

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

Project/Grant Period: 09/15/2013 - 08/31/2020

Reporting Period: 09/01/2018 - 08/31/2019

Submitting Official (if other than PD\PI): Donald A Walker
Principal Investigator

Submission Date: 08/30/2019

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

Goals of the Project:

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 — 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 project does that with detailed ground studies, local community input, industry involvement and an international perspective. A project has three major components:

1) Case study of the cumulative effects of industrial infrastructure at Prudhoe Bay, Alaska. This component focuses on infrastructure-related effects associated with gravel mines, roads and other areas of gravel placement. The study includes 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 is developing 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?”

2) Arctic Infrastructure Action Group: Rapid Arctic Transitions due to Infrastructure and Climate (RATIC). The goal of RATIC is to bring cumulative-effects-of-infrastructure issues to greater prominence within the international Arctic research community and encourage research on the joint effects of climate change and expanding infrastructure in the Arctic. The initiative was developed during the Climate Change 2014 Conference in Ottawa and the Third International Conference on Arctic Research Planning (ICARP III) in Yohama, Japan. RATIC consists of 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.

3) Education/outreach component. A new field course is training students in arctic system science and introducing them to the issues of industrial development and adaptive management approaches. The 21-day course includes a 16-day expedition along the Elliott and Dalton highways in Alaska. The course includes a visit to Minto, an Athabaskan village on the Tolovana River; Wiseman, an old mining community along the Dalton Highway; and the Prudhoe Bay Oilfield, where they learn firsthand about the issues with oilfield infrastructure, its impacts and the oil industry's ecological monitoring and vegetation rehabilitation practices.

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

Major Activities: 1. Continued monitoring of the road effects sites at Prudhoe Bay, AK.

2. RATIC workshop, papers, at Arctic Science Summit Week 2019, Arkhangelsk, Russia: <https://www.geobotany.uaf.edu/ratic/workshop2019.php>
3. Development of Infrastructure Action Group as part of the T-MOSAIC initiative: <https://www.t-mosaic.com/infrastructure.html>
4. Production of a white paper regarding the likely effects of 3-D seismic in the Arctic National Wildlife Refuge and submittal of a related paper to *Ecological Applications*. https://www.geobotany.uaf.edu/library/pubs/WalkerDA2019_seismic_exploration_whitepaper.pdf
5. Work on synthesis papers for the project.

Specific Objectives:

1. RATIC workshop, papers, at Arctic Science Summit Week 2019,

Significant Results:

- Arkhangelsk: <https://www.geobotany.uaf.edu/ratic/workshop2019.php>
2. Development of Infrastructure Action Group as part of the T-MOSAIC initiative: <https://www.t-mosaic.com/infrastructure.html>

Key outcomes or Other achievements:

3. Seismic white paper https://www.geobotany.uaf.edu/library/pubs/WalkerDA2019_seismic_exploration_whitepaper.pdf
4. 4 published journal publications, 1 thesis,

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

1. Three graduate students received partial support from this grant.

Tracie Curry: Partial support for Ph.D. Thesis, Learning from scale: identifying and addressing information blind spots in environmental governance

Shawnee Gowan: Partial support for M.S. thesis: *Plant succession in the arctic Brooks Range: floristic patterns from alpine to foothills, along a glacial chronosequence and elevation gradient.*

Allison Woodward: Partial support for Ph.D. research: *Social-ecological implications of climate change and thawing permafrost in two Iñupiaq communities of arctic Alaska.*

2. Summer course, "Arctic Alaska Vegetation, Field Excursion to the Brooks Range and Beyond" 14-30 June 2018.

*** How have the results been disseminated to communities of interest? If so, please provide details.**

1. Numerous publications reported here.
2. ArcSEES project web page: <https://www.geobotany.uaf.edu/arcsees/>.
3. To the international community through workshops, the new RATIC initiative, and the T-MOSAIC infrastructure Action Group.

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

A. Convert our data management system (Alaska Arctic Geoeological Atlas, AAGA (<http://arcticatlas.geobotany.org>) from the current content management system called gLynx to CKAN (Comprehensive Kerbal Archive Network). This is an emergency unanticipated cost that is needed because the Geographic Information Network of Alaska (UAF), which currently houses the AAGA, will no longer support gLynx. CKAN is widely a used open-source cataloging system, and the conversion to CKAN will make the data catalog and user interface more stable and more portable for long-term security of the data. This will require 2 months of support for two programmers, project management, and computer support (Cost: estimated \$70K).

B. Complete 4 publications that are currently in preparation:

1. Long-term effects of arctic oil-field roads & infrastructure on adjacent permafrost. (Walker)
2. Comparison of cumulative effects of development at Prudhoe Bay, Alaska and Bovanenkovo, Russia (Raynolds, Kumpula)
3. Impact of 2015 Sagavanirktok River flood to permafrost (Shur)
4. Synthesis of results from the 2018 and 2019 Rapid Arctic Transitions due to Infrastructure and Climate (RATIC) workshops at Arctic Science Summit Week (Peirce)

Products**Books****Book Chapters****Inventions****Journals or Juried Conference Papers**

Blair, B and G Kofinas (2018). A comparison of risk perceptions between levels of government in Arctic Alaska underscores the importance of scale in problem definition for adaptation decisions. *Frontiers in Ecology and the Environment – Frontiers in Ecology and the Environment –*

Special Issue "Social-Ecological Dynamics at the Extreme: Arctic Alaska". . Status = AWAITING_PUBLICATION; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Brinkman, T, Kofinas, G. et al. (2018). Community research fatigue: A search for solutions. *Frontiers in Ecology and the Environment – Special Issue "Social-Ecological Dynamics at the Extreme: Arctic Alaska"*. . Status = AWAITING_PUBLICATION; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Kanevskiy, M., Shur, Y., and Jorgenson, T. (2018). Ice-wedge thermokarst: Past, present, and future. In: *Deline P., Bodin X. and Ravanel L. (Eds.), 5th European Conference On Permafrost – Book of Abstracts, 23 June – 1 July 2018, Chamonix, France.* 647. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Kofinas, G and J. Schmidt (2018). The Art and Science of Assessing Resilience of Arctic Alaska. *Frontiers in Ecology and the Environment – Special Issue "Social-Ecological Dynamics at the Extreme: Arctic Alaska"*. . Status = AWAITING_PUBLICATION; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Raynolds, M. K., Walker, D. A., Balsler, A., Bay, C., Campbell, M., Cherosov, M. M., et al. (2019). A raster version of the Circumpolar Arctic Vegetation Map (CAVM). *Remote Sensing of the Environment.* 232 111297. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; OTHER: <https://authors.elsevier.com/sd/article/S0034425719303165>

Schmidt, J and G Kofinas (). Local knowledge and western science in a rapidly changing socio-ecological system. *Frontiers in Ecology and the Environment – Special Issue "Social-Ecological Dynamics at the Extreme: Arctic Alaska"*. . Status = AWAITING_PUBLICATION; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Schmidt, J, G Kofinas, N. O'Neal, T. Brinkman (). Local Knowledge and Science: Observations of Landscape Change in the Nuiqsut Homelands. *Special Report published by the University of Alaska Fairbanks – A report of the Alaska EPSCoR Project.* 1-24. Status = AWAITING_PUBLICATION; Acknowledgment of Federal Support = Yes ; Peer Reviewed = No

Walker, D. A., Raynolds, M. K., Breen, A. L., Druckenmiller, L. A., Šibik, J., Epstein, H. E., et al. (2019). Circumpolar arctic vegetation classification, mapping, and transects: a framework for arctic change monitoring and analysis. *Walker, D. A., Schaepman-Strub, G., Plekhanova, E., & Pierce, J. (Eds.). (2019). Arctic Vegetation Archive and Arctic Vegetation Classification, proceedings and abstracts from two workshops, CAFF Proceedings Report.* 70. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = No ; OTHER: <https://caff.is/proceedings-series/492-arctic-vegetation-archive-and-arctic-vegetation-classification-proceedings-and-a>:

Walker, D. A., Raynolds, M. K., Jorgenson, J. C., Jorgenson, M. T., Kanevskiy, M., Liljedahl, A. K., & Sturm, M. (2019). Landscape impacts of arctic 3D seismic surveys with reference to the 1002 Area, Arctic National Wildlife Refuge, Alaska. *Ecological Applications.* . Status = SUBMITTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Walker, D.A., Epstein, H.E., Sibik, J., Bhatt, U., Romanovsky, V.E., Breen, A.L., et al. (2019). Vegetation on mesic loamy and sandy soils along a 1700-km maritime Eurasia Arctic Transect. *Applied Vegetation Science.* 22 150. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: doi:1111/avsc.12401

Licenses

Other Conference Presentations / Papers

Walker, D. A., Raynolds, M. K., Breen, A. L., Druckenmiller, L. A., Sibik, J., Epstein, H. E., & Bhatt, U. S. (2018). *Circumpolar arctic vegetation classification, mapping, and transects: a framework for arctic change analysis.* International Association for Vegetation Science 61st Annual Symposium. Bozeman, Montana. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Kumpula, T., Raynolds, M.K. & Walker, D.A. (2019). *Mapping of Cumulative Impacts of Oil and Gas Development in Arctic Alaska and the Yamal Peninsula.* Arctic Science Summit Week 2019. Arkhangelsk, Russia. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Walker, D.A., Peirce, J.L., Kumpula, T., Romanovsky, V., Schweitzer, P. & Vincent, W. (2019). *RATIC—T-MOSAIC connections and opportunities.* Oral presentation at Arctic Science Summit Week 2019. Arkhangelsk, Russia. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Walker, D.A., Epstein, H.E., Sibik, J., Bhatt, U., Romanovsky, V., Breen, A.L., Chasnikova, S., Daanen, R., Druckenmiller, L.A. & (...) Timling, I. (2019). *Vegetation along the 1700-km Yamal Peninsula Franz Josef Land Eurasia Arctic Transect.* Arctic Science Summit Week 2019. Arkhangelsk, Russia. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Other Products

Other Publications

Walker, D. A., Schaepman-Strub, G., Plekhanova, E., & Pierce, J. (Eds.). (2019). *Arctic Vegetation Archive and Arctic Vegetation Classification, proceedings and abstracts from two workshops.* Conservation of Arctic Flora and Fauna Proceedings Report, <https://caff.is/proceedings-series/492-arctic-vegetation-archive-and-arctic-vegetation-classification-proceedings-and-a>. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Walker, D. A., Jorgenson, M. T., Kanevskiy, M., Nolan, M., Reynolds, M. K., Sturm, M. (2019). *Likely impacts of proposed 3D-seismic surveys to the terrain, permafrost, hydrology, and vegetation in the 1002 Area, Arctic National Wildlife Refuge, Alaska*. Alaska Geobotany Center Report #AGC 19-01. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Patent Applications

Technologies or Techniques

Thesis/Dissertations

Kasanke, S. A.. *Plant succession in the arctic Brooks Range: floristic patterns from alpine to foothills, along a glacial chronosequence and elevation gradient*. (2019). University of Alaska Fairbanks. Acknowledgement of Federal Support = Yes

Websites or Other Internet Sites

Participants/Organizations

What individuals have worked on the project?

Name	Most Senior Project Role	Nearest Person Month Worked
Walker, Donald	PD/PI	4
Kofinas, Gary	Co PD/PI	1
Shur, Yuri	Co PD/PI	1
Buchhorn, Marcel	Postdoctoral (scholar, fellow or other postdoctoral position)	0
Reynolds, Martha	Postdoctoral (scholar, fellow or other postdoctoral position)	3
Matyshak, George	Other Professional	0
Peirce, Jana	Other Professional	2
Wirth, Lisa	Other Professional	0
Curry, Tracie	Graduate Student (research assistant)	0

Full details of individuals who have worked on the project:

Donald A Walker

Email: dawalker@alaska.edu

Most Senior Project Role: PD/PI

Nearest Person Month Worked: 4

Contribution to the Project: 1. Published 2 major papers, 2. Wrote a major white paper regarding the effects of 3-D seismic in the ANWR. 3. Wrote two workshop proceedings reports. 4. Organized the Infratstructure Action Group of T-MOSAIC. 5. Organized the AVA/AVC and RATIC workshops at Arctic Science Summit Week 6. Submitted a major paper to *Frontiers of Ecology and Environment* (rejected and will submit to another journal)

Funding Support: NSF ArcSEES award 1263854 NASA LCLUC grant NNX14AD90G 2 IASC workshop awards Institute of Arctic Biology, UAF

International Collaboration: No

International Travel: Yes, Russian Federation - 0 years, 0 months, 7 days

Gary P Kofinas

Email: gary.kofinas@alaska.edu

Most Senior Project Role: Co PD/PI

Nearest Person Month Worked: 1

Contribution to the Project: Managed the human dimensions portion of the project

Funding Support: This award

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: Managed the permafrost portion of the award

Funding Support: This award

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: 0

Contribution to the Project: Post-doc, 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

George Matyshak

Email: matyshak@gmail.com

Most Senior Project Role: Other Professional

Nearest Person Month Worked: 0

Contribution to the Project: Soils descriptions and analysis at field sites

Funding Support: travel support from this grant

International Collaboration: Yes, Russian Federation

International Travel: No

Jana L. Peirce

Email: jlpeirce@alaska.edu

Most Senior Project Role: Other Professional

Nearest Person Month Worked: 2

Contribution to the Project: Writing and editing reports, field work, data analysis

Funding Support: this grant

International Collaboration: No

International Travel: Yes, Russian Federation - 0 years, 0 months, 7 days

Lisa Wirth

Email: lisa@gina.alaska.edu

Most Senior Project Role: Other Professional

Nearest Person Month Worked: 0

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

Funding Support: This project, NASA PreABoVE project

International Collaboration: No

International Travel: No

Tracie Curry

Email: tncurry3@alaska.edu

Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 0

Contribution to the Project: Ph.D. thesis

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?

Allison Woodward, Ph.D. Student

Impacts

What is the impact on the development of the principal discipline(s) of the project?

1. The project has had a major impact on the emphasis that is being placed on cumulative effects of infrastructure and climate change at the national and international level. This is demonstrated by our Rapid Arctic Transitions due to Infrastructure and Climate ([RATIC](#)) initiative, which

is the T-MOSAIc Arctic Infrastructure Action Group during the 2019–2021 MOSAIc Arctic Drift Expedition. The action group will collaborate with T-MOSAIc to identify and promote activities and synergies that lead toward sustainable Arctic infrastructure, including those that:

- Monitor the consequences to natural terrestrial systems of unusual climate sea-ice, atmosphere, and ocean changes during the MOSAIc ice-drift expedition.
- Observe and monitor consequences to the built environment, including, roads, runways, railways, pipelines, and indigenous, village, and urban infrastructure.
- Examine the consequences of climate and infrastructure changes to Arctic social systems.
- Begin developing an Arctic infrastructure observing network, with a focus on coastal and near-coastal social-ecological systems in ice-rich-permafrost environments.

2. Members of the project have made major contributions to several other related projects and have been extraordinarily productive in writing publications. The following list of publications is a partial list of the publications by members of the ArcSEES team during the last year that are directly related to the goals of our ArcSEES project.

- Coulombe, S., Fortier, D., Lacelle, D., Kanevskiy, M., and Shur, Y. (2018). Origin, burial and preservation of late Pleistocene-age glacier ice in Arctic permafrost (Bylot Island, NU, Canada). *The Cryosphere*. 10((8), 1312. <http://doi.org/10.3390/rs10081312>
- Farquharson, L. M., Romanovsky, V. E., Cable, W. L., Walker, D. A., Kokelj, S., & Nicolsky, D. (2018). Climate change drives widespread and rapid thermokarst development in very cold permafrost in the Canadian High Arctic. *Geophysical Research Letters*. 46 2019GL082187–6689. <https://doi.org/10.1029/2019GL082187>
- Frost, G. V., Christopherson, T., Jorgenson, M. T., Liljedahl, A. K., Macander, M. J., Walker, D. A., & Wells, A. F. (2018). Regional patterns and asynchronous onset of ice-wedge degradation since the mid-20th century in arctic Alaska.. *Remote Sensing*. 21 1312. <http://doi.org/10.3390/rs10081312>
- Jones, B.M., Farquharson, L.M., Baughman, C.A., Buzard, R.M., Arp, C.D., Grosse, G., Bull, D.L., Günther, F., Nitze, F., Urban, F., Kasper, J.L., Frederick, J.M., Thomas, M., Jones, C., Mota, A., Dallimore, S., Tweedie, C., Maio, C., Mann, D.H., Richmond, B., Gibbs, A., Xiao, M., Sahs, T., Iwahana, G., Kanevskiy, M., and Romanovsky, V.E. (2018). A decade of remotely sensed observations highlight complex processes linked to coastal permafrost bluff erosion in the Arctic. *Environmental Research Letters*. 13 115001. <https://doi.org/10.1088/1748-9326/aae471>
- Kanevskiy, M., Connor, B., Schnabel, W., Bjella, K., Trochim, E. (2019). Determination of Communities At-Risk from Thawing Permafrost. *Proceedings of the 18th International Conference on Cold Regions Engineering and the 8th Canadian Permafrost Conference, Quebec City, Quebec, Canada, August 18–22, 2019*.
- Koch, J.C., Jorgenson, M.T., Wickland, K.P., Kanevskiy, M., and Striegl, R. (2018). Ice wedge degradation and stabilization impact water budgets and nutrient cycling in Arctic trough ponds. *Journal of Geophysical Research: Biogeosciences*. 123 2604. <https://doi.org/10.1029/2018JG004528>
- Loranty, M. M., Abbott, B. W., Blok, D., Douglas, T. A., Epstein, H. E., Forbes, B. C., ...Walker, D. A. (2018). Reviews and syntheses: Changing ecosystem influences on soil thermal regimes in northern high-latitude permafrost regions. *Biogeosciences*. 15 5287. <http://doi.org/10.5194/bg-15-5287-2018>
- Stephani, E., Jones, B.M., Kanevskiy, M. (2019). Assessing riverbank erosion and land cover changes in permafrost regions based on a terrain analysis approach, an example from the Colville River Delta, northern Alaska. *Proceedings of the 18th International Conference on Cold Regions Engineering and the 8th Canadian Permafrost Conference, Quebec City, Quebec, Canada*. 678.
- Zhang, W., Witharana, C., Liljedahl, A.K., and Kanevskiy, M. (2018). Deep convolutional neural networks for automated characterization of Arctic ice-wedge polygons in very high spatial resolution aerial imagery. *Remote Sensing*. 10 1487. doi:10.3390/rs10091487.
- Kanevskiy M., Connor, B., Schnabel, B., Shur, Y., Bjella, K., Trochim, E., Dean, K., Ellison, A. (2019). *Evaluation for Permafrost-Related Threats: Methods of Risk Estimation and Sources of Information*. Institute of Northern Engineering Report #INE 2019.10.
- Walker, D. A., Jorgenson, M. T., Kanevskiy, M., Nolan, M., Reynolds, M. K., Sturm, M. (2019). *Likely impacts of proposed 3D-seismic surveys to the terrain, permafrost, hydrology, and vegetation in the 1002 Area, Arctic National Wildlife Refuge, Alaska*. Alaska Geobotany Center Report #AGC 19-01.

What is the impact on other disciplines?

There is a considerable new cross disciplinary collaboration between the permafrost, climate, hydrology, vegetation, and human dimensions of change within RATIC and T-MOSAIc.

RATIC was born with the goal of promoting sustainable Arctic infrastructure as a key research theme requiring a collaborative multidisciplinary approach involving scientists, local communities, governments and industry.

RATIC is a strong collaboration between natural scientists and social scientists who are working with villages and local governments on issues such as adaptive management of infrastructure development. The recent RATIC–T-MOSAIc workshop in Arkhangelsk was attended by 51 international participants and about half of those were social scientists, permafrost scientists, and engineers working on issues related to arctic infrastructure.

What is the impact on the development of human resources?

The project has triggered renewed interest in the topic of cumulative impacts of development among young investigators, particularly at the international level, through providing funding for young investigators to attend the two IASC workshops at Arctic Science Summit Week 2019.

What is the impact on physical resources that form infrastructure?

The project is helping in process of finding a stable web based portal to support data management of Arctic vegetation data. The current content management system called gLynx is being converted to CKAN (Comprehensive Kerbal Archive Network). This conversion to CKAN will make the data catalog and user interface more stable and more portable for long-term security of the data.

What is the impact on institutional resources that form infrastructure?

Nothing to report.

What is the impact on information resources that form infrastructure?

The method we are using for vegetation data management is a prototype for other Arctic vegetation data management systems in Canada, Greenland, and Russia through the paper:

Walker, D. A., Daniëls, F. J. A., Alsos, I., Bhatt, U. S., Breen, A. L., Buchhorn, M., et al. (2016). Circumpolar arctic vegetation: a hierarchic review and roadmap toward an internationally consistent approach to survey, archive and classify tundra plot data. *Environmental Research Letters*, 11(5), 055005. <http://doi.org/10.1088/1748-9326/11/5/055005>

What is the impact on technology transfer?

Nothing to report.

What is the impact on society beyond science and technology?

The project is having a major impact on approaches to integrate the human dimension in the analysis the cumulative effects of Arctic infrastructure and climate change. For example, the special issue of *Frontiers of Ecology and the Environment* "Social Ecological Dynamics at the Extreme: Arctic Alaska".

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

1. The Geographic Information Network of Alaska (GINA) is handling the development of our portal for archiving our plot and map information. GINA is in the process of converting our data management system from the current content management system called gLynx to CKAN (Comprehensive Kerbal Archive Network). This is an emergency unanticipated cost because GINA will no longer be able to support the gLynx system because of the high cost. CKAN is a widely used open-source cataloging system, and the conversion to CKAN will make the data catalog and user interface more stable and more portable for long-term security of the data. This will require 2 months of support for two programmers, project management, and computer support. (Cost: estimated \$70K). We should be able to cover these costs with remaining funds in the award which are mainly unspent participant support costs. We have submitted a no cost extension to do this and also complete several publications that are in preparation. We have submitted a no cost extension to do this and also complete several publication that are in preparation.

2. The Human Dimensions component of the ArcSEES project was delayed in completing its research because our PhD student, Tracie Curry, left the project. In the past year we have been making up lost time, completing interviews of North Slope resource managers and industry personnel, analyzing the data, and writing up a paper for publication. At the time of this annual report we have completed 50 interviews, with some being group interviews of agency or industry staff. The interviews focused on how cumulative effects are being assessed by agencies, the extent to which the principles of adaptive management are being employed by organizations, and the adequacy of available information to complete these activities. Two UAF PhD students are participating in this final phase of the study – Barbara Johnson and Allison Woodward. Interviews will be completed at the end of August and the coding of interviews will be completed by the end of September. Initial findings show how conceptual ambiguity for the term cumulative effects is a key barrier in its assessment, and how all North Slope management organizations are using a diversity of methods to learn from past experiences and facilitate innovation in management. Johnson and Woodward will work with Kofinas to publish one or more papers from the findings. Our target journal is *Ecology and Society*.

Changes that have a significant impact on expenditures

See 1. above

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.

Nothing to report.