Cover

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Project Title:	Cumulative Effects of Arctic Oil Development - planning and designing for sustainability
PD/PI Name:	Donald A Walker, Principal Investigator Gary P Kofinas, Co-Principal Investigator Yuri L Shur, Co-Principal Investigator
Recipient Organization:	University of Alaska Fairbanks Campus
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Reporting Period:	09/15/2013 - 08/31/2014
Submitting Official (if other than PD\PI):	Donald A Walker Principal Investigator
Submission Date:	09/16/2014
Signature of Submitting Official (signature shall be submitted in accordance with agency specific instructions)	Donald A Walker

Accomplishments

*** What are the major goals of the project?**

Cumulative Effects of Arctic Oil Development -- Planning and Designing for Sustainability

Developing arctic oil & gas resources requires extensive networks of roads, pipelines and other forms of infrastructure. The cumulative environmental and social effects of expanding developments are difficult to assess and impossible to predict — especially in the face of rapid climate change and unpredictable politics, oil markets, and social and economic changes. Previous analyses of the cumulative effects (CE) of oil and gas development in northern Alaska have recommended comprehensive adaptive planning approaches to 1) minimize the spread of infrastructure across land that is used by indigenous people for subsistence, and 2) reduce the indirect effects of infrastructure that result in the thawing of ice-rich permafrost. A sustainable approach to CE requires collaboration between indigenous people, industry, and scientists from a broad spectrum of disciplines to address these infrastructure-related concerns. This proposal does that with detailed ground studies, local community input, industry involvement and an international perspective. A three-component initiative is proposed:

*** What was accomplished under these goals (you must provide information for at least one of the 4 categories below)?**

Major Activities:

1) A *case study of the cumulative effects of industrial infrastructure at Prudhoe Bay, Alaska* will focus on infrastructure-related effects associated with gravel mines, roads and other areas of gravel placement. The study will include ground-based studies, an examination of infrastructure and landscape change at multiple scales, and a human dimension component that includes evaluation of adaptive management planning for infrastructure in northern Alaska and CE studies associated with the Iñupiat village of Nuiqsut. The study will develop a process-based understanding of infrastructure-related permafrost/ landform/ vegetation succession in terrain undergoing thermokarst formation (the development of highly eroded landforms that result from the thawing of ice-rich permafrost). The study will help to answer the questions “What will these areas look like in 50-100 years?” and “Can adaptive management methods address the complex issues related to placement, usage and decommissioning of

infrastructure in Northern Alaska?" This is the largest research component, which has three parts, each with a set of specific research questions:

Part !: Hierarchical Change analysis:

1. *What has been the historical pattern of infrastructure and infrastructure-related thermokarst formation in the Prudhoe Bay region? How do the patterns vary with respect to distance from roads, different types of roads, and in different types of terrain? How can infrastructure-related and climate-change related thermokarst be differentiated?*
2. *Are the changes in thermokarst affecting local patterns of plant productivity? If so, are the changes widespread enough to be detected using time-series of global-scale remote sensing products such as Landsat, MODIS, and AVHRR?*

Part II: Roadside thermokarst study

1. *How do roads and other infrastructure affect the process of thermokarst? Are the complex interactions between thermokarst formation, hydrology, patterned-ground landforms, and vegetation succession modified in infrastructure-modified environments?*
2. *What will these landscapes look like in 50-100 years? In natural conditions, ice-wedge thermokarst often ceases under the negative feedback created by fast growing vegetation in warm shallow ponds above melting ice wedges (Fig. 7, blue arrows). Will ice-wedge thermokarst in infrastructure-modified environments also terminate or will the ice wedges and segregated ice in central parts of polygons continue to thaw forming large thaw lakes (Fig. 7, red arrows) and a continuously eroding landscape? Do the changes on the soil surface affecting local patterns of plant productivity promote thermokarst development? What are the implications of the changes for local biodiversity and carbon accumulation?*

Part III: Local peoples's perceptions of change, responses to change and the implications to livelihoods

1. *How do local residents at Nuiqsut perceive cumulative effects related to the infrastructure at Prudhoe Bay, including the nearby Alpine field?*
2. *How are infrastructure changes affecting ecosystems services and important subsistence-cash economies at the community level?*
3. *How do Iñupiat evaluate their capacities to respond to change, given the projections for future industrial development and climate change?*
4. *Do landscape changes associated with infrastructure expansion and landscape change associated with thermokarst have relevance to the local people? How do these factors affect their use of the land (summer and winter travel, access to subsistence resources)? Do concerns outweigh the economic benefits of development for local residents?*

2) An *Arctic Infrastructure Action Group (AI-AG)* will bring the CE issues to greater prominence in the international Arctic research community. The AI-AG will consist of local people who interact with development infrastructure, permafrost scientists, ecologists, hydrologists, engineers, social scientists and educators seeking to develop adaptive management strategies that address the unique issues related to networks of infrastructure in arctic permafrost environments. Three workshops will bring panarctic participants together, first in a scoping workshop and then to focus specifically on the two most rapidly expanding areas of Arctic infrastructure, the North Slope of Alaska and the Yamal Peninsula, Russia.

3) An *education/outreach component* will train students in arctic systems and introduce them to the issues of industrial development and adaptive management approaches during an expedition along the Elliott and Dalton highways in Alaska. The course will include a section at Prudhoe Bay to learn firsthand about the issues with oilfield infrastructure, its impacts and vegetation rehabilitation practices. Students will also visit the village of Nuiqsut to experience village life and discuss CE issues with the local residents.

Specific Objectives:

- See above.

Significant Results:

Component 1) A case study of the cumulative effects of industrial infrastructure at Prudhoe Bay, Alaska:

Part I: Hierarchical Change analysis:

1. A major landmark paper was written, submitted and publilshed: M. K. Raynolds, D. A. Walker, K. J. Ambrosius, J. Brown, K. R. Everett, M. Kanevskiy, G. P. Kofinas, V. E. Romanovsky, Y. Shur, and P. J. Webber, “Cumulative geoecological effects of 62 years of infrastructure and climate change in ice-rich permafrost landscapes, Prudhoe Bay Oilfield, Alaska.,” *Global Change Biology*, no. 20, pp. 1211–1224, Mar. 2014. (attached)

2. We are preparing a second publication as a University of Alaska Biological Papers series that will provide hard copy of the above with the 3 supplementary appendices and an Epilogue that describes the field component of the project: D. A. Walker, M.K. Raynolds, M. Kanevskiy, Y. Shur, M. Buchhorn, L. Wirth, “Landscape and permafrostst Change in the Prudhoe Bay Oilfield, Alaska.”

Part II: Roadside thermokarst study :

We completed a field season at Prudhoe Bay examining roadside effects of the Spine Road, the oldest most heavily traveled road in the oilfield. During 2-14 August 2014, we examined thermokarst features that were easily accessible within Deadhorse, the main service area located outside the oilfield. Our search focused in the Lake Colleen region, which contains Lake Colleen, the roads and infrastructure surrounding Lake Colleen, and a ice-wedge polygon study area described by Torre Jorgenson and colleagues. The main objectives of our 2014 field program were to document the extent and effects of road dust and road-related flooding to the topography, landforms, permafrost, soils, and vegetation. We were particularly interested in changes to the permafrost and ice-wedges. We chose an intensive study site along the Spine Road. The field research included:

- *Transects*: We established two 200-m transects at the Colleen Site A study area to quantify differences in micro-topography, soil temperatures, active layer, soils, vegetation, and permafrost and snow in relationship to distance from the road. Transect T1 is on the northeast side of the road and T2 is on the southwest side. Pin flags were placed at one-meter intervals to 100 m from the road and then at 5-m intervals to 200 m. Vertical 150-cm PVC posts were placed at 50, 100, and 200 m.
- *Permanent* plots: We also established permanent vegetation plots and photo points in polygon centers and troughs at 5, 10, 25, 50, 100, and 200 m from the road along both transects. Soil cores were extracted from a spot adjacent to the plot with a Sharpshooter shovel and briefly described. Soil samples were taken from the surface dust horizons and top organic horizons for laboratory analysis to determine soil moisture, bulk density, dry and moist soil color, and soil pH. The species at the top of the plant canopy was recorded at 100 gridpoints within each plot. Leaf Area Index (LAI) was measured using an AccuPAR LP-80 PAR/LAI Ceptometer.
- *Permafrost boreholes*:We drilled 57 shallow boreholes using a motorized SIPRE corer to study soil stratigraphy, different types of ground ice, and dimensions of ice wedges. The boreholes were drilled in polygon centers and troughs at 5, 10, 25, 50, 100, and 200 m from the road along both transects. The boreholes in ice-wedge polygon centers were drilled along both transects (12 boreholes totally) to a depth where gravel was encountered, preventing deeper drilling. Cores were examined to study cryostratigraphy of the upper permafrost and to determine the ground-ice volume in the surface deposits.
- We are currently preparing an Alaska Geobotany Center Data Report with all the data collected.

Part III: Local peoples's perceptions of change, responses to change and the implications to livelihoods

Component 2) An Arctic Infrastructure Action Group (AI-AG): We developed an initiative called Rapid Arctic Transitions relateed to Infrastructure and Climate change (RATIC) through an IASC proposal to host a session and forum at the Arctic Change 2014 in Ottawa, Dec 8-12, 2014. The topic of the forum is developing and sharing new ideas and methods to facilitate the best practices for assessing, responding to, and adaptively managing the cumulative effects of Arctic industrial infrastructure and climate change. Invited participants include members ot the Integrated Regional Impact Studies (IRIS) and the Arctic Development and Adaptation to Permafrost in Transition (ADAPT) in Canada, the North Slope Science Initiative (NSSI) in Alaska, and the Finnish-sponsored Environmental and Social Impacts of Industrialization in Northern Russia (ENSINOR) project. The results of the workshop will: (1) Summarize the status of international efforts to examine the cumulative effects of rapid transitions in Arctic social-ecological systems caused by infrastructure development and climate change; 2) develop of a set of shared international objectives focused on developing effective means to address the key issues related to rapid transitions in Arctic social-ecological systems related to infrastructure and climate change; and 3) develop a coordinated international science plan that will be presented at the Third International Conference on Arctic Research Planning (ICARP III) to be held in Yohama, Japan, 23-30 April 2015. Funds for inviting speakers, particularly Association of Polar Early Careers Scientists (APECS), local indigenous leaders, and industry representatives are provided by the International Arctic Science Committee (IASC), the NSF Arctic Science Engineering and Education for Sustainability (ArcSEES) program, and the NASA Land-Cover Land-Use Change (LCLUC) program.

Component 3) An education/outreach component:

We conducted a field excursion course through the University of Alaska Fairbanks. The course titled "BIOL 495/695, Arctic Alaska Environmental Change: Field Excursion to the North Slope, June 6-21, 2014" is a 4-credit course . We recruited 8 students from a wide geographic area, including France, The Netherlands, Virginia, Texas, and Korea. We offered a scholarship to the course to an Alaska Native student. The course spent three days at the University of Alaska Fairbanks, introducing students to the boreal forest ecosystem, permafrost, and social issues. We then traveled for ten days camping along the Dalton Highway, examining the transition from boreal forest to tundra. The course will be taught by three researchers, Dr. Donald Walker (focus - tundra ecology), Dr. Amy Breen (focus - arctic flora), and Dr. Martha Raynolds (focus - remote sensing and mapping of tundra). We have included guest speakers, including permafrost scientists Dr. Yuri Shur and Mikhail Kanevskiy, hydrologist Dr. Ronald Daanen and Dr. Margaret Darrow. We will be excursion in the Prudhoe Bay Oilfield to look at oil development and revegetation projects.talking to residents in Wiseman and National Park Service and Bureau of Land Management staff, to introduce students to aspects of living in the north and land management in northern Alaska. Dr. William Streever, BP Alaska Environmental Monitoring Program and author of several environmental books, lead an excursion in the Prudhoe Bay Oilfield to look at oil development and revegetation projects.

Key outcomes or Other achievements:

The major accomplilshment were:

1. Writing and publishing the the Global Change Biology paper.

2. A very successful summer field season.

3. An excellent summer field course.

4. Hiring a great post-doc.

*** What opportunities for training and professional development has the project provided?**

1. We hired a post-doc Marcel Bucchorn, who is leading the remote sensing effort and also performed the field topographic surveys for the field component at Prudhoe Bay.

2. The field course provided training for 8 students.

*** How have the results been disseminated to communities of interest? If so, please provide details.**
Nothing to report.

*** What do you plan to do during the next reporting period to accomplish the goals?**

1. Complete the remote sensing aspects of the project.
2. Another field season at Prudhoe Bay examining effects of infrastructure on the Prudhoe Bay ecosystems.
3. Conduct another field course.
4. Host the Arctic Change 2014 RATIC workshop and session.
5. develop a coordinated international science plan for RATIC that will be presented at the Third International Conference on Arctic Research Planning (ICARP III) to be held in Yohama, Japan, 23-30 April 2015.

Products

Books

Book Chapters

Inventions

Journals or Juried Conference Papers
Buchhorn, M., D. A. Walker, B. Heim, M. K. Raynolds, H. E. Epstein, and M. Schweider. (2013). Hyperspectral characterization of Low Arctic tundra vegetation along environmental gradients.. *Remote Sensing*. 5 3971-4005. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: doi:10.3390/rs5083971

Kanevskiy, M., Jorgenson, M.T., Shur, Y., O'Donnell, J.A., Harden, J.W.,Zhuang, Q., and Fortier, D. (2014). Cryostratigraphy and permafrost evolution in lacustrine lowlands of west-central Alaska.. *Permafrost and Periglacial Processes*. 25 14-34. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

M. K. Raynolds, D. A. Walker, K. J. Ambrosius, J. Brown, K. R. Everett, M. Kanevskiy, G. P. Kofinas, V. E. Romanovsky, Y. Shur, and P. J. Webber (2014). Cumulative geoecological effects of 62 years of infrastructure and climate change in ice-rich permafrost landscapes, Prudhoe Bay Oilfield, Alaska.. *Global Change Biology*. 20 1211-1224. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Licenses

Other Conference Presentations / Papers
Walker, D. A., U. Bhatt, Marcel Buchhorn, A. Breen, J. Comiso, H. Epstein, K. Ermokhina, B. Forbes, G. Frost, B. Heim, G. Kofinas, A. Kumotov, T. Kumpula, M. Leibman, G. Matyshak, J. Pinzon, M. Raynolds, V. Romanovsky, C. Tucker, L. Wirth, and Q. Yu. (2014). *A synthesis of remote-sensing studies, ground observations and modeling to understand the social-ecological consequences of climate change and resource development on the Yamal Peninsula, Russia, and relevance to the circumpolar Arctic.*. NASA Land-Cover and Land-Use Change Science Team Meeting, , April 23-25, 2014. Rockville, MD. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Jorgenson, M.T., Shur, Y., Kanevskiy, M. (2014). *JA Thermokarst Monitoring Network for Alaska*. EUCOP4 – 4th European Conference on Permafrost, 18-21 June 2014. Évora, Portugal. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Jorgenson, M.T., Shur, Y., and Walker, H.J. (2014). *Tale of two deltas:Permafrost dynamics on the Colville and Yukon-Kuskokwim deltas*. EUCOP4 – 4th European Conference on Permafrost, 18-21 June 2014. Évora, Portugal. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Kanevskiy M., Shur, Y. and Jorgenson, M.T. (2014). *Yedoma in Alaska: distribution, cryostratigraphy, vulnerability to thermokarst and thermal erosion.*. EUCOP4 – 4th European Conference on Permafrost, 18-21 June 2014. Évora, Portugal.

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Murton, J., Goslar, T. Edwards, M., Danilov, P.,Savvinov, G., Gubin, S., Ghaleb, B., Haile, J., Kanevskiy, M., Lozhkin, A., Lupachev, A., Murton, D., Shur, Y., Tikhonov, A., Vasil'chuk, A., Vasil'chuk, Y. (2014). *eolian deposition, chronology and palaeoenvironments of Late Pleistocene yedoma silts (Ice Complex) at Duvanny Yar, NE Siberia.*. EUCOP4 – 4th European Conference on Permafrost, 18-21 June 2014. Évora, Portugal. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Other Products

Other Publications

Patent Applications

Technologies or Techniques

Thesis/Dissertations

Websites or Other Internet Sites
Alaska Geobotany Center
http://www.geobotany.uaf.edu

This website will include the ArcSEES pages as soon as we hire a new web master.

Participants/Organizations

What individuals have worked on the project?

Name	Most Senior Project Role	Nearest Person Month Worked
Walker, Donald	PD/PI	3
Kofinas, Gary	Co PD/PI	1
Shur, Yuri	Co PD/PI	1
Buchhorn, Marcel	Postdoctoral (scholar, fellow or other postdoctoral position)	3
Raynolds, Martha	Postdoctoral (scholar, fellow or other postdoctoral position)	3
Wirth, Lisa	Other Professional	2

Full details of individuals who have worked on the project:

Donald A Walker
Email: ffdaw@uaf.edu
Most Senior Project Role: PD/PI
Nearest Person Month Worked: 3

Contribution to the Project: PI, Field research, workshop organizer,

Funding Support: IASC support for RATIC workshop and APECS support

International Collaboration: Yes, Finland
International Travel: No

Gary P Kofinas
Email: gary.kofinas@alaska.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 1

Contribution to the Project: Organizing the human dimension component of the project

Funding Support: UAF ESPSCoR

International Collaboration: No
International Travel: No

Yuri L Shur
Email: yshur@alaska.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 1

Contribution to the Project: Directing the permafrost component of the project

Funding Support: None

International Collaboration: No
International Travel: No

Marcel Buchhorn
Email: mbuchhorn@alaska.edu
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 3

Contribution to the Project: Field work, GIS/remote sensing lab manager, building new facility

Funding Support: This project plus NASA LCLUC Grant, and PreABoVE

International Collaboration: Yes, Germany
International Travel: No

Martha K Raynolds
Email: mkraynolds@alaska.edu
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 3

Contribution to the Project: Field research, mapping, writing publications

Funding Support: This project

International Collaboration: No
International Travel: No

Lisa Wirth
Email: lisa@gina.alaska.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 2

Contribution to the Project: Mapping, GIS, web site, field work

Funding Support: This project

International Collaboration: No
International Travel: No

What other organizations have been involved as partners?

Name	Type of Partner Organization	Location
Earth Cryosphere Institute	Other Organizations (foreign or domestic)	Tyumen, Russia
University of Eastern Finland	Academic Institution	Finland

Full details of organizations that have been involved as partners:

Earth Cryosphere Institute

Organization Type: Other Organizations (foreign or domestic)
Organization Location: Tyumen, Russia

Partner's Contribution to the Project:
Financial support
In-Kind Support
Collaborative Research
Personnel Exchanges

More Detail on Partner and Contribution: Helping with RATIC workshop and Russian case study

University of Eastern Finland

Organization Type: Academic Institution
Organization Location: Finland

Partner's Contribution to the Project:
Financial support
Collaborative Research
Personnel Exchanges

More Detail on Partner and Contribution: Helping with the RATIC workshop and Russian case study

What other collaborators or contacts have been involved?

YES

Impacts

What is the impact on the development of the principal discipline(s) of the project?
Nothing to report.

What is the impact on other disciplines?
Nothing to report.

What is the impact on the development of human resources?
Nothing to report.

What is the impact on physical resources that form infrastructure?
Nothing to report.

What is the impact on institutional resources that form infrastructure?
Nothing to report.

What is the impact on information resources that form infrastructure?
Nothing to report.

What is the impact on technology transfer?
Nothing to report.

What is the impact on society beyond science and technology?
Nothing to report.

Changes/Problems

Changes in approach and reason for change
Nothing to report.

Actual or Anticipated problems or delays and actions or plans to resolve them
Nothing to report.

Changes that have a significant impact on expenditures
Nothing to report.

Significant changes in use or care of human subjects
Nothing to report.

Significant changes in use or care of vertebrate animals
Nothing to report.

Significant changes in use or care of biohazards
Nothing to report.

Special Requirements

Responses to any special reporting requirements specified in the award terms and conditions, as well as any award specific reporting requirements.