

**Water and Environmental Research Center
Annual Technical Report
FY 2009**

Introduction

Research Program Introduction

None.

Study of Streamflow Response to Seasonal Snowcover Change in the Yukon River

Basic Information

Title:	Study of Streamflow Response to Seasonal Snowcover Change in the Yukon River
Project Number:	2008AK71B
Start Date:	3/1/2008
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Congressional District:	AK-1
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Focus Category:	Hydrology, None, None
Descriptors:	None
Principal Investigators:	Daqing Yang

Publications

There are no publications.

12: Title: Yukon River Streamflow Response to Seasonal Snowcover Change

13. Statement of Critical State Water Problem

Arctic hydrologic system has experienced very significantly changes over past several decades due to climate variations and human impacts. For instance, recent assessments of long-term (50-60 years) hydrologic records identify significant changes in streamflow regimes over Siberia, such as increases of yearly and winter streamflow (*Lammers et al., 2001; Serreze et al., 2002; Peterson et al., 2002*), shifts of peak discharge timing associated with early snowmelt (*Yang et al., 2002, 2003*), and river-ice regime changes (*Smith, 2000*). The causes for these changes are not all clear due to insufficient investigations of arctic hydrology changes. This raises a challenging science question for the Arctic and global change research at large. It has been suggested that spring discharge increase is primarily due to an earlier snowmelt associated with climate warming during the snowmelt period (*Nijssen et al., 2001; Yang et al., 2002; Serreze et al., 2002*), and changes in winter streamflow are perhaps associated with reduction in permafrost and an increase in active layer thickness under a warming climatic condition (*Serreze et al., 2002; Yang et al., 2002; 2004a,b*).

The Yukon River is one of the largest rivers in the northern regions. It contributes 203 Km³ per year freshwater to the Bering Sea. Hydrologic conditions and its changes of the Yukon river significantly affect regional biologic and ecologic systems. Unlike other large northern rivers, Yukon River has received less research attention. The USGS (2000) produced a report to document the major hydrologic patterns with the basin. Zhang et al. (2000) found that large parts of southern Canada and Yukon Territories have experienced reduced runoff. Snowcover is one of the critical land memory processes that significantly affect atmosphere, hydrology and ecosystems in the high latitude regions. Snowcover melt and associated floods are the most important hydrologic event of the year in the northern river basins (*Kane et al. 2000*). Studies show that snowmelt has started early over the recent decades in the northern regions of Canada, Alaska and Siberia associated with warming in winter and spring seasons (*Whitfield and Cannon, 2000; Zhang et al., 2000, USGS, 2000; Yang et al., 2002*). This change in the melt pattern may indicate a hydrologic regime shift over the high latitudes (*Yang et al., 2002, 2004a,b*). Due to insufficient investigation and lack of long-term records, *our current understanding of Yukon River hydrology and climate changes, particularly large-scale snowmelt processes and their interaction with climatic change and variation, is incomplete. This limits our capability of documenting past change and predict future change over this largest watershed in Alaska.*

14. Statement of Benefits

This research will apply remotely sensed long-term snowcover data in investigation of snowmelt runoff response to climate change and variation in the Yukon watershed. The methods and results of this research will be important to snowmelt model and process studies. They will improve our understanding of the spatial and temporal variability of high-latitude snowcover and its contribution to river runoff and hydrology of the arctic regions. They will also enhance our

ability of modeling cold region land memory processes and predicting future changes in water cycle over large northern regions.

The outcomes of this study will also include a comprehensive data set (including snowcover, streamflow, temperature, and precipitation) for the Yukon river basin. This dataset will support land surface model development and verifications, and is useful to ongoing international and national research programs, particularly for the GEWEX, CliC, and the SEARCH and IPY. This research will involve and train students at various levels. It will directly benefit research and education in Alaska. This project will also support the USGS programs, particularly the predictability of water cycle and its change in the northern watersheds.

15. Nature, Scope and Objective of Study

This research will use the weekly NOAA snowcover extent data to study the streamflow hydrology in the Yukon River. The focus of this research is to examine the streamflow response to snowcover extent change during the spring melt season. *The overall objective of this research is to determine the potential of using remotely sensed snowcover information to improve our capability of snowmelt runoff modeling and forecasting over large northern river basins.* The major work to be completed includes:

A. Generation and analysis of weekly snowcover extent and runoff time-series

We will calculate the basin-mean snowcover extent over the Yukon river for the entire NOAA records (1966-present) and generate a weekly basin snowcover time-series. We will use these weekly data to examine the seasonal changes of snowcover extent, such as defining the weekly snowcover climatology, determining the dates of snowcover formation/disappearance and duration of snowcover/snow-free days, and quantifying the rates of snowcover change during the accumulation and melt seasons. We will also examine snowcover extent changes and variations over time, including trend analysis, identifying extreme snowcover cases and investigating their association with climate conditions. Long-term weekly discharge time-series will be generated from the daily streamflow data collected at different locations within the watersheds and used to describe the seasonal runoff changes, including weekly runoff regime, rates of streamflow rise and peakflow during the melt period. We will also examine the spatial and temporal runoff changes including extremes and trends. In addition, precipitation and temperature records will be acquired and used to aid the investigation into the response of river hydrology to snowcover changes.

B. Examination of streamflow response to snowcover extent change

Snow cover depletion is a useful indicator of snowmelt process and streamflow generation (Rango, 1997). This project will use the weekly snow data to develop snow cover depletion curves for each melt season from the maximum accumulation through complete melt. Changes in the timing and pattern of the snow cover melt are sensitive indicators to climate change at the high latitudes. This study, based on the long-term snow cover, runoff and climatic records, will investigate the spatial and temporal sensitivity of snowmelt runoff to regional climate changes and variations. We will examine the weekly correlation of streamflow with basin-mean snowcover extent and temperature and determine the consistency between snow cover and runoff changes during the snowmelt period. We will also investigate the associations between

snowcover and runoff anomalies, identify extreme snowmelt runoff cases, and examine their correspondence with snowcover and climate conditions. These analyses will define the weekly relation between snowmelt runoff and snowcover changes for the watershed.

C. Cross-validation of results

We will use microwave-derived (SMMS & SSM/I) maps of extent and SWE, ground snow survey and other field observations to calibrate/validate the results we obtain using the NOAA snowcover product at selected locations/sub-basins within the watershed. This will include cross-comparison of the timing of snowcover formation and disappearance, the rates of snowcover accumulation in fall/winter seasons and its depletion during spring and early summer seasons. Furthermore, we will compare the snowcover-runoff relation between Alaskan and Siberian rivers and explain the regional difference in sensitivity of river runoff to basin snow cover changes.

PROJECT TIMELINE

<i>Milestone</i>	<i>Definition</i>	<i>Completion</i>
1.	Complete dataset preparation and a literature review	9/2009
2.	Complete analyses of basin climatic and hydrologic changes	12/2009
3.	Complete and submit an annual progress report to USGS	2/2010
4.	Complete examination of interaction and feedback among climate-snowcover-river flow	8/2010
5.	Complete and submit a summary report to USGS	2/2011

16. Methods, procedures, and facilities

Statistical techniques will be used in this project to: 1) quantify the magnitude of changes and regime shifts in river discharge and related climatic parameters, 2) reveal major spatial and temporal variation of the climatic parameters, such as snowfall and snow cover, and, 3) examine the associations between discharge and climate parameters. Changes in discharge and climatic variables will be determined by computing trends and identifying step changes in monthly and daily time series. Statistical significance of trends will also be considered in trend discussions. The statistical associations among river flow, basin snow cover, precipitation and temperature will be evaluated by regression analyses.

We have experience working on the Serbian large rivers. We have developed useful methods and procedures to examine large-scale snow-river flow relations. We will use similar approaches for this study. Specifically, we will use daily data to generate weekly basin-mean SWE time-series for the Yukon River during 1988–2001. On the basis of these weekly records, we will examine the seasonal changes of snowcover, by defining the SWE climatology based on weekly statistics,

determining the dates of snowcover formation/ disappearance and duration of snowcover/snow-free days, and quantifying the rates of snowcover mass change during the accumulation and melt seasons. We will also derive weekly discharge time-series from the daily streamflow data collected near the basin outlet, and use the weekly data to describe the seasonal streamflow changes, including discharge regime, rates of streamflow rise, and peak flow during the melt period. We will calculate the weekly correlation of streamflow with basin SWE, and determine the consistency between SWE and streamflow changes over the seasons. Furthermore, we will identify extreme snowmelt streamflow cases and examine their correspondence with basin snowcover conditions. These analyses define the weekly relationship between snowmelt runoff and basin SWE changes for the Yukon River. In addition to streamflow and snowcover data, basin-mean weekly precipitation and temperature time series will be created from the gridded global datasets for the study period (Hulme, 1991; Jones, 1994), and used to investigate the compatibility of SWE/SCE data with climate variables and to explain the streamflow response to seasonal snowcover changes.

It is important to point out that the approach of this project is not a complete water budget calculation; rather, we focus on the major terms in basin water budget, i.e. SWE, winter precipitation, and streamflow. We relate snow cover data (SWE and SCE) with streamflow data measured near the basin outlet, since discharge represents the integrated response of basin hydrology to climate influence.

17. Related Research

Over the last few years, we have applied remote sensing snowcover data and products for snowcover and snowmelt runoff analyses over the large arctic basins. Below is a summary of our preliminary activities and results.

A: Application of snowcover extent data

Remote sensing data/products have been very useful to cold region climate and hydrology investigations. For instance, the NOAA weekly maps (since June 1999, daily) based on visible data, despite some limitations, are quite reliable at many times and in many regions, and have shown to be important for polar regions climate, snow/ice and hydrology studies (*Steffen et al., 1993*). The establishment of the weekly snow cover dataset over the Northern Hemisphere permits quantitative assessments of changes and variations in regional snow cover extent (*Robinson et al., 1990*). These maps extend back to late 1966, and have recently had several inconsistencies rectified. They may be viewed at <http://climate.rutgers.edu/snowcover>. The NOAA snow cover maps are also useful for developing snowcover depletion curves and for generating the input snowcover data necessary to run the hydrologic and snowmelt runoff models (*Rango et al., 1997*).

We recently applied the weekly snowcover data in large Siberian watersheds (Lena, Yenisei and Ob rivers) and identified a close association of the runoff to snowcover extent changes during the spring melt period (*Yang et al., 2002*). Our initial analyses of snowcover and streamflow data in Alaska also show a strong correlation of monthly runoff with snowcover extent during early summer season (*Zhao, 2004*). These encouraging results clearly indicate the potential of using the weekly snowcover information to improve snowmelt runoff modeling and prediction in the

high latitude regions. This proposed research will continue our effort in the Yukon River with a focus on analyzing sub-basin snowmelt processes.

B: Application of SSM/I SWE data

Snow water equivalent (SWE) derived from passive microwave satellite data (SMMR and SSM/I) for the Northern Hemisphere have been produced at the NSIDC (*Armstrong and Brodzik, 2002*) using a modified version of the *Chang et al. (1987)* algorithm. Regional maps and products have also been developed in Canada from the SMMR and SSM/I data, and used for analyses of snowcover variations over space and time (*Walker and Goodison, 1993*). These data have been used for climate and hydrology analyses, including arctic active layer depth simulation (*Oelke et al. 2003*), arctic hydrologic model (*Su et al. 2005*). *Armstrong et al. (2005)* recently developed SWE data and climatology for the arctic watersheds.

Our initial analyses explored the compatibility between winter snowfall and snowcover data. Comparisons of Yukon basin winter snowfall and SWE accumulation show basin that maximum SWE is generally less than winter snowfall accumulation in most winter during 1988-2001, except for a few years when SWE was greater than total snowfall. It is expect to see the max SWE usually being less than winter snowfall due to snow sublimation. The comparisons also show greater inter-annual variations in snowfall relative to the basin SWE, i.e. higher and lower snowfall winters associated with similar SWE amounts. The differences between the total snowfall and maximum SWE are smaller in lower snowfall winters. These results indicate a discrepancy between the basin SWE and snowfall data. The possible causes may include, at least, biases in Arctic snowfall observations (*Yang et al., 2005*) and the uncertainty in remote sensing snowcover algorithm (*Armstrong and Brodzik, 2002; Walker and Goodison, 1993*). Nevertheless, it is important to identify this inconsistency, as it clearly illustrates the difficulties of accurately determining the major water budget fluxes in the large Arctic watersheds. In this project, we will use bias corrected daily precipitation data (*Yang et al., 2005*) to compare with SSM/I and *in-situ* snowcover data over the Yukon basin and its sub-basins.

18. Training potential

This project has significant training potential. The funds required will be used mainly to support graduate student(s). This project will train graduate and undergraduate students at UAF. It will directly involve 1 graduate and 2 (part-time) undergraduate students for dataset development and analyses. This project will also make efforts to increase the participation of Alaskan Natives in undergraduate and graduate studies, and to integrate this proposed research into the existing UAF Alaska Native Science & Engineering education infrastructure.

19. Investigators Qualifications (CV):

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PROFESSIONAL PREPARATION

- McMaster University, Hamilton, Ontario, Canada, Cold Region Hydrology, Postdoctoral Research Associate, April 1995 - March 1998
- Canadian Meteorological Service, Downsview, Ontario, Canada, Snow Hydrology and Climate, Post Doctoral Fellow, February 1992 - March 1995
- Chinese Academy of Sciences, Lanzhou, China, Hydrology, Ph.D., 1988
- Hohai University, Nanjing, China, Hydrometeorology, M.Sc., 1984
- Xinjiang University, Urumqi, China, Hydrology, B.Sc., 1981

APPOINTMENTS

- July 2006 - present, Associate Professor, CEE Dept. and Water and Environmental Research Center, Inst. of Northern Engineering, UAF.
- July 2005 – June 2006, Research Professor, Water and Environmental Research Center, Inst. of Northern Engineering, UAF.
- June 2002 – June 2005, Associate Professor, Water and Environmental Research Center, Inst. of Northern Engineering, University of Alaska Fairbanks.
- July 1999 – May 2002, Assistant Professor, Water and Environmental Research Center, Inst. of Northern Engineering, University of Alaska Fairbanks.
- April 1998 - June 1999, Research Scientist, Inst. for Global Change Research/Frontier Research System for Global Change, Tokyo, Japan.
- September 1989 - January 1992, Research Associate, Lanzhou Inst. of Glaciology and Geocryology, Chinese Academy of Sciences, Lanzhou, China.
- January 1989 - August 1989, Visiting Scientist, Centre for Remote Sensing and Environmental Optics, University of California, Santa Barbara.

RESEARCH INTERESTS

Cold Region Hydro-climatology, Snow Hydrology, Climate and Climate Change, and Applications of Remote Sensing Data/Products in the high latitude regions.

SELECTED PUBLICATIONS

- Woo, M-K., D. Kane, S. Carey, **D. Yang**, 2008: Progress in permafrost hydrology in the new millennium, *Permafrost and Periglacial Processes*, Volume 19 Issue 2, 237-254.
- Majhi, I., and **D. Yang**, 2008: Streamflow characteristics and changes in Kolyma basin in Siberia, *Journal of Hydrometeorology*, Vol. 9, 267-279.
- Yang, D.**, Y. Zhao, R. Armstrong, D. Robinson, and M.-J. Brodzik, 2007: Streamflow response to seasonal snow cover mass changes over large Siberian watersheds, *J. Geophys. Res.*, 112, F02S22, doi:10.1029/2006JF000518.

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- Sugiura, K., **D. Yang**, and T. Ohata, 2003: Systematic error aspects of gauge-measured solid precipitation in the Arctic, Barrow, Alaska, *Geophysical Research Letters*, 3(4), 1192, doi: 10.1029/2002GL015547.
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- Yang, D.**, D.L. Kane, L.D. Hinzman, B.E. Goodison, J.R. Metcalfe, P.Y.T. Louie, G.H. Leavesley, D.G. Emerson, C.L. Hanson, 2000: An evaluation of the Wyoming gauge system for snowfall measurement. *Water Resources Research*, 2665-2678.
- Yang, D.**, 1999: An improved precipitation climatology for the Arctic Ocean. *Geophysical Research Letters*, Vol.26, No.11, 1625-1628.

SYNERGISTIC ACTIVITY

- Member, Science Team of the NASA Cold Land Process Pathfinder Mission (2004-present)
- Member, Northern Research Basin (NRB) Committee on Prediction in Undergauged Basins (PUB) (2004-present)
- Development of bias-corrected precipitation dataset and climatology for the Arctic
- Investigation of hydrologic response of large arctic rivers to climate change and variation
- Synthesis of water balance data from northern experimental watersheds
- Application of remote sensing snowcover data and products for Arctic hydrology research

COLLABORATORS

Barry Goodison, Canadian Meteorological Service, Downsview, Ontario, Canada

David Robinson, Department of Geography, Rutgers University, New Jersey

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Douglas Kane, Larry Hinzman, and Svetlana Berezovskaya, Water and Environmental Research Center, University of Alaska Fairbanks, AK

Tetsuo Ohata, Hokkaido University, Sapporo, Japan

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Reconstruction of the Lake Pleistocene Glacial Lake Ahtna, Copper River Basin, Alaska

Basic Information

Title:	Reconstruction of the Lake Pleistocene Glacial Lake Ahtna, Copper River Basin, Alaska
Project Number:	2008AK73B
Start Date:	3/1/2008
End Date:	12/30/2009
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Research Category:	Climate and Hydrologic Processes
Focus Category:	Floods, Geomorphological Processes, Hydrology
Descriptors:	Alaska
Principal Investigators:	Michael Gregg Loso

Publications

There are no publications.

Reconstruction of Late Pleistocene Glacial Lake Ahtna, Copper River Basin, Alaska

Statement of Critical Region State Water Problem

Over 700 contemporary Alaskan lakes are impounded by glaciers, and all are subject to sudden, catastrophic drainage (Post & Mayo, 1971). The “trigger” for sudden drainage events varies, but in most cases leakage at the base of the ice dam is followed by rapid enlargement of subglacial tunnels, partial or complete evacuation of the lake in a period of hours to days, and massive downstream flooding where subglacial waters emerge from the glacier terminus as a proglacial stream (Walder & Costa, 1996). The frequencies, seasonal timing, and magnitudes of such glacier outburst floods, or *jökulhlaups*, are difficult to predict because they bear no statistically-discernible relationship to flood-frequency plots based upon precipitation and melt-driven flood events. Because these floods threaten transportation infrastructure, human settlements, ecological habitats, and increasingly, recreational users, we seek a better understanding of the factors controlling glacier-dammed lake formation and drainage.

Contemporary global climate changes are projected to include accelerated warming in arctic regions (ACIA, 2004), and subsequently accelerated glacier retreat is likely to have a significant impact on glacier-dammed lakes. Glacier-dammed lakes are probably more common during periods of extensive glaciation, because larger glaciers have larger overall margins available for impounding lakes. No systematic effort has been made to estimate the number of glacier-dammed lakes present in Alaska during the last, late-Pleistocene ice age, however, and an ongoing study of modern glacier-dammed lakes clearly demonstrates that while some lakes are disappearing in response to ongoing glacier retreat, new lakes are also forming (Wolfe, personal communication, 2007).

Whether a given climatic change results in the creation, alteration, or destruction of a glacier-dammed lake in some particular location is determined largely by the geomorphic setting. Glacier shrinkage typically exposes newly deglaciated terrain, and in some settings (particularly in tributary valleys), that new terrain provides suitable “habitat” for creation of new lakes or expansion of existing lakes. The relationship between climatic changes and glacier-dammed lake behavior is more complicated than it first appears. Contemporary warming will alter, but not eliminate, the hazards posed by Alaskan glacier-dammed lakes.

Studies of former glacier-dammed lakes provide an opportunity to better understand the interrelated geomorphic and climatic factors that govern the hydrologic behavior of contemporary lakes. In the Pacific Northwest, for example, careful study of remnant lacustrine and fluvial features (including lake-bottom sediments, strandlines, beaches, deltas, spillways, and channels) associated with the occupation and drainage of paleo-Lake Missoula have provided substantial insights into the behavior of contemporary glacier-dammed lakes (e.g. O’Connor & Baker, 1992; Waitt, 1985). In Alaska, the study of such features has a more direct and tangible benefit: the identification and characterization of geomorphic features that impact modern hydrology. In the substantial portions of southcentral Alaska once covered by glacier-dammed lakes, remnant features provide both constraints (e.g. low permeability fine-grained lake bottom sediments) and opportunities (e.g. coarse-grained deltas) for communities and persons interested in



Figure 1. The Copper River basin, showing the approximate outline of the 745 m altitude strandline. Possible spillways, modern glaciers, Glennallen and Copper River are shown.

appropriately siting wells, septic fields, and drainage systems. These features are also potentially important for determining the suitability of sites for construction of residential/commercial structures, pipelines, roads, and other infrastructure at risk for seismic shaking, permafrost degradation, and other hazards. Surficial exposures of such features are for the most part well-mapped, but Quaternary deposits in southcentral Alaska are commonly stratigraphically complex, with hydrologically significant units hidden beneath younger deposits. More detailed mapping and field investigations will provide better information for hydrologists, planners, engineers, and developers.

In summary, geomorphic studies of former glacier-dammed lakes provide an opportunity to address the following hydrologic problems:

1. Hundreds of modern glacier-dammed lakes routinely give rise to floods that threaten property, life, and infrastructure;
2. Ongoing climate change makes it difficult to predict where and when glacier-dammed lakes will form, change, or disappear, with obvious consequences for the distribution of potentially damaging floods; and
3. Geomorphic features associated with former glacier-dammed lakes exert an important (and in many cases, the primary) control on the suitability of southcentral Alaskan lands for hydrologic and development purposes, but in many cases the geometry and characteristics of these features are unknown or poorly understood.

Statement of Results or Benefits

While extensive glaciation in the Copper River basin during the Little Ice Age (LIA) may have erased many of the landforms commonly associated with outburst floods described by Maizels (1997) and Walder (1996), we view the proposed research as an integral piece of larger efforts to understand Alaska's Quaternary history. Perhaps more importantly, this research contributes to the currently small body of knowledge about modes, mechanisms, timing, and consequences of outburst floods from glacier-dammed lakes. Given that there are currently 683 of such lakes in Alaska, and that the response of the Alaskan landscape to ongoing climate change includes not only loss of glacier-dammed lakes (as expected), but also creation of new lakes (141 in mainland Alaska between 1971 and 2000; Wolfe, 2007).

The purpose of the research identified in this proposal is to continue a reconstruction of the paleo-environment associated with late Pleistocene ice-dammed lakes in the Copper River basin, and to better understand the paleo-hydrology of outburst floods from paleo-Lake Ahtna. The proposed work builds upon an existing body of knowledge (largely from unpublished literature) about Lake Ahtna, and importantly, also upon the results of our previously-funded summer 2007 research.

With financial support from NIWR and significant logistical support from the Bureau of Land Management (BLM) Glennallen Field Office, graduate student Lucas Gamble, along with Principal Investigator Michael Loso (APU) and collaborators Jason Geck (APU) and John Jangala (BLM), visited numerous sites during the 2007 field season. Most notably, we visited three sites within the Gulkana Wild and Scenic River Corridor (glaciolacustrine and glaciofluvial

deposits), Gakona 1 and Gakona 2 (glaciolacustrine bluff exposures), Hogan Hill (anomalous strandline feature at approximately 745 m), Meier's Lake gravel pit (paleo-river delta), Alphabet Hills terrace (strandline), Canyon Lake deposit (dune or strandline), Meier's Lake terrace (paleo-river terrace), Suslo Mountain terraces (possible 745 m strandline), Nabesna Road, Wrangell – St. Elias National Park deposit (745 m strandline). It is important to note that some of the features observed during the summer 2007 field season warrant further attention in 2008, specifically 745 m strandline features along the southwestern flank of Suslo Mountain near Mentasta Pass, Alaska.

The data gathered during the summer 2007 field season will be used, along with the research proposed here, to further quantify the paleo-environment by using lake volume regression equations to estimate the peak discharge from the 745 m altitude Lake Ahtna, and describe the outburst flood hydrograph using paleo-evidence and/or HEC-RAS computer model. In addition, we propose to identify and visit new potential study sites based upon observations made during the summer 2007 field season to further describe and interpret landforms which may yield clues to the mode of ice-dam failure and magnitude of an outburst flood from the dominant 745 m altitude shoreline of paleo-Lake Ahtna.

A final project report, or thesis manuscript, will be assembled to meet both Alaska Pacific University's thesis and library copy guidelines. Abstract for either a poster or paper presentation will be submitted for one or more of the following professional conferences: the 105th Annual Geological Society of America (GSA) Cordilleran Section Meeting in 2009, the 2009 Annual GSA Meeting in Portland, Oregon, the 39th Annual Northwest Glaciology Meeting in 2009, and various other local brownbag and luncheon presentations, and annual meetings.

In addition, the final project report will be appropriately formatted and submitted for publication in one of the following geoscience journals: *Quaternary Science Reviews*, *Geology* or *GSA Bulletin*, *Earth Surfaces Processes and Landforms*, or as a U.S. Geological Survey special paper (with Peter Haeussler). We will provide one copy of the report to Ahtna Inc., an Alaska Regional Native Cooperation, members of whom expressed interest in our work during the previous year. Finally, we will also provide one copy of the report to the Wrangell – St. Elias National Park and Preserve park geologist as a professional courtesy.

Nature, Scope, and Objectives of the Research

Building upon the successful outcome of our 2007 field season, we propose a new set of problem statements based upon observations of Lake Ahtna features and data collected during summer 2007 field season: Which spillways would allow for a stable 745 m altitude Lake Ahtna? What is the likely mode of drainage and outburst mechanism? What is the peak discharge from an outburst flood from the 745 m altitude Lake Ahtna, and what would the hydrograph look like? Specifically, the results of our proposed research include (with an approximate timeline):

1. Inventory of USGS field notebook from the Copper River basin archives (3/1/2008)
2. Inventory of USGS aerial photography and stereoscopic analysis of geomorphic anomalies in the Copper River basin (3/1/2008)

3. Comparison of mode drainage and mechanism for outburst flood based upon topography (3/1/2008)
4. Estimation of peak discharge from a 745 m altitude Lake Ahtna outburst flood using lake volume regression equations (6/1/2008)
5. Calculation of flow characteristics based upon Manning's equation and HEC-RAS computer modeling (6/1/2008)
6. Comparison of empirical estimates for peak discharge and flow to calculations based on paleo-evidence and data collected during field season (11/1/2008)
7. A comprehensive GIS database of Lake Ahtna features and geomorphic landforms with radiocarbon dates where applicable (12/1/2008)
8. A complete digital map of 745 m altitude Lake Ahtna, spillways, glacier termini, location of ice-dam and likely outburst flood routing (2/1/2009)

Funding for the proposed research will allow for further understanding of the paleo-geologic environment surrounding genesis and ultimate draining of Lake Ahtna and continue to build upon the data, analysis and interpretation from the summer 2007 field season. Additionally, this research provides direct training and education for Lucas in applied geomorphology and glacial geology. Lucas is anticipated to continue to benefit from this research by hands on field study of post-glacial and lacustrine geomorphic features in the Copper River region of Alaska.

An important part of this research is to further quantify the mode of ice-dam failure and the magnitude of an outburst flood from the 745 m altitude Lake Ahtna by continuing to analyze previous observations of Lake Ahtna and search for further paleo-evidence in the Copper River basin.

Methods, Procedures, and Facilities

A reoccurring theme in the literature is the ambiguity of predominant landforms. Paleo-evidence has been altered by periglacial processes, buried by later sediments and covered in dense vegetation. To mitigate these challenges we propose scouring the USGS archives for field notebooks by pioneering geologists in the Copper River basin including, Ferrians, Schmoll, Yehle, Williams, Galloway and others. Previous observations of geomorphic landforms by these geologists will be noted, digitized in our GIS geodatabase, and will guide selection of study sites for summer 2008. Further these sites, if found, will be examined by topographic maps, aerial photography, stereopairs, digital elevation models (DEMs) and other digital imagery available. Both new features and anomalous landforms identified will be digitized in GIS and, when possible, visited and documented during the field season.

In existing published literature, in the field notes of others, and in our own fieldwork, the most conspicuous Lake Ahtna features are associated with the 745 m strandline. The research in this proposal is concentrated on the 745 m altitude Lake Ahtna reconstruction. Peak discharge from outburst floods will be based empirically on the 745 m altitude Lake Ahtna and lake volume regression equations (Herget, 2004). Similarly, application of Manning's equation and use of HEC-RAS computer modeling will be based upon topographic constraints at this elevation.

Generally, research techniques employed in the field will typically include, 1) delimit boundaries of landform or feature, and locate exposed stratigraphy; 2) use mapping grade GPS to collect geodetic coordinate and elevation data as accurate as possible; 3) expose stratigraphy by digging, coring or cleaning of natural features; 4) describe stratigraphy by facies description following Evans and Benn (2004); 5) collect samples for grain size analysis and radiocarbon dating.

Facilities

Numerous studies of have been conducted in the Copper River basin by the USGS. Many of these investigations have not been published, yet may be of importance to this research. Field notebooks of observations within the study area exist as archives at the USGS Alaska Science Center located on APU campus. Collaborator and studies committee member Peter Haeussler works at the USGS and will coordinate access to these archives.

Sedimentological analysis of collected sediments, including textural analysis, photography, thin-section preparation (if necessary), and extraction of organic material for radiocarbon dating will be completed in APU's geology lab, located on the third floor of Grant Hall. The geology lab includes soil-drying ovens, sediment sieves and a rotap shaker, sample splitters, and other necessary equipment. If extremely fine-grained textural analysis is necessary, we have cooperative access to a USGS-owned Micromeritics Sedigraph at the Alaska Volcano Observatory, also located on the APU campus (Kristi Wallace, personal communication, 12/13/2006).

Mapping and spatial data analysis will be completed in APU's GIS laboratory. The lab contains 17 Dell Dimension 360 Workstations with ArcGIS 9.2, Erdas Imagine 9.0, a Dell Poweredge 2600 server, and a complete suite of large format printers, plotters, digitizers and scanners. The lab maintains a large collection of digitized Alaskan topographic maps, georectified aerial photos, and satellite imagery. Access to additional maps and images (including 15 m ASTER imagery) is facilitated by our close cooperative relationship with USGS researchers at the USGS Alaska Science Center. APU also owns a Trimble® Pathfinder® ProXH™ global position system (GPS), an external Zypher™ antenna, and H-Star™ postprocessing technology used for mapping Lake Ahtna features.

Accelerator Mass Spectrometry (AMS) radiocarbon dating of collected organic material will be completed at the ¹⁴CHRONO Centre for Climate, the Environment and Chronology at the Queen's University Belfast. The Centre was established in 2003. Research collaborator, Dr. Paula Reimer, is the Centre director and has had a significant role in the development of radiocarbon calibration data sets since 1986. Reimer has experience with AMS ¹⁴C sample pre-treatment and dating of a variety of samples including, shells, bone, peat, wood, plant macrofossils and speleothem carbonate. Lucus has recently sent 10 samples for radiocarbon dating to the Centre for analysis.

APU has developed an outstanding cooperative relationship with the BLM GFO, namely archeologist and research collaborator, John Jangala. The BLM GFO has offered APU researchers free housing for the duration of the 2008 field season (John Jangala, personal communication, 11/11/07). BLM housing includes power, cooking facilities, communication and a convenient logistical base for research in the Copper River basin. Further, the BLM graciously

offered both raft and air-support to APU researchers during the summer 2007 field season. APU researchers will continue to mitigate logistical and travel costs incurred during the field season by planned coordination with BLM and USGS researchers. Support for travel to and from the Copper River basin, field season meals and basic field equipment is requested in this proposal.

We intend on taking advantage of collaborative opportunities with the BLM field crews performing archeological studies in the summer of 2008, similar to that performed during the summer of 2007.

Related Research

As early as the 1960s, geologists have concluded that during any major glaciation, including those during the late Pleistocene, the Copper River and other areas of the basin have been dammed by advancing glaciers, forming a large proglacial lake (Ferrians, 1963; Ferrians and Nichols, 1965; Ferrians, 1989; Nichols, 1989; Williams, 1989).

More recently, Bennet et. al (2002) have further supported the general proposition of a large ice-dammed lake by mapping and describing the lithofacies of thick lacustrine deposits exposed in bluffs along the Copper River near Gakona, Alaska.

Extensive research has been done by Herget (2004) on outburst floods from ice-dammed lakes in Siberia. The methods discussed in this proposal follow Herget's (2004) reconstruction of Pleistocene ice-dammed lakes.

Archeologists and cultural resource scientists at the BLM Glennallen Field Office are currently collecting pollen samples from known Lake Ahtna shoreline features to identify if plants and animals were present that were attractive to early-human hunters in the basin 10,000 ya. The BLM is also putting together a GIS database of topographic features related Lake Ahtna and locations where evidence of early human occupations was observed to model other likely high probability archeological sites.

Training Potential

APU is a small, private, predominately undergraduate institution with a strong emphasis in teaching. We have no Ph.D. program and minimal reliance on large NSF-style grants. We therefore depend strongly on small grant programs like this one for support of student research, and thus as a student-oriented institution we are accustomed to placing student training first when identifying the benefits of research funding.

The majority of federal funding being requested for this project is for salary and logistical support for graduate student Lucas Gamble, a Master of Sciences candidate in the Environmental Science program at Alaska Pacific University. Principal Investigator Michael Loso is the chair of Lucas's research committee and will oversee training, academic instruction and project status during this study period. Lucas will also receive mentorship from several other research collaborators, including:

- Peter Haeussler, Research Geologist, USGS, Alaska Science Center
- John Jangala, Archeologist, BLM, Glennallen Field Office
- Paula Reimer, Director, ¹⁴CHRONO Centre for Climate, the Environment and Chronology, Queen's University Belfast
- Dick Reger, Geologist, Reger Geologic Consulting

When possible, training opportunities, both in the field and lab, will be made available to other undergraduate and graduate students at APU during this project. Results of this project will be used in the classroom and lab activities by Michael Loso in future geoscience related courses offered at APU.

Investigator's Qualifications

Resumes are attached for the salaried principal, collaborating investigator and graduate student.

Michael G. Loso

Alaska Pacific University; principal investigator; supervision and geomorphic training for students, fieldwork and analysis.

Paula J. Reimer

¹⁴CHRONO Centre for Climate, the Environment and Chronology; collaborator; AMS dating and analysis.

Peter Haeussler

United States Geological Survey; collaborator; thesis committee member and technical peer review.

Lucus Gamble

Alaska Pacific University; Masters candidate, graduate student performing research.

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Research Interests

Glacial geology: glacier-dammed lakes, subglacial hydrology, jökulhlaups, glacial erosion, applied geomorphology

Paleoclimate: late-Quaternary climate, Holocene dating techniques,

Geoecology: Holocene periglacial environments, vegetation history, landscape-scale climate/glacier/vegetation interactions, lichenometry

Education

Ph.D. Earth Sciences, University of California Santa Cruz, 2004

Advisor: Robert S. Anderson

Dissertation: Late Holocene climate and glacier response reconstructed using stratigraphy and lichenometry at Iceberg Lake, Alaska

M.S. Botany/Field Naturalist Program, University of Vermont, 1996

B.A. Environmental Studies, University of California Santa Barbara, 1990

Selected Recent Publications

- in review Loso, M.G., Doak, D. F., and Anderson, R.S., Application of a new, process-based lichenometric technique to the dating of Little Ice Age glacier moraines. *Arctic, Antarctic, and Alpine Research*.
- 2007 Loso, M.G., Anderson, R.S., Doak, D.F., and Anderson, S.P. A disappearing lake reveals the Little Ice Age history of climate and glacier response in the massive icefields of Wrangell-St. Elias National Park and Preserve. *Alaska Park Science*, 6(1):30-35.
- 2006 Loso, M.G., Anderson, R.S., Anderson, S.P., and Reimer, P.J. A 1500 year, high resolution reconstruction of Little Ice Age climate and glacial response from varved Iceberg Lake, southcentral Alaska. *Quaternary Research*, 66: 12-24, doi:10.1016/j.yqres.2005.11.007.
- 2005 Loso, M.G. and Doak, D. F. Lichens die: the biology behind lichenometric calibration curves. *Oecologia*, 146: 168-174, doi:10.1007/s00442-005-0265-3.
- 2005 Riihimaki, C.A., MacGregor, K.R., Anderson, R.S., Anderson, S.P., and Loso, M.G. Sediment evacuation and glacial erosion rates at a small alpine glacier. *JGR Earth Surface*, 110, doi:10.1029/2004jf000189.
- 2005 Loso, M.G. A McCarthy Creek Forest Resource Inventory. *National Park Service Resource Technical Report*: NPS/AR/NRTR-2005-52.

- 2004 Loso, M.G. Late Holocene climate and glacier response reconstructed using stratigraphy and lichenometry at Iceberg Lake, Alaska. *Ph.D. Dissertation*.
- 2004 Loso, M.G., Anderson, R.S., and Anderson, S.P. Post-Little Ice Age record of coarse and fine clastic sedimentation in an Alaskan proglacial lake. *Geology*, 32: 1065-1068.
- 2004 Anderson, R.S., Anderson, S.P., MacGregor, K.R., Waddington, E.D., O'Neel, S., Riihimaki, C.A., and Loso, M.G. Strong feedbacks between hydrology and sliding of a small alpine glacier. *JGR Earth Surface*, 109, doi:10.1029/2004JF000120.
- 2004 Doak, D.F., and Loso, M.G. Effects of grizzly bear digging on alpine plant community structure. *Arctic, Antarctic, and Alpine Research*, 35(4): 421-428.
- 1999 Loso, M.G. Vegetation history of the Kennecott townsite, in *Kennecott National Historic Landmark Cultural Landscape Report*: US Department of Interior National Park Service, Washington DC.
- 1999 Loso, M.G. "Playing God on Denali." pp. 58-67 in *The Best of Rock and Ice Magazine—an Anthology*. Seattle, WA: The Mountaineers Books.
- 1998 Loso, M.G. Productivity, population structure, and subsistence use of a white spruce forest in the Kennicott Valley, Alaska. *Mountain Research and Development*, 18: 285-308.
- 1998 Loso, M.G. Playing God on Denali. *Rock and Ice* (May).
- 1997 Loso, M.G., Schwartz, H.K., Wright, S.F. and Bierman, P.R. Composition, morphology, and genesis of a moraine-like feature in the Miller Brook Valley, Vermont. *Northeastern Geology and Environmental Sciences*, 20: 1-10.

Professional Activities

- 2005 – present: Assistant Professor. Department of Environmental Sciences, Alaska Pacific University, Anchorage, AK.
- 2002 – present: President of the Board of Directors. Wrangell Mountains Center, McCarthy, AK.
- 1999 – present: Consulting Geomorphologist/Hydrologist/Ecologist (various projects). Wrangell – St. Elias National Park, Copper Center, AK.
- 2005 – 2006: Senior Geomorphologist. HDR Alaska, Anchorage, AK.
- 2000 – 2004: National Science Foundation Graduate Research Fellow. University of California, Santa Cruz, CA.
- 1996 – 2000: Executive Director. Wrangell Mountains Center, McCarthy, AK.
- 1996: Research Associate. US Geological Survey, Anchorage, AK.
- 1993 – 1994: Mountaineering Ranger. Denali National Park, Talkeetna, AK.

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• American Quaternary Association

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Research Interests

Chronology: ¹⁴C measurement, calibration, regional offsets and marine corrections

Palaeoclimate: Effect of past climate change on the ocean-atmosphere-biosphere system

Carbon cycle: origin, diagenesis and residence time of organic carbon compounds in lake sediments, soils, and peats

Education

Ph.D. Geological Sciences, University of Washington, 1998

Advisor: Prof. Minze Stuiver,

Dissertation: Carbon cycle variations in a Pacific NW lake from late glacial-early Holocene

M.S. Biophysics, Iowa State University, 1976

B.Sc. Physics, Iowa State University, 1974

Professional Activities

2004 – present: Senior Lecturer & Director. School of Geography, Archaeology and Palaeoecology & The ¹⁴CHRONO Centre for Climate, the Environment and Chronology, Queen's University Belfast, Belfast, UK

2001 – 2004: Postdoctoral Research Staff Member, Center for AMS Dating. Lawrence Livermore National Laboratory LLNL, Livermore, CA, USA

1998 – 2001: Postdoctoral Research Fellow, School of Archaeology and Palaeoecology, Queen's University Belfast, Belfast, UK

1980 – 1998: Scientific programmer. Quaternary Isotope Lab, Department of Geological Sciences, University of Washington, Seattle, WA, USA

1977 – 1980: Research Assistant, Quaternary Isotope Lab, Department of Geological Sciences, University of Washington, Seattle, WA, USA

1976 – 1977: Physics instructor, Edmonds Community College, Edmonds, WA, USA

1974 – 1976 : Research/ teaching assistant, Department of Biochemistry and Biophysics, Iowa State University, Ames, IA, USA

Selected Recent Publications

Barratt, P., and Reimer, P. J. (in press). Radiocarbon dating: a practical overview. *In* "Environmental Archaeology in Ireland." (E. Murphy, and N. J. Whitehouse, Eds.). Oxbow Books, Oxford.

Blackwell, P. G., Buck, C. E., and Reimer, P. J. (2006). Important features of the new radiocarbon calibration curves. *Quaternary Science Reviews* 25, 408-413.

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EDUCATION:

1984 B. Sc. (Geology) Michigan State University
1991 Ph. D. (Earth Sciences) University of California Santa Cruz
1992-1994 Postdoctoral Researcher, U.S. Geological Survey, Anchorage, Alaska

PROFESSIONAL EXPERIENCE:

1994-present Geologist, U.S. Geological Survey, Anchorage, Alaska
1992-1994 Post-doctoral researcher, U.S. Geological Survey, Anchorage, Alaska
1992 Geologist, U.S. Geological Survey, Menlo Park, California
1985 Geologist, Lancer Energy Corporation, Wilmore, Kentucky

CURRENT RESEARCH

Earthquake hazards

- Denali fault paleoseismology and slip rate
- Identification and characterization of seismic sources across southern Alaska

Submarine landslides

- Characterization and description of submarine landslides in coastal fjords of southern Alaska generated by the 1964 M9.2 earthquake

Framework geology

- Currently mapping the Tyonek 1:250K-scale quadrangle
- Exhumation of the western Alaska Range
- Susitna basin subsurface geology

SERVICE

- Member: State of Alaska Geologic Mapping Advisory Board
- Member, Working Group: Advance National Seismic System
- Project chief: USGS Alaska Earthquake Hazards Project
- Member: USGS Geologic Discipline Science Strategy Team (to come up with 10 yr plan for USGS)
- Co-convenor, AGU Chapman Conference (2006): Active Tectonics and Seismic Potential of Alaska
- Former commissioner, Municipality of Anchorage, Geotechnical Advisory Commission
- Reviewer of numerous papers and proposals
- Spokesman for USGS Earthquake Hazards program in Alaska
- Numerous TV appearances: Discovery Channel, History Channel, Weather Channel, Dateline, KTUU news, etc.
- Author: Next Big Earthquake – earthquake preparedness pamphlet. Most used earthquake preparedness pamphlet used in Alaska.

SOME RECENT PUBLICATIONS

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Research Interests

Glacial geology: glacier-dammed lakes, subglacial hydrology, jökulhlaups, glacial erosion, applied geomorphology, glacial dynamics

Hydrology: Flood frequency and magnitude, surface water / groundwater interactions, riparian restoration

Geophysics: tectonics, isostasy

Education

M.S. Candidate, Environmental Science, Alaska Pacific University

B.S. Environmental Science, University of Alaska Southeast, 2005

Professional Activities

2001-present: Senior Environmental Scientist, Restoration Science & Engineering

1999-2002: Teaching assistant, University of Alaska Southeast

Professional Affiliations

American Institute of Hydrology

Geological Society of America

Alaska Geological Society

Accomplishments

Poster presentation on isostatic rebound and rates of uplift in Southeast Alaska at the 2002 Geological Society of America Cordilleran Section Annual Meeting

Oral presentation on coastal migration of early humans into North America at the 2002 Alaska Anthropological Association Annual Meeting

Acknowledgments

Motyka, R.J., O'Neel, S., Connor, C.L., and Echelmeyer., 2002. 20th Century Thinning of Mendenhall Glacier, Alaska, and its Relationship to Climate, Lake-Calving, and Glacier Run-Off. *Journal of Global and Planetary Change*. V. 35, pp. 93–112.

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

Basic Information

Title:	The diminishing role of glacier runoff into Eklutna Lake; potential impacts of hydropower and water supply for the Municipality of Anchorage
Project Number:	2009AK75B
Start Date:	3/1/2009
End Date:	2/28/2010
Funding Source:	104B
Congressional District:	AK-1
Research Category:	Climate and Hydrologic Processes
Focus Category:	Water Supply, Climatological Processes, Sediments
Descriptors:	None
Principal Investigators:	Michael Gregg Loso

Publications

There are no publications.

**2009 NIWR Funded Research Project
Progress Report December 2009**

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, 2010

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

Congressional District: Alaska

Abstract: 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 existing work by APU faculty and students demonstrates that the Eklutna Glacier has retreated dramatically over the last 50 years, losing approximately 1.5 km³ 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. Here, I propose an expansion of existing research on the Eklutna Glacier and Eklutna River to assess the impacts of ongoing climatic changes on the glacier runoff contribution to Eklutna Lake. The existing research is a long-term, student-led glacier mass balance monitoring program initiated two years ago by Alaska Pacific University. The new work proposed here will be led by two new graduate students. One, focused on the glacier, will expand the mass balance and velocity measurement program to assess the nature and magnitude of the glacier's response to expected climatic changes. The second student, focused on hydrology, will collect a time-series of water and sediment discharge on the glacier-fed West Fork Eklutna River and a comparable time-series from the predominantly non-glacial East Fork to predict the hydrological response to shrinkage of the Eklutna Glacier. Support is requested primarily for graduate student salary and logistical expenses and for acquisition of an additional stream monitoring station to augment the existing West Fork station; mentoring will be provided by research collaborators from Alaska Pacific University, US Geological Survey, the College of Charleston, the Anchorage Water and Wastewater Utility, and Municipal Light and Power.

Summary of Results to Date

This progress report summarizes progress on an Alaska Pacific University study, led by PI Michael Loso and two graduate students, Louis Sass and Ann Marie Larquier, on the Eklutna Glacier and River and their contributions to Eklutna Lake and the water supply of the Municipality of Anchorage. A brief description of activities to date (December 2, 2009) is provided below, and corresponds numerically to the seven tasks outlined in our original proposal. We anticipate completing all funded activities (what remains is primarily data analysis) by the conclusion of the grant period (Feb. 28, 2010), and in a separate document request modest additional salary to continue our fieldwork in the melt season of 2010.

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

Graduate student Ann Marie Larquier, with the help of USGS hydrologist Jeff Conaway (a member of her thesis committee, installed instrument packages on both forks of Eklutna River on May 6, 2009 and removed the instruments on October 28 (later than expected due to a warm autumn with enhanced late season flows). The installation was assisted by in-kind fabrication work donated by the Anchorage Water and Wastewater Utility, and included temperature, river stage, and turbidity gauges coupled to a shore-mounted Campbell Scientific CR800 datalogger at each site (figure 1). A high-water event in late July damaged the data cable for the west fork installation, cutting off data from the turbidity and stage (but not temperature) gauges, but Ann Marie responded quickly to this event by installing a USGS standard stage board on a nearby boulder and monitoring the stage with an automated camera for the remainder of the melt season. These photographs have not yet been analyzed for conversion to stage, and are not shown in figure 1, but the compromise of our dataset was minimal and amounts only to the unfortunate loss of turbidity data from the west branch during the latter portion of the melt season.

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

Graduate student Ann Marie Larquier, assisted by field assistant Meghan Humphrey (who is working as Ann Marie's assistant for her senior project), visited the Eklutna River regularly during the summer to collect discharge measurements using a USGS standard bridgeboard

apparatus with a Price AA velocity meter mounted on a lead weight. They made these measurements on twelve occasions representing a wide range of discharges. During each visit, they also collected a 1-liter water sample for later filtration and calculation of suspended sediment concentration. The filtration is in progress as of December 2009, and the construction of appropriate rating curves will occur over the winter break.

3. Concurrent measurements (ten minimum on each fork) of bedload on both Forks to assess the relative proportions of suspended sediment and bedload discharge

In response to higher than anticipated flow conditions on the two forks of the Eklutna River, and in consultation with APU's Risk Management Committee, it was decided by the PI and graduate student that in-stream measurements of bedload discharge were not safe or practical during the range of flows on these rivers, and we have decided to utilize (as is standard practice in many comparable studies of glacial river sediment discharge) to base our sediment transport estimates on an assumption of approximately equal contributions from suspended sediment (measured) and bedload (estimated).

4. Complete melt-season (May – September) measurements of accumulation, ablation, and velocity at an expanded network of sites (minimum 5 for accumulation and ablation, minimum 9 for velocity) on the Eklutna Glacier

Graduate student Louis Sass, in conjunction with the PI and undergraduate students participating in the "Glaciology and Glacier Travel" course taught by the PI during May 2009, installed 33 ablation/velocity stakes on the Eklutna Glacier. Three were located along the centerline near the top of the accumulation zone, the ELA, and the lower ablation zone, and the other 30 were installed in a regular grid (3 wide, 10 long) spanning the upper ablation zone and lower accumulation zone. Accumulation was measured in 3 full depth snow pits (the deepest was nearly 4 m deep). These stakes were then monitored regularly by Louis Sass and undergraduate John Sykes during regular visits throughout the melt season until removed September 12. Mass balance calculations based upon these and other, similar measurements on the nearby Eagle Glacier and in previous years are shown in figure 2. Velocity measurements from the regular grid are shown in figure 3.

5. Complete hourly melt-season (May – September) measurements of air temperature at an expanded network of sites (minimum 5) on the Eklutna Glacier to complement the existing complete meteorological measurements carried out at mid-glacier

A complete met station was installed at mid-glacier by APU students during the May field course (figure 4) and 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 on the nearby Eagle Glacier. Of these, one sensor (near the Eklutna Glacier terminus) failed and the data was lost. Other sites provide complete information, as shown in figure 5).

6. 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. These measurements were combined with the data collected under item 7, below, to construct the map presented in figure 6.

7. Ground-penetrating radar measurements of, at minimum, one longitudinal profile and three transverse profiles on each major fork of the Eklutna Glacier

This work was completed by graduate student Louis Sass in collaboration with Joe MacGregor, a postdoctoral researcher and radar specialist at the University of Texas Austin. The work was very logistically complicated, and required substantial contributions from several field assistants, but was completed successfully in early June of 2009 and allowed creation, along with the data collected under item 6, above, of complete maps of the surface and bed elevations of the Eklutna Glacier (figure 6).

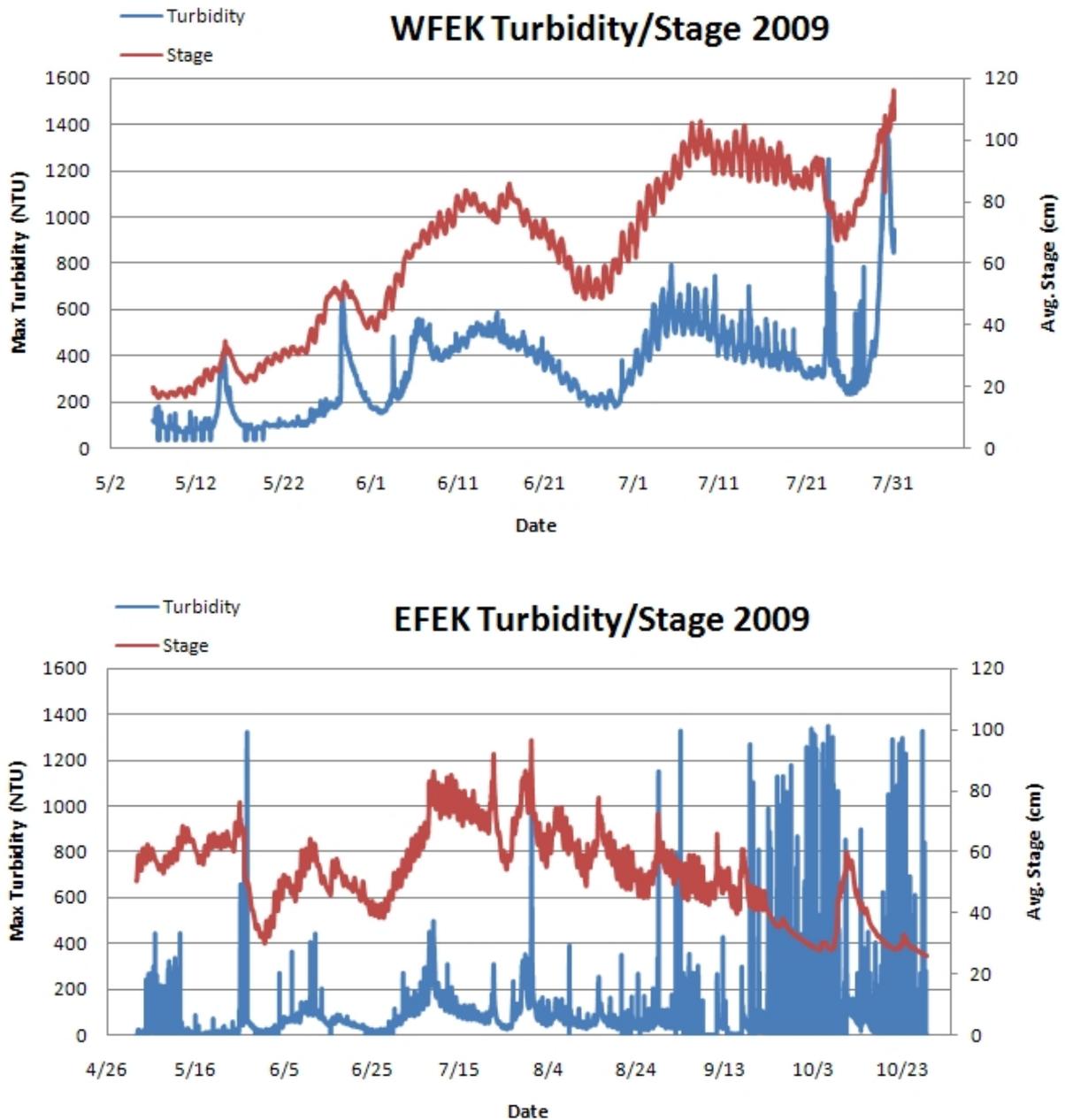


Figure 1. Turbidity and stage measurements from the West Fork (upper panel) and East Fork (lower panel) of the Eklutna River. Note the differing time axes: West Fork values go only through late July, when a high water event damaged the sensor cables (see text for details). High turbidity values late in the season on the East Fork are artifacts of turbidity values too low for the sensor’s calibration, and are interpreted as zero.

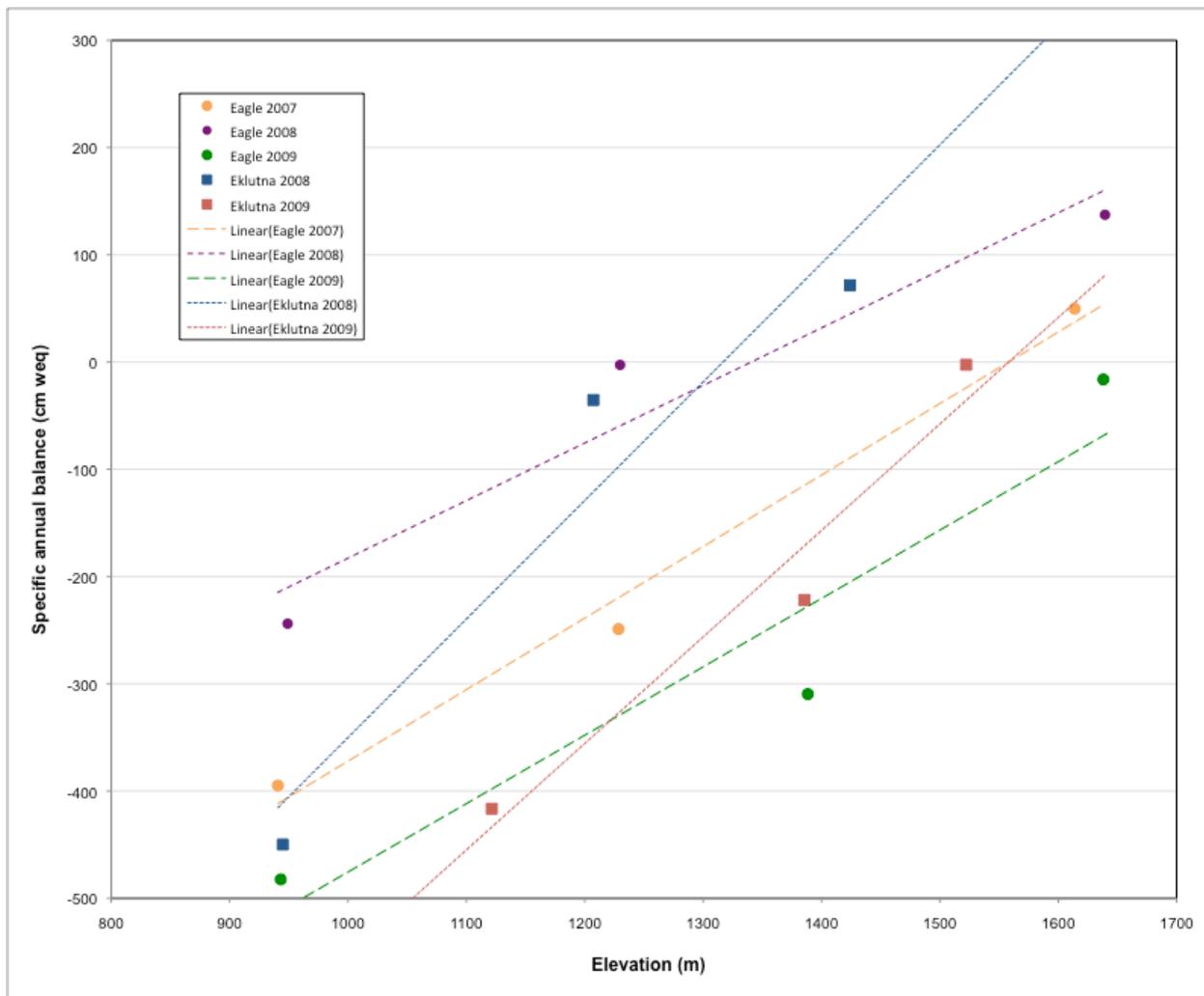


Figure 2. Accumulation, ablation, and mass balance for Eklutna and Eagle Glaciers for years 2007-2009, based on 3 primary measurement stations on each glacier. Note consistency of mass balance gradients at each glacier over the years of differing weather.

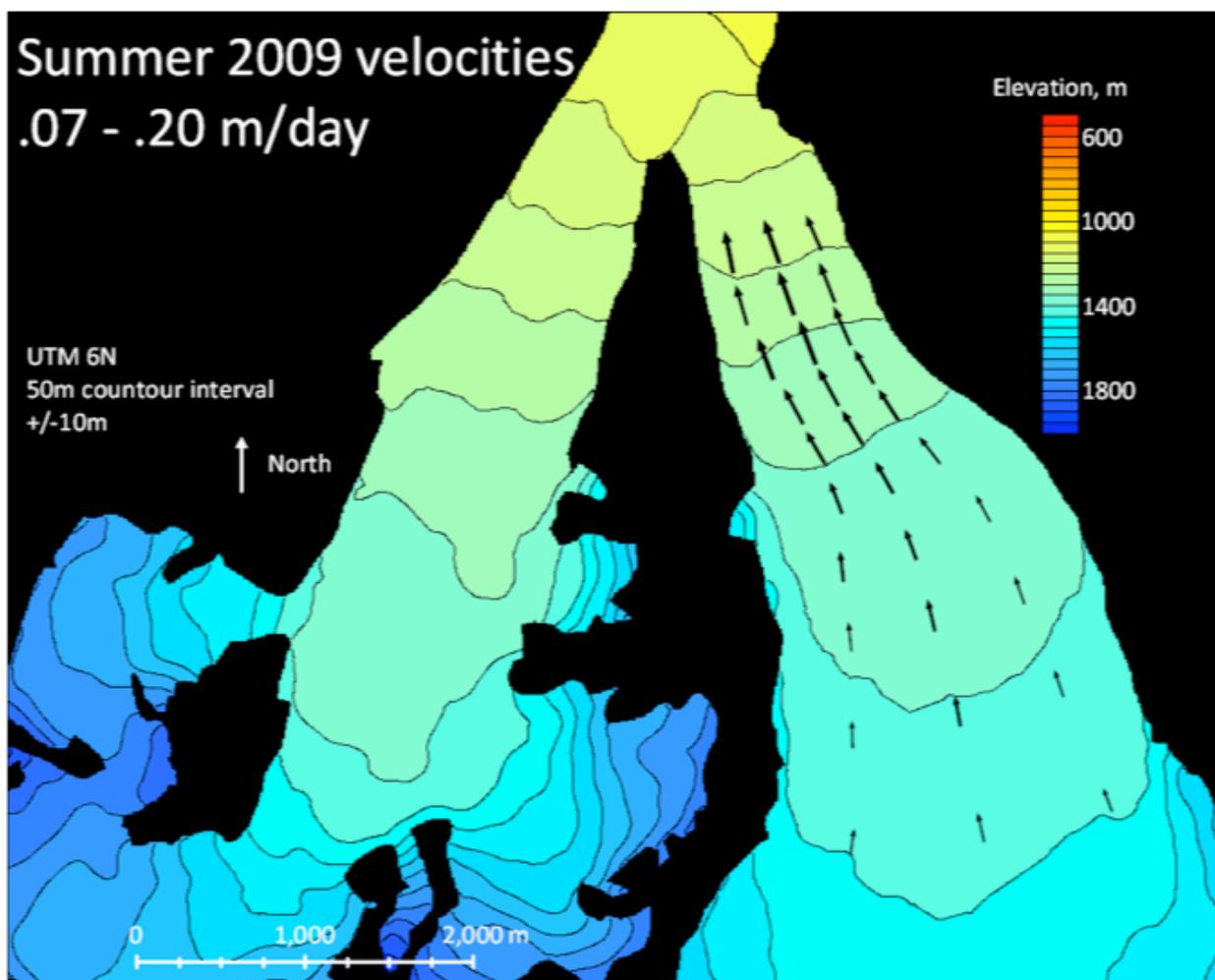


Figure 3. Surface velocities measured at 30 sites on a regular grid on the Eklutna Glacier's main (east) branch in summer 2009. Velocities were estimated using differential, survey-grade GPS between May and July 2009.



Figure 4. APU undergraduates installing a met station on the upper Eklutna Glacier in May 2009. The tripod at right forms the “floating” base for the station, while the steam drill at left will be used to mount a rigid pole with a down-looking sonic snow depth gauge.

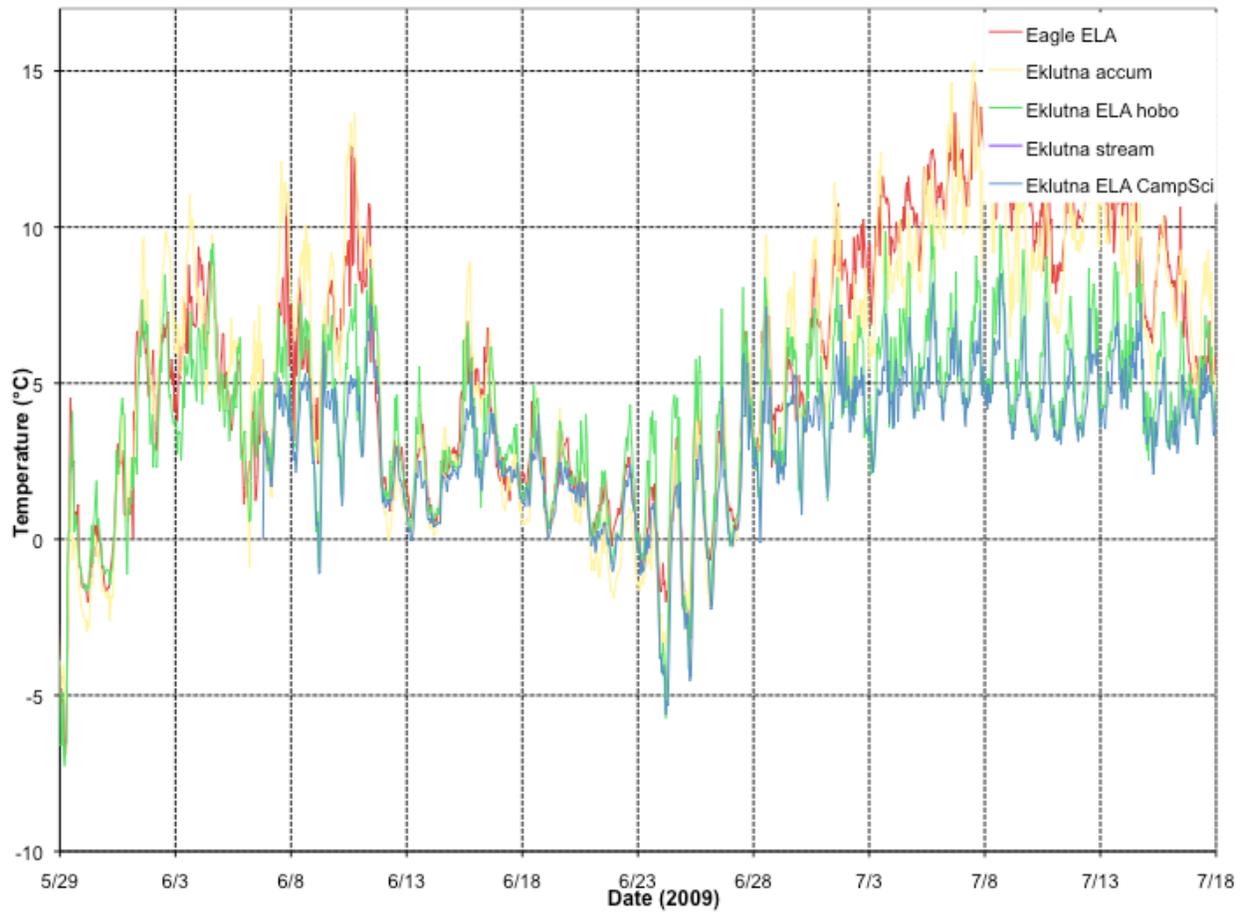


Figure 5. Temperature measurements from 5 sites on and near the Eklutna Glacier. Note that one site (Eklutna Stream, from near the glacier terminus) is not shown because the sensor failed in mid-season.

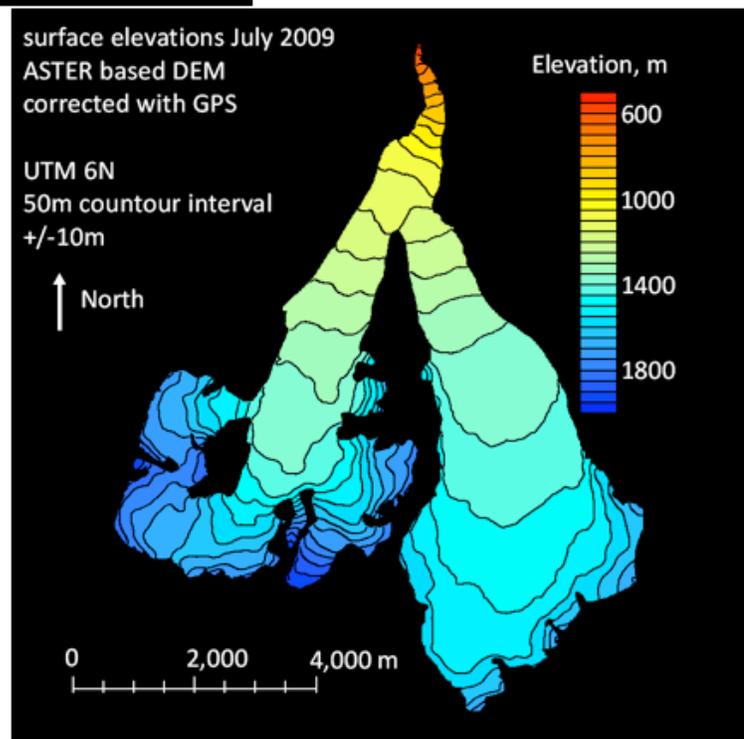
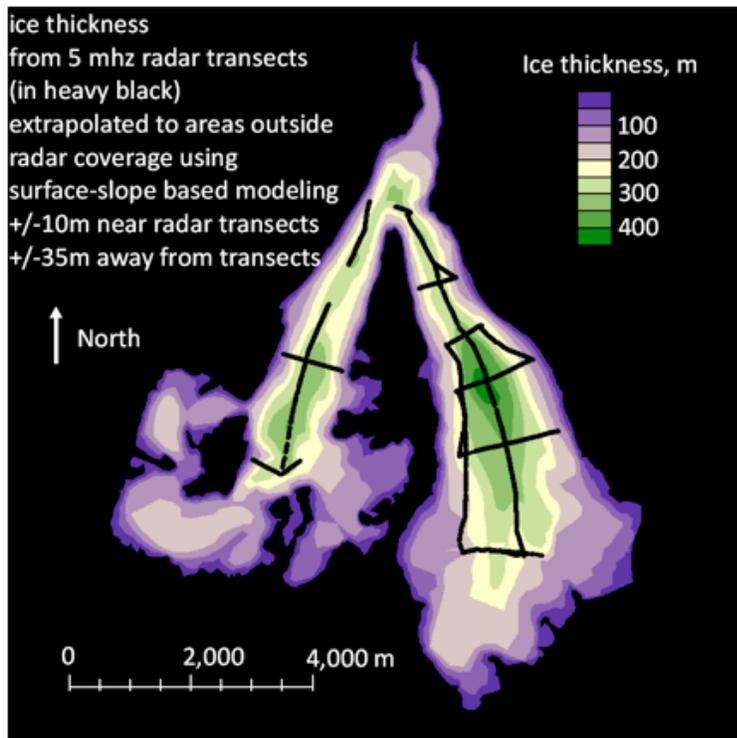


Figure 6. Ice thickness (upper panel) and surface elevations (lower panel) measured on the Eklutna Glacier in summer 2009. In upper panel, radar profiles are shown as dark lines, and other thicknesses are interpolations based on radar data and glacier edge locations. In the lower panel, surface elevations are based upon dGPS measurements combined with 2007 laser altimetry mapping and constrained by surface shape on older topographic maps.

Impacts of Cold Regions Open Dumps on Microbial Water Quality

Basic Information

Title:	Impacts of Cold Regions Open Dumps on Microbial Water Quality
Project Number:	2009AK78B
Start Date:	3/1/2009
End Date:	2/28/2010
Funding Source:	104B
Congressional District:	AK-1
Research Category:	Water Quality
Focus Category:	Solute Transport, Toxic Substances, Wastewater
Descriptors:	None
Principal Investigators:	William Schnabel, David L. Barnes

Publications

There are no publications.

are sampling groundwater resources surrounding open dumps throughout Alaska to assess the impacts of an array of potential chemical contaminants. Our study is supplementing the RARE project with information related to microbial contaminants in surface and groundwaters. In exchange, our study is leveraging the RARE project logistical coordination and field preparation (e.g., sampling wells) for our use. Data collected in both parallel projects will be made available for all participating researchers. In addition, this study is leveraging the activities of the Rural Alaska Community Action Program (RuralCAP). Specifically, Ted Jacobson, the RuralCAP coordinator for solid waste, has been escorting Ms. Mutter to village dumpsites in order to familiarize her with site water resource issues and provide an opportunity for additional sampling.

In August 2009, Edda Mutter and Ted Jacobson visited the dumpsites of seven rural villages to collect microbial indicator samples and conduct preliminary assessments. The names of the villages have been omitted from this report at the request of village officials as a condition of gaining access to their dumpsites. The methods and results to date are detailed below.

Methods

Microbial indicator analysis was performed using IDEXX equipment available at the WERC (i.e., Colilert[®] for *E. coli*, and Total Coliform; and Enterolert[®] for *Enterococcus*). Due to the relatively short recommended holding times for microbial samples (6 hours), the equipment was shipped to the field, and where possible, sample analysis was conducted onsite. For each sampling event, the student sampled surface waters proximal to the open dumps. As only one RARE site had groundwater sampling wells installed at the time of the sampling trip, groundwater samples were limited to a single site. The remaining six village dumpsites sampled were not associated with the RARE project. Sampling techniques were consistent with EPA protocols for pathogen indicator organisms.

Results

Screening level results of the sampling trip are presented in Tables 1 and 2. As indicated in the tables, indicator organisms were prevalent in the proximity of all the dump sites in water and soil samples.

Table 1: Pathogen Indicator Bacteria Observed in Surface Waters Collected In or Near the Village Dumpsites

Village	Water Samples Obtained	Log of Average MPN/100mL		
		Total Coliforms	E. Coli	Enterococcus
#1	6	2.4	0.9	3.1
#2	4	2.4	2.0	1.4
#3	12	2.4	0.9	2.9
#4	5	3.1	0.5	2.1
#5	8	3.2	3.2	3.0
#6	2	3.1	3.1	2.3
#7	2	2.2	1.7	1.3

Table 2: Pathogen Indicator Bacteria Observed in Soil Samples Collected In or Near the Village Dumpsites

Village	Soil Samples Obtained	Log of Average MPN/g soil		
		Total Coliforms	E. Coli	Enterococcus
#1	4	3.4	3.2	3.6
#2	4	2.6	1.0	3.3
#3	6	2.9	0.4	2.2
#4	1	3.3	0.3	3.3
#5	7	2.8	2.6	3.3
#6	9	2.5	0.8	2.2
#7	5	3.0	2.5	2.1

Discussion

Developing proper disposal and management techniques for solid waste in rural Alaska is a challenging issue (Figure 1). Highway infrastructure is limited throughout most of rural Alaska, thereby limiting the utility of regional landfills. Barge traffic is often discontinued during the winter, thus diminishing transport options for river communities. Many communities import goods and materials via air freight, but the option of flying solid waste out to distant landfills is not cost effective. Consequently, many villages are limited to disposing their solid waste (and wastewater) in swampy terrain relatively close to drinking and subsistence water resources (Figure 2). As a result, it is crucial to better understand the mobilization of contaminants such as pathogenic organisms from the waste sites to the surrounding environment.



Figure 1: Rural Alaskan Waste Sites are Typified by Limited Disposal Options and Poor Management



Figure 2: Dumpsite Adjacent to Wastewater Lagoon Amidst Tundra Ponds in Village #5

This initial screening has demonstrated that fecal indicator bacteria are prevalent in the soils and water surrounding dump sites in rural Alaska. Moreover, it has provided an entree into the communities to conduct further, more contaminant-specific studies now and in the future. Our team is presently returning to these and other villages to continue our screening level assessments during the spring and summer of 2010. In addition to fecal indicator organisms, we are evaluating the distribution of metals, VOCs, and other contaminants of concern. We anticipate that this project will allow us to develop the seed data and relationships necessary to fund and execute the long-term, site-specific projects necessary to find solutions.

water quality and membrane characteristics on membrane fouling and effluent quality for filtration of surface water with high

Effect of raw water quality and membrane characteristics on membrane fouling and effluent quality for filtration of surface water with high organic matter content

Basic Information

Title:	Effect of raw water quality and membrane characteristics on membrane fouling and effluent quality for filtration of surface water with high organic matter content
Project Number:	2009AK79B
Start Date:	3/1/2009
End Date:	2/28/2010
Funding Source:	104B
Congressional District:	AK-1
Research Category:	Water Quality
Focus Category:	Treatment, Surface Water, Water Quality
Descriptors:	None
Principal Investigators:	Silke Schiewer

Publications

There are no publications.

USGS Final Report

Title: Effect of raw water quality and membrane characteristics on membrane fouling for filtration of surface water with high organic matter content

Start date: March 1 2009

End date: Feb. 28 2010

Focus Category: Treatment, Surface water, Water quality. TRT, SW, WQL

Descriptors: membrane filtration, DOM, fouling

PI: Silke Schiewer

Products of Project

Conference Poster and Abstract:

McDonald, E.; Schiewer, S.: The effects of surface water quality and microfiltration membrane charge characteristics on membrane fouling. *American Water Resources Association, Alaska Section 2009 Annual Meeting "Managing Water Resources and Development in a Changing Climate"*. Anchorage, AK, May 4-6 2009

Oral Conference Presentation:

McDonald, E.; Schiewer S.: The effects of surface water quality and microfiltration membrane charge characteristics on membrane fouling. *American Water Resources Association 2009 Annual Meeting, Seattle, November 9-12 2009*

Awards:

Erin McDonald, the student supported by this project, won the student poster competition of the AWRA 2009 Conference May 4-6, Anchorage, AK

Journal Publications:

McDonald, E.; Schiewer, S.: Surface water quality and microfiltration membrane material properties: effects on membrane fouling. *Desalination* (to be submitted)

McDonald, E.; Schiewer, S.; Schnabel, W.: Seasonal variation of microfiltration fouling filtering tundra pond water. *Journal of Membrane Science* (to be submitted)

MS Thesis

McDonald, E. Microfiltration membrane material properties and surface water characteristics: effect on membrane fouling. MS thesis, Environmental Engineering, Department of Civil & Environmental Engineering, University of Alaska Fairbanks, May 2010.

Introduction: problem, objectives, and relevance

Problem

In recent years, the use of membrane filtration for drinking water production has increased. Membrane filtration has the advantages of providing effective treatment with high product water quality in a compact setup with very few treatment steps. Especially if the source water has a high content of organic matter, a further advantage of membrane filtration is the reduced potential for the formation of disinfection byproducts, harmful substances that are formed during the reaction of chlorine with organic matter. However, membrane filtration suffers from fouling that can be caused by organic matter present in the raw water. Fouling is the largest problem in membrane applications and the biggest obstacle to its more widespread application.

Goal

The goal of the present study was to better understand how properties of the membranes themselves and of the raw water, such as pH, and concentration of DOM, are related to membrane fouling.

Objectives

For this purpose, the project objectives were to conduct experiments at laboratory and the pilot and scale, using an existing operational pilot scale treatment plant at Toolik Field Station during several field trips in the summer of 2009. The collected water was to be analyzed and used for additional laboratory membrane filtration tests with and without modifications of the water. A mathematical model was to be applied to describe the development of permeate flux over time in order to allow easier comparison of fouling rates between different water types and membrane types.

Relation to first phase of project

In the first phase of this USGS project, where Toolik Lake and Chena River samples were investigated in lab scale, data were presented as absolute values of the permeate flux. Compared to that, this second phase included Toolik Lake samples at different seasons, the use of more different membranes in laboratory experiments, the use of the Toolik Lake membrane filtration pilot plant, and further data analysis (converting data to relative flux, calculation of the resistance, modeling fouling rates).

Main Findings

The pH value had a big impact on membrane fouling. However, due to seasonal variations in water quality, the optimal pH varied. Therefore no generally valid recommendations can be made with respect to pH adjustment before membrane filtration. This decision has to be specifically made for a given water type.

Membrane material was shown to be more important to membrane fouling than pH or season. Overall the charged, hydrophilic membranes performed the best, with the lowest fouling rate. Hydrophobic membranes had the highest fouling rate. It is therefore recommended to use hydrophilic membranes for waters as those investigated in this study.

Relevance

This knowledge will make it possible to use membrane filtration in an effective way, e.g. by choosing the optimal type of membrane, selecting a suitable raw water source, and designing pre-treatment processes if necessary. Overall, this research will facilitate the use of membrane technology in areas with limited source water quality.

Methods

For the second phase of this project, surface water samples were collected from Toolik Lake on Alaska's North Slope (68°38'N) in June, July and August 2009, which represents the spring, summer and fall seasons at that location. Effluent samples were collected from an inline MF and nanofiltration MEMCOR® 6M10C hollow fiber pilot scale plant using neutral, hydrophobic polypropylene membranes with a nominal pore size of 0.2 µm. Lake water and effluent samples were frozen prior to transport and stored at 1° C thereafter to halt biological activity. Water samples were analyzed for TOC in the WERC facilities.

A bench scale, dead end filtration system as shown in Figure 1 was used. The apparatus contains a pressurized reservoir connected via a hose to the filter holder which contains a circular flat sheet membrane with 47 mm diameter. For each run a fresh membrane was used. This allows analysis of the fouled membranes after each filtration run. The permeate flux rate was determined gravimetrically by continuously monitoring the permeate quantity via an electronic balance connected to a computer.

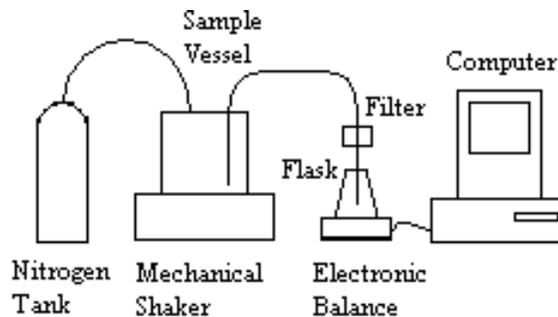


Figure 1 Filtration apparatus

This system was used to investigate fouling characteristics of different influent waters and different membrane materials. To allow a fair comparison, all membranes featured the same pore size of 0.2 µm. Membrane materials used were:

- Cellulose acetate (CA), which is hydrophilic and negatively charged
- Polyethersulfone (PES), which is hydrophilic and charge-neutral
- Polypropylene (PP), which is hydrophobic and charge-neutral
- Polyvinylidene fluoride (PVDF) is hydrophobic and positively charged
- Nylon (NY) is hydrophilic and positively charged

For some experiments, the pH of the solution was changed from the collection pH to pH 5 or pH 9 by addition of NaOH or HCl. The pH affects both the NOM charge and membrane properties.

The effect of organic matter size was investigated by pre-filtration, removing the larger particles from the water sample. By removing certain size classes of organic matter, their contribution to the overall fouling can be evaluated.

Scanning electron microscopy was performed on clean and fouled membrane to assess pore structure and deposition of foulants.

From the flux value J at any given time, the total resistance R_T of the fouled membrane can be calculated from equation 1 for a known constant transmembrane pressure Δp and fluid viscosity μ .

$$J = \frac{\Delta p}{\mu R_T} \quad \text{Equation 1}$$

Principal Results

For all membranes, the permeate flux declined initially rapidly and then started leveling out, as shown for June raw water in Figure 2a. To better compare the severity of fouling between membranes and for different feed water types, rather than using the absolute flux $J(t)$, the flux was normalized for further data analysis. The relative flux J/J_0 is obtained by dividing the flux at any point in time, J , over the initial flux J_0 . The resulting relative flux for June raw water is shown in Figure 2b. As also observed for other water types, the hydrophilic membranes performed better, with higher relative permeate flux than the hydrophobic ones.

As an indicator for the severity of fouling, the resistance was calculated using equation 1. To describe the increase of resistance compared to the initial value, and to be consistent with the use of relative flux, the relative resistance values were calculated by dividing the resistance at any given time over the initial resistance. Figure 3 shows the relative resistance for the dissolved fraction, obtained after pre-filtering June and July Toolik water respectively. Again, the hydrophilic membranes (open symbols) performed clearly better, with a much slower increase of the relative resistance than the hydrophobic ones (filled symbols).

It is noticeable that the resistance increased mostly linear over time. Therefore, linear regressions were used to describe the data (Equation 2) with k being the slope of each line, i.e. the fouling rate constant, which is equivalent to the rate of change of R_T/R_0 . Larger values of k indicate that the resistance is increasing more quickly and hence the membrane is being fouled more quickly.

$$\frac{R_T}{R_0} = 1 + kt \quad \text{Equation 2}$$

To confirm whether a flux model based on a linear increase of the resistance can successfully describe the relative flux development, the relative flux was calculated using equation 3 with the fouling rate constants k as determined by linear regression. Figure 4 gives an example of the results for August raw water and dissolved fraction. The model generally fits well except that in the initial phase the measured flux declined faster than the model predicted one.

$$\frac{J}{J_0} = \frac{1}{1 + kt} \quad \text{Equation 3}$$

To compare fouling for all experiments, including those with varied pH, which are not shown in figures 2-4, the fouling rates k for all experiments are compiled in Figure 5. It is noticeable that the fouling rates were on average lowest for the negatively or positively charged hydrophilic membranes and highest for the hydrophobic membranes.

For different pH values, large differences in the fouling rate were observed, however the results varied between the months. The pH values with the lowest average fouling were pH 5 for June, pH 9 for July and August. Average fouling rates were highest at natural pH in June and July and at pH 5 in August. This means no generalized recommendations for pH adjustment can be made. If pH adjustment is to be performed to reduce fouling (fouling rates can less than half of those without pH adjustment), this has to be tailored to a specific raw water.

In pilot plant studies with a polypropylene membrane (neutral, hydrophobic), a TOC reduction was only observed in August. This is the case because in June (just after breakup) and July (dry period), virtually all organic carbon was dissolved, whereas in August, larger concentrations of particulate organic matter were present that presumably had been carried in with the runoff during the rainy season.

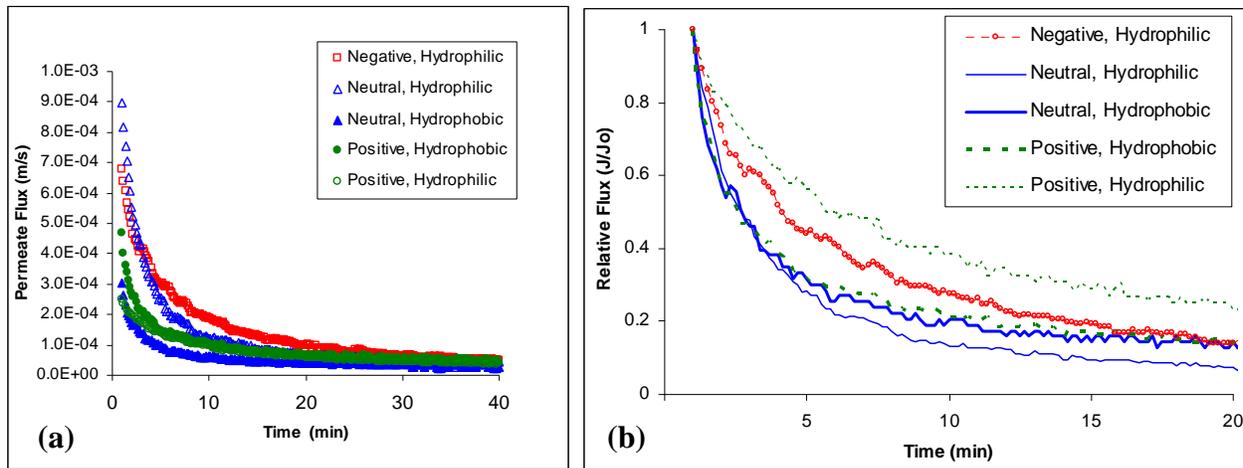


Figure 2 Absolute (a) and relative (b) permeate flux for filtration of June Toolik Lake raw water by membranes with different properties

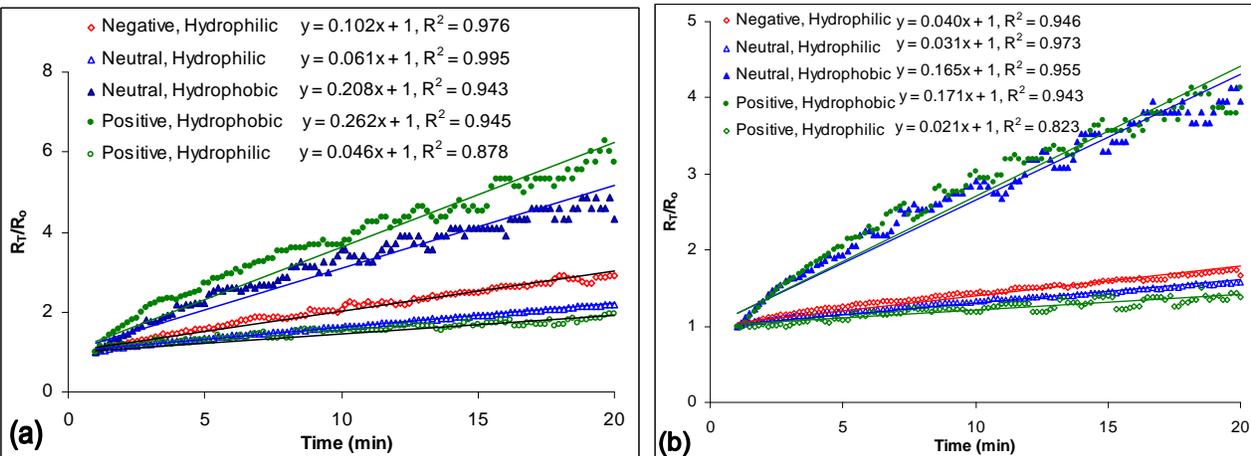


Figure 3 Relative resistance for June DF (a) and July DF (b) for different membrane properties

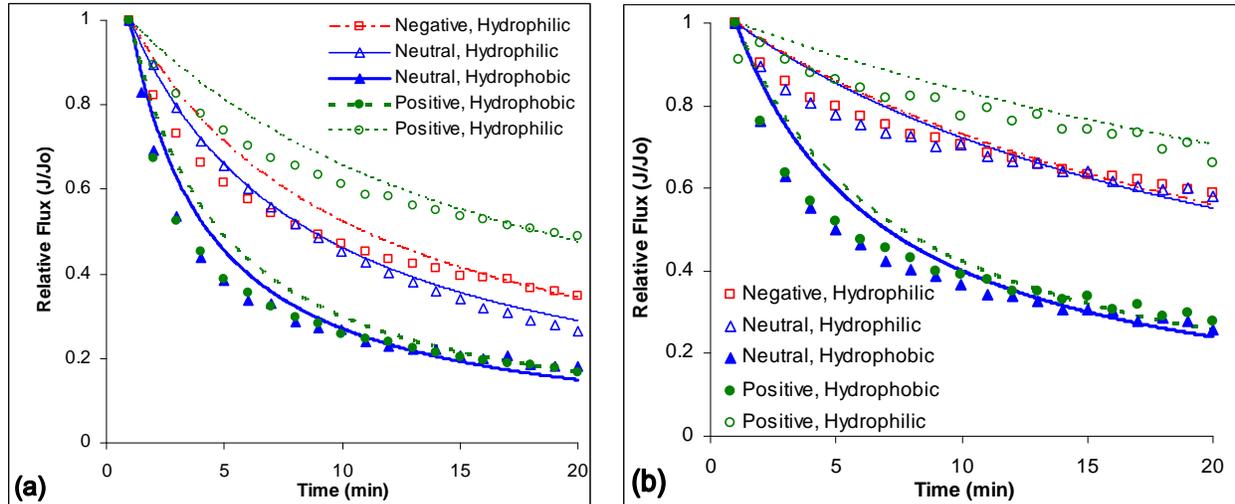


Figure 4 Relative flux of August raw water (a) and August DF (b) with model predictions for different membrane properties

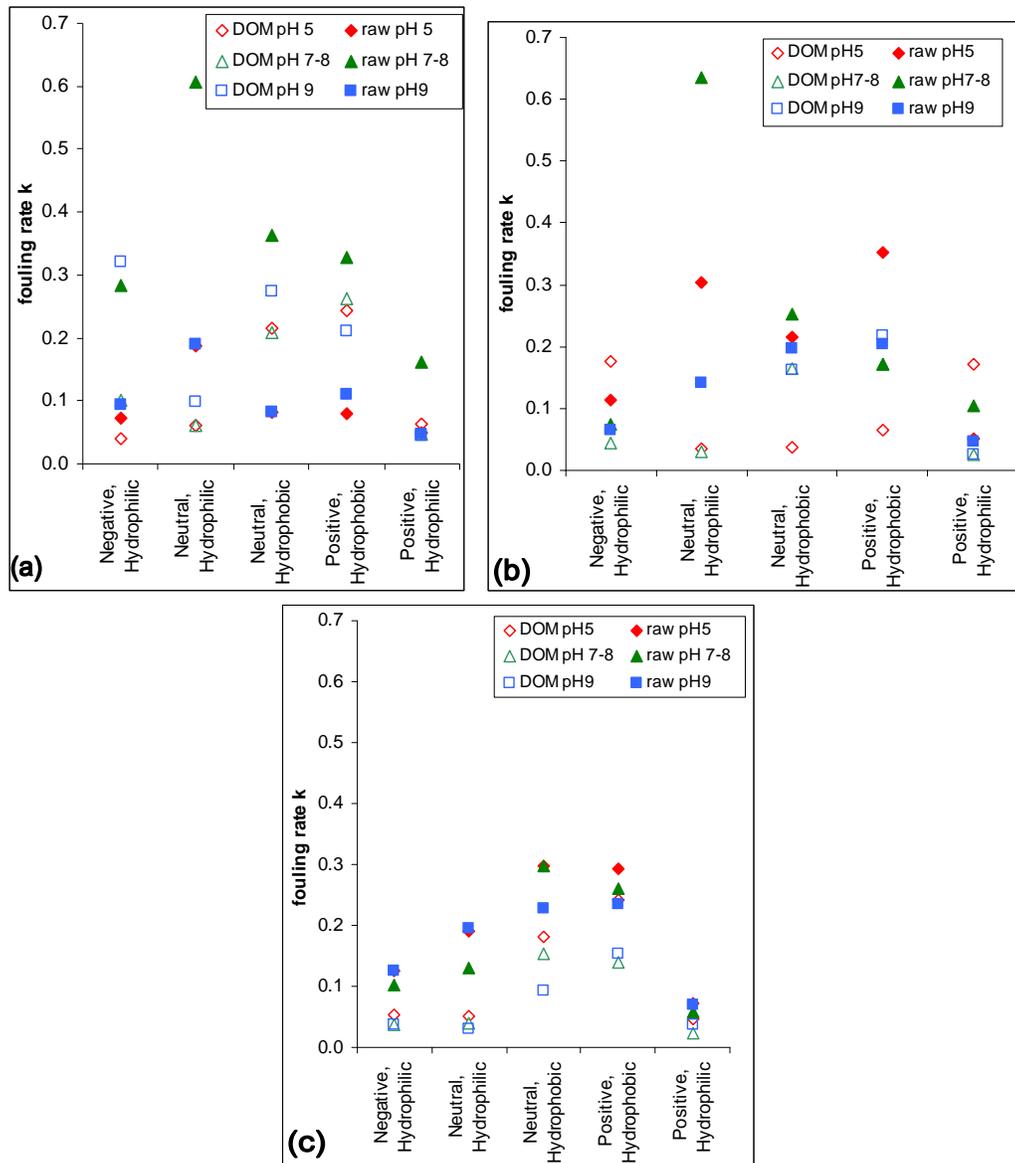


Figure 5 Fouling rates for June (a), July (b), and August (c) raw water and dissolved fraction at different pH values for different membrane properties

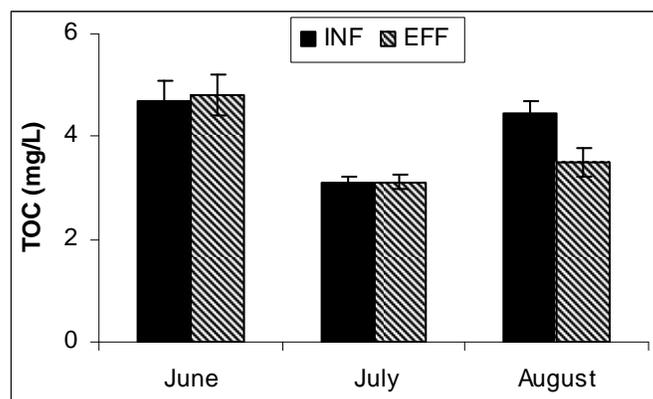


Figure 6 Average TOC during pilot plant operation for influent (INF), and Effluent (EFF)

Information Transfer Program Introduction

None.

USGS Summer Intern Program

None.

Notable Awards and Achievements

Publications from Prior Years