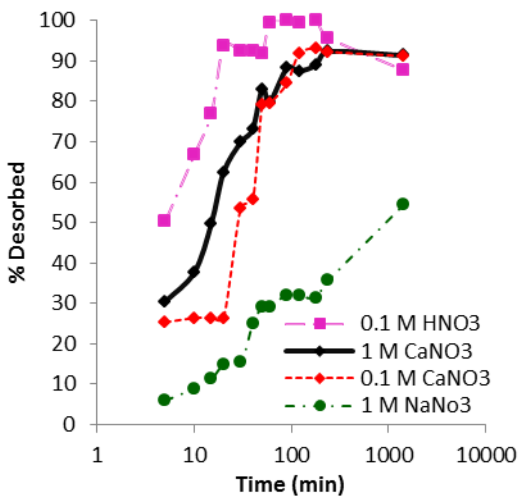


Figure 2 Cadmium desorption efficiency of different desorbing agents for grapefruit peels with an initial uptake of 0.42 meq/g;

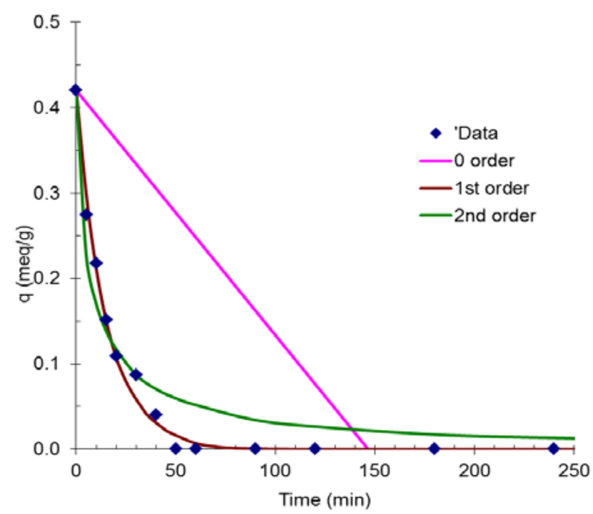


Figure 3. Cadmium desorption kinetics by 0.01M HNO_3 for grapefruit peels with an initial uptake of 0.42 meq/g. Data and predictions of zero, first and second order model

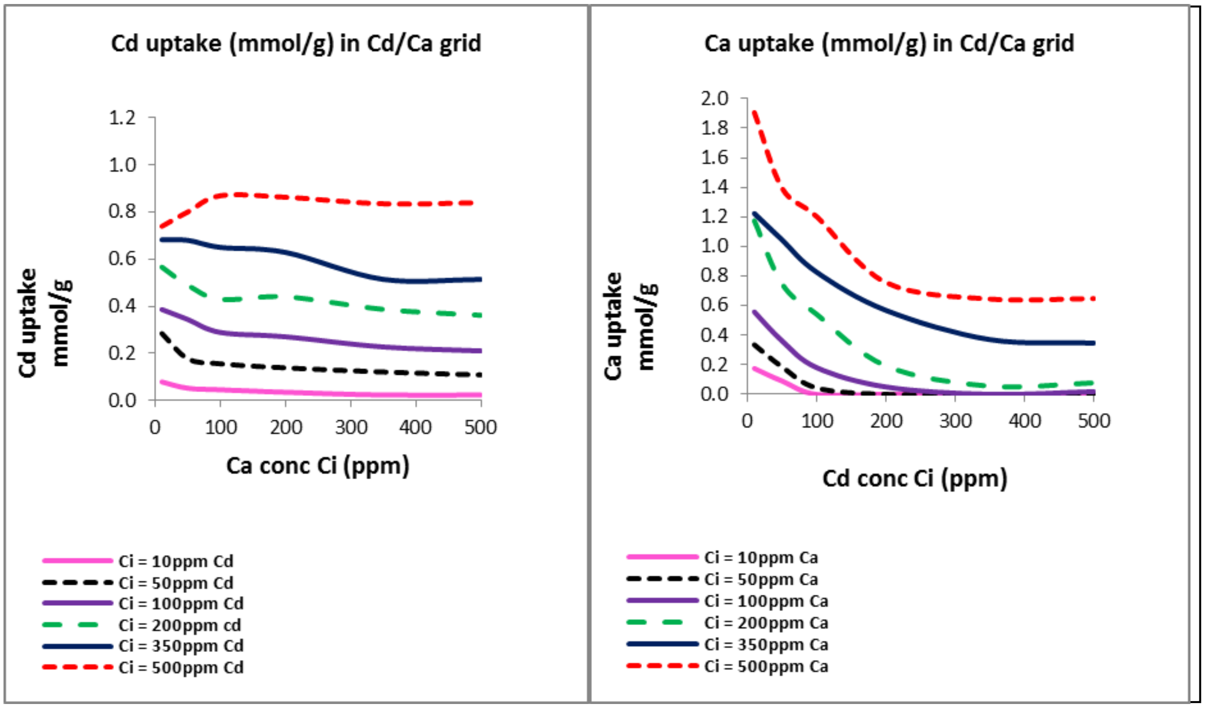
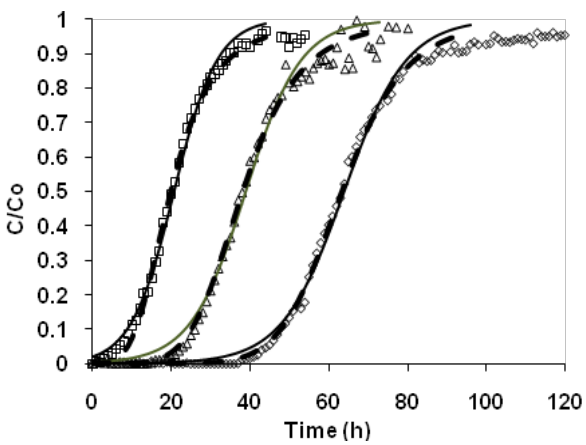


Figure 4 Competition between Ca and Cd on uptake by citrus peels at pH 5.



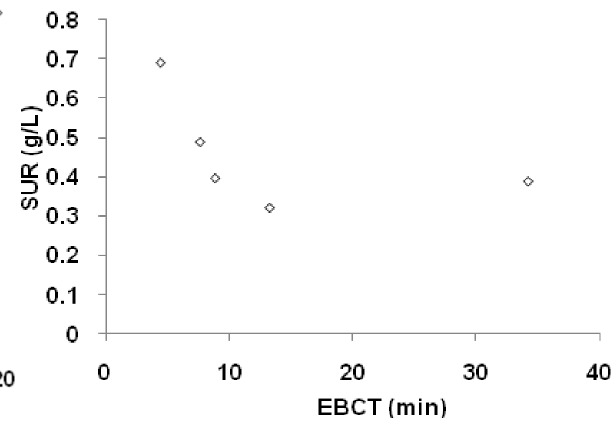


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Figure 5. Breakthrough curves for biosorption of cadmium onto protonated citrus peels at different bed heights (□) 24 cm; (Δ) 48 cm; (o) 72 cm; (–) Prediction of Bohart-Adams model; (---) Prediction of Dose-Response model.

Figure 6. Variation of sorbent usage rate (SUR) per purified water volume with empty bed contact time (EBCT) for several column runs with different flow rates and bed heights all for Cd sorption to protonated peels

Information Transfer Program Introduction

None.

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	4	0	0	0	4
Masters	2	0	0	0	2
Ph.D.	5	0	0	0	5
Post-Doc.	0	0	0	0	0
Total	11	0	0	0	11

Notable Awards and Achievements

Student paper award for Abhijit Chatterjee at 5th International Conference on Environmental Science and Technology, American Academy of Sciences, Houston TX, July 12-16 2010. This paper was also one of 20 papers selected (one of only two from the USA) among 200 papers presented at the conference to be considered for publication in a special issue of the peer reviewed journal CLEAN – Soil, Air, and Water. Abhijit is a PhD student supported under the 104(b) program.