Alaska's Climate Change Strategy: Addressing Impacts in Alaska




Final Report
Submitted by the Adaptation Advisory Group to the Alaska Climate Change Sub-Cabinet

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ACKNOWLEDGEMENTS

The Alaska Adaptation Advisory Group (AAG) thanks former Governor Sarah Palin for the opportunity to meet and address the issues confronting Alaska due to climate change.

Special thanks for their dedication, thoughtful direction, and good humor are due to Commissioner Larry Hartig of the Alaska Department of Environmental Conservation (ADEC), Chairman of the Governor's Climate Change Sub-Cabinet, and to Jackie Poston, ADEC Project Coordinator, who coordinated and supervised the activities associated with the AAG and this report.

The AAG acknowledges the collective and individual contributions of the many who worked tirelessly to provide the careful analysis and research underlying the recommendations, and to draft the report itself. Special appreciation is extended to the Technical Work Group (TWG) members (listed in Appendix D) and other participants in the TWG process. For their outstanding organization and dedication, the AAG also thanks Fran Sussman of ICF International, and the ICF team of experts and facilitators:

Melinda Harris, ICF International
Randy Freed, ICF International
Nancy Tosta, Ross and Associates
Barbara Sheinberg, Sheinberg Associates
Jan Caulfield, Jan Caulfield Associates
Kristie L. Ebi, ESS, LLC
Jason Vogel, Stratus Consulting

This work would not have been possible without the valuable coordination and technical assistance provided by Kolena Momberger, Susan McNeil, and Claire Fishwick of ADEC, and support for the Alaska website provided by Joan Hardesty of ADEC and Caroline Cochran and Jeremy Vanderlan of ICF International. Thanks are also due to Paul Stewart of ICF International and to Rebecca Guterman for assistance with production of the final report.

For assistance in defining the climate impacts of concern early in the process, the AAG would like to thank Sasha Mackler and David Rosner (National Commission on Energy Policy of the Bipartisan Policy Center), Deborah Williams (Alaska Conservation Solutions), and Joel Smith and Jason Vogel (Stratus Consulting). The AAG also wishes to thank Ken Colburn, Gloria Flora, and the Center for Climate Strategies (CCS) and its team of experts for providing a template for the start-up of the stakeholder-driven process.

For graciously allowing the use of their facilities to host meetings on a gratis basis, the AAG thanks the University of Alaska Fairbanks (UAF) and John Rubini, of JL Properties. For support of the February meetings, the AAG extends thanks to Molly McCammon, of the Alaska Ocean Observing System (AOOS).

The AAG is grateful to Brian Rogers, Chancellor of UAF, for facilitating all of the AAG meetings with determination, professionalism, and a steady hand. We would like to thank UA President Mark Hamilton for recognition of the importance of this project and for supporting the involvement of key faculty from both the Anchorage and Fairbanks campuses (as specified on the AAG list and in the TWG Appendix D). Special thanks also go to Scott Rupp, Sarah Trainor, and Nancy Fresco, with the Scenarios Network for Alaska Planning (SNAP) Team, to Sanjay Pyare of University of Alaska Southeast, and to Dan White of the Alaska Center for Climate Action and Policy (ACCAP), for their scientific contributions to the report.

Finally, and by no means least, this project was made possible in large part thanks to generous support from Joel D. Scheraga, National Program Director, and Michael Loughran, Environmental Scientist, both of the U.S. Global Change Research Program in the Office of Research and Development and the Mercury

Research Program.. The AAG acknowledges them for their outstanding contributions to climate science and commitments to help stakeholders develop adaptation measures at the local level.

Alaska's Climate Change Strategy: Addressing Impacts in Alaska
Executive Summary

INTRODUCTION

In Alaska, climate change has begun to touch almost every aspect of the natural world and the human systems that have evolved around, and rely on, a set of stable and predictable climatic conditions and seasons. It is a world where a warming environment has already begun to render ground and building foundations unstable, disrupt transportation routes, and trigger phenomena placing coastal communities in imminent danger from flooding and erosion. Impacts have resulted in myriad consequences to residents of the state, to subsistence livelihoods, to the wildlife and vegetation in Alaska's terrestrial and marine environments, and to the many industries that support the Alaskan economy.

While these changes are of critical import to Alaskans, they have also garnered attention of leaders in the United States and around the world. The primary driving force has been the accelerated retreat of Arctic sea ice, which has been a catalyst for multi-disciplinary planning and has underscored the need for increased domestic and international cooperation. A navigable Arctic Ocean presents opportunities for shipping and commerce in the Northwest Passage and has elevated interest in developing fisheries and mineral resources. Consequently, this creates a need for additional and improved weather and navigational tools, research to better understand and manage our strategic assets, and increased efforts to provide national, environmental, and economic security. Widespread interest in the Arctic has also been elevated by the important role that the Earth's polar region plays in influencing climate and oceans on a global scale. What happens in Alaska has far-reaching and long-lasting implications.

Box 1. Sectors Addressed by the AAG Report

Alaska's economy and the health and well-being of its residents will be affected by climate change. Key impacts being addressed include:

Public Infrastructure

Impacts of climate change on public, private, or cooperatively owned infrastructure for the public good including buildings, transportation, shoreline protection, water and sanitation systems, and defense facilities.

Health and Culture

Climatic changes and associated changes in natural systems are increasing the potential for health impacts from vector-, water-, and food-borne diseases and are beginning to cause stress on subsistence communities. Erosion, changes in permafrost, and extreme events are already impacting coastal communities, sanitation infrastructure, and archaeological sites and gravesites. Weather related injuries and detrimental effects on mental health have also been associated with rapidly changing conditions.

Natural Systems

Impacts of changing climate on marine, terrestrial, and freshwater ecosystems will have implications for Alaska's economy and subsistence communities. Changes in fisheries and forest resources, modes of travel, and the diversity and location of different plant and animal species have both beneficial and adverse impacts on natural systems and the services they provide.

Other Economic Activities

Changing climate may affect all sectors of Alaska's economy dependent on weather conditions and/or the natural environment or reliant on engineered infrastructure that is threatened by changes. This sector addresses their adaptation needs and also explores possibilities for new and/or expanding potential economic development created by a warming environment.

The adaptation component of Alaska's climate change strategy contains adaptation options designed to reduce the vulnerability of Alaska's natural and human systems to climatic changes and examine the potential growth of economic opportunities that might arise.

The *Arctic Climate Impact Assessment*, a comprehensive assessment conducted by hundreds of scientists and indigenous peoples, confirms that the Arctic is now experiencing some of the most rapid and severe climate changes on earth and is extremely vulnerable to both observed and projected climate change and its effects. To address the impacts of climate change on Alaska, Governor Sarah Palin signed Administrative

Order 238 on September 14, 2007, which established and charged the Alaska Climate Change Sub-Cabinet to advise the Office of the Governor on the preparation and implementation of a comprehensive Alaska Climate Change Strategy (AO 238). This document represents the recommendations of the Adaptation Advisory Group (AAG), which was charged with evaluating and developing options to adapt to climate change. The report also provides additional background on projected climate and impacts for Alaska.

The types of recommendations contained in this report vary. The options range from new systems approaches and institutional structures to adoption of new or revised policies, initiatives, and other actions. The Sub-Cabinet will consider these, as well as recommendations from the Immediate Action Work Group, the Mitigation Advisory Group, and the Research Needs Work Group in the context of other complementary efforts. A comprehensive Climate Change Strategy for Alaska will then be drafted for consideration by the Governor. While no one report or event can set a definitive course of action in the dynamic and uncertain set of circumstances created by a changing climate, the work of the Adaptation Advisory Group establishes a foundation from which to make progress towards improving our individual and societal ability to adapt.

IMPACTS ON HUMAN AND NATURAL SYSTEMS IN ALASKA

Over the past three decades, Alaska has experienced a sharp reduction in snow-cover extent and duration, shorter river- and lake-ice seasons, melting of mountain glaciers, sea-ice retreat and thinning, permafrost retreat, and increased depth of summer thaw. These changes are in turn affecting human and natural systems. The AAG, with the support of four Technical Working Groups, has developed options to adapt to these changes, i.e., to reduce the adverse impacts or take advantage of the opportunities presented by climate change (see Box 1).

Permafrost Thawing and Sea Ice Melting

Permafrost underlies most of Alaska. Air temperature, snow cover, and vegetation affect the temperature of the frozen ground and the depth of seasonal thawing. Recent decades of warmer temperatures have produced extensive thawing, which has resulted in increased coastal erosion, landslides, and sinking of the ground surface, as well as consequent disruption and damage to forests, buildings, infrastructure, and coastal communities. In addition, many industrial activities depend on frozen ground surfaces, and many northern communities rely on ice roads for transport of groceries and other materials. Continued warming will further impair transport by shortening the seasonal use of ice roads. Thawing is projected to accelerate under future warming, with as much as the top 10 to 30 feet of discontinuous permafrost thawing by 2100.

Sea ice off the Alaskan Coast is retreating and thinning, with widespread effects on marine ecosystems, coastal climate, human settlements, and subsistence activities. Recent studies estimate arctic-wide reductions in annual average sea-ice extent of about 5-10% and a reduction in average thickness of about 10-15% over the past few decades. Retreat of sea ice allows larger storm surges to develop, increasing the risk of inundation and increasing erosion on coasts already made vulnerable by permafrost thawing. Loss of sea ice also causes large scale changes in marine ecosystems, and threatens populations of marine mammals and polar bears that depend on ice. At the same time, the continued reduction of sea ice is very likely to increase the navigation season, and within several decades a seasonal opening of the Northern Sea Route is likely to make trans-arctic shipping feasible during summer months, although increasing ice movement will initially make shipping more difficult in some channels of the Northwest Passage.

Threats to Coastal Communities, Habitats, and Infrastructure

Alaska has more coastline than the other 49 states combined. Increases in the frequency and intensity of storm surges have triggered increased coastal erosion that is threatening a number of coastal villages. A recent report from the Government Accountability Office (GAO) indicated that 31 villages face imminent threats. Storm surges have also reduced the protection that barrier islands and spits provide to coastal habitats. Both coastal and inland infrastructure face threats due to the climate change. Thawing permafrost threatens water and sanitation infrastructure, and roads, buildings, pipelines, power lines and other infrastructure are threatened by coastal erosion and degrading permafrost.

Forest and Vegetation Changes

The Arctic region, particularly Alaska, is already experiencing major ecological impacts as a consequence of warming. Rising temperatures have caused northward expansion of boreal forest in some areas, significant increases in fire frequency and intensity, and unprecedented insect outbreaks. Current projections suggest that, due to increases in burn area per decade, the tundra-dominated landscape on Seward Peninsula will eventually be replaced by deciduous forest. In other areas, forested areas are likely to convert to bogs as permafrost thaws. Growing-degree days have increased by 20%, with benefits for agriculture and forest productivity on some sites, and reduced growth on others.

Sensitivity of Marine Ecosystems and Fisheries

The Gulf of Alaska and Bering Sea support marine ecosystems of great diversity and productivity as well as the nation's largest commercial fishery. Perhaps one of the most daunting threats lies in increasing acidification of the cold Alaskan waters. This would affect all organisms that possess calcifying shells, and these organisms play an integral role in the food web. Recent climate-related impacts observed in the Bering Sea include significant reductions in seabird and marine mammal populations, unusual algal blooms, abnormally high water temperatures, and low harvests of salmon on their return to spawning areas. Future projections for the Bering Sea suggest productivity increases at the base of the food chain, poleward shifts of some cold-water species, and negative effects on ice-dwelling species. Warmer temperatures will also affect commercial fisheries by inducing large northward shifts of fish and shellfish species. This would result in decreased harvesting of cold-water species such as salmon and pollock, and increased harvesting of other species.

Changes In the Diversity, Ranges, and Distributions of Species

The Arctic sub-region that includes Alaska, Chukotka, and the Western Canadian Arctic is home to over 70 percent of the rare plant species that occur only in the Arctic and a number of plant and animal species already classified as "threatened." Species concentrated in small areas, such as Wrangell Island, are particularly vulnerable to the direct effects of climate change combined with competition from migrating non-native species.

Increased Stress on Subsistence Livelihoods and Lifestyles

Subsistence makes an important contribution to livelihood in many isolated rural communities, especially but not exclusively for native peoples. Livelihoods that sustain indigenous communities include hunting, trapping, gathering, and fishing. These activities not only make significant contributions to the diet and health of many indigenous populations, but also play large and important social and cultural roles. Reduced or displaced populations of marine mammals, seabirds, and other wildlife, together with continuing thinning of sea-ice, have affected the safety and the dietary and economic well-being of subsistence communities.

ALASKA'S APPROACH TO ADAPTATION: RECOMMENDED OPTIONS

Climate change presents both potential impacts and opportunities for Alaskans and the Alaska economy. Developing a viable set of policies and actions to adapt to climate change requires recognizing the decentralized nature of government decision making, and the role of all levels of government. Successful adaptation will require engaging not only governments, but also private business, communities and community leaders, and individual households. Developing information on climate and other information needed for adaptation and making this information accessible is key to enabling these public and private entities to take action. Finally, an adaptation strategy must recognize both the need for immediate action to address observed effects of climate change (in some cases) as well as the importance of developing a foundation of data, policies, and knowledge about adaptation strategies that will enable successful adaptation over the long term.

The options recommended by the AAG are summarized below. These are actions that the state of Alaska, sometimes in partnership or cooperation with other agencies or organizations, can take to adapt to climate change. The options include actions such as increased coordination within and outside the state, data collection or assessment, regulatory or programmatic changes, capacity building and education, capital improvements, and financial assistance. In some cases the options may require new institutions or new legislative authority, but in many cases they have been designed to build on existing programs and staff.

Public Infrastructure

These options address the observed and projected impacts of climate change on Alaska's infrastructure, and include priority adaptation actions that the State of Alaska should take to address the impacts and their associated vulnerabilities. Public infrastructure is defined to include essential facilities and utilities under public, cooperative, or private ownership that deliver goods and services to communities. Such infrastructure includes infrastructure related to road, air, water, and other transportation (ranging from highways to landing strips); public buildings; seawalls and river shoreline protection; power, water, communication, and other utilities and their supporting structures; and national defense infrastructure. The goal of these options is to develop a system that increases the likelihood that Alaska has sustainable infrastructure to support communities in an uncertain environment.

The options developed for public infrastructure are designed to address three critical problems. First, the vulnerability of, and risk to, public infrastructure is growing. In some locations, entire Alaskan villages are at immediate risk; in other locations, critical roads and public buildings are at risk. Second, adaptive capacity for existing infrastructure is low, so new construction provides an opportunity for adaptation. Most public infrastructure is hard and fixed (for example, roads and buildings) and cannot easily alter its alignment, elevations, or structural foundation to accommodate coastal erosion or increased flood risk. Third, increased communication and coordination is critical. Increased communication and coordination across agencies, communities, and scientific and applied researchers is needed to adapt Alaska's public infrastructure.

The AAG is recommending a systems approach to reduce the impacts of climate change on Alaska's public infrastructure by accomplishing actions under three policies/programs.

PI-1 Create a Coordinated and Accessible Statewide System for Key Data Collection, Analysis, and Monitoring

Baseline data on the condition of current infrastructure and on regional and local environmental conditions needs to be collected, so that decision makers can identify what the problems are and where they occur, and what approaches are and are not working. Decision making also requires that projections of climate and other

information be based on the best science and collected empirical data. The Environmental Atlas of Alaska should be updated. The resulting information needs to be available to all interested parties.

PI-2 Promote Improvements that Use the Current Best Practice

Managing the risks and/or reducing the uncertainties associated with climate change will take time. Promoting sustainability, reducing operating costs, and protecting/extending the service life of existing infrastructure is always worthwhile. Simultaneously with PI-1, improvements to existing infrastructure that are worth doing regardless of climate change effects should be undertaken.

PI-3 Build to Last; Build Resiliency into Alaska's Public Infrastructure

As PI-1 and PI-2 are enacted and our knowledge base expands, new and upgraded infrastructure needs to be sited, planned, designed, and built to be resilient and sustainable in an uncertain environment. Systematic feedback with a performance review and analysis needs to be integrated into the public infrastructure funding, development, construction, and operations, so that planners and builders use "what works" and codes and standards are assessed and improved as needed to achieve the best results.

Natural Systems

The Natural Systems sector addresses the observed and projected impacts of climate change on Alaska's ecosystems and the services they provide. The AAG recommends priority adaptation actions that the state of Alaska should take to address the impacts and vulnerabilities associated with these impacts. Key impacts for Alaska include:

- those on marine ecosystems in the seas around Alaska and the communities and industries reliant on marine-based fisheries;
- changes in terrestrial ecosystems and in species' diversity, ranges, distribution, and abundance, with consequences for forestry and subsistence harvest of fish and wildlife; and
- changes to freshwater ecosystems, with consequences for freshwater appropriates and for freshwater species and the people who access and harvest the fish and wildlife.

The goal of the options below is to sustain natural ecosystem services in Alaska that meet society's essential needs, through adaptation to changing environmental conditions.

The five adaptation options recommended for this sector are targeted to sustaining the natural ecosystem services that meet Alaska's essential needs for food, water, renewable resource economies, community stability and safety, and cultural well-being. The recommendations build on existing state authorities and programs, and will move Alaska forward substantially in its ability to adapt to climate change impacts. Implementation of these options will require leadership and policy direction, as well as a moderate investment in staffing and funding to complete priority tasks. Through this work, the State will take a major step forward in integrating adaptive management to long-term climate change into the State's resource management programs and practices, so that it becomes a way of doing business and not a suite of separate initiatives.

NS-1 Fisheries Management

This option incorporates climate change into fisheries assessment and management and assists fishing communities and users in adaptation. This option includes several key elements: (1) review of the state's fishing-related statutes; (2) a comprehensive assessment of existing habitat, fish species, and stock

monitoring programs; (3) development of a centralized source of information on climate effects; and (4) development of a long-term strategy to work with fishing-reliant communities and business.

NS-2 Wildland Fire

This option would review and modify as appropriate Alaska's wildland fire policy and programs to address potential climate-induced increases in wildland fire frequency, size, and geographic location. Key elements include: (1) increasing the capacity of communities to initiate, complete, and implement Community Wildfire Protection Plans (CWPP); (2) reviewing selected wildland fire management practices for lands in Alaska; and (3) developing a comprehensive fuels management program to treat high-risk areas.

NS-3 Freshwater Management

This option addresses the effects of climate change on Alaska's freshwater resources through adaptive management, supported by improved hydrologic data. This option includes data collection, coordination, and protection. It also includes a review and adjustment as necessary of water management laws, policies, and practices in order to improve adaptive capacity.

NS-4 Invasive and Eruptive Species

Under this option, the state would expand its efforts to be an active partner with all levels of government and with other entities in addressing the problem of invasive and eruptive species in Alaska. The goal is to reduce introduction and spread of invasive species and eruptive species in the context of climate change.

NS-5 Fish and Wildlife

Under this option, the state would improve its capability to manage fish and wildlife species adaptively in Alaska to assure sustainable management of these important resources. The option includes two specific actions: (1) develop and adopt a more timely regulatory process for the harvest of wildlife; and (2) develop a coordinating framework that documents existing fish and wildlife monitoring efforts, identifies priorities for monitoring, and identifies gaps and potential for collaboration.

NS-6 Sustainable Agriculture

Under this option, the state would support and expand sustainable agriculture production and marketing in Alaska. This option recognizes the importance of local agriculture to Alaska's food security and seeks to develop an Alaska food policy and strategic plan that increases reliance on locally produced agricultural products. The option includes three specific actions: (1) encourage community-based agriculture and practices that optimize the use of the land and resources available; (2) research the magnitude and composition of food consumption in the state; and (3) research the sources of food supply and the risk associated with high reliance on imported foods.

Other Economic Activities

Some of Alaska's major economic activities, such as tourism and shipping, are highly dependent on weather conditions and/or the natural environment, both of which can be significantly affected by climate change. Some activities, such as mining and oil and gas exploration, rely on engineered infrastructure that is also potentially affected by climate, weather, and underlying environmental conditions. At the same time, climate change could create economic development opportunities in existing and new sectors. The options developed for this sector identify adaptive actions and options that contribute to the ability of sectors of the Alaska

economy not directly supported by living systems (e.g., fishing) to adapt to the effects of climate change and ensure the sustainability of a robust Alaska economy.

The recommendations in this sector focus on broad issues relevant to the economy as a whole, rather than actions designed to address the concerns of a particular economic group or industry. Three options are recommended.

EA-1 Evaluate Capability Needs for Potential Expansion of Arctic Economic Activities

This option recommends that the State recognize and address the potential for increased Arctic economic activities and identify gaps in infrastructure and the ability to provide an adequate presence in the Arctic coastal region to protect environmental resources, human health, and safety.

EA-2 Develop and Evaluate Scenarios for the Alaskan Economy

Components of the Alaska economy will experience varying impacts due to potential effects of climate change. An assessment of economic strengths, weaknesses, opportunities, and threats by sector is needed to better understand current and potential future components of the economy. This understanding will aid state agencies and other stakeholders in identifying and acting on optimum adaptive strategies and policies to help address future conditions. This option recommends conducting and managing a project to develop and evaluate possible economic scenarios for the State, based on potential climate change effects.

EA-3 Improve Availability of Mapping, Surveying, Charting and Imagery Data

Accurate, timely information about the distribution and magnitude of changes is needed to better address economic challenges and opportunities. This option recommends improving the availability of data, specifically real-time mapping, digital elevation model, and imagery, to better track and understand the impacts of climate change. This option would build on the work of the Statewide Digital Mapping Initiative and aid in transitioning between locations at the water-land interface.

Health and Culture

Climate change is being linked to increases in the geographic range and incidence of certain infectious and non-infectious diseases, new problems in sanitation and solid waste management, contaminant exposures, and diseases related to diet as well as mental health. Current programs are insufficient to identify and control these changes. To protect the health of humans, domesticated animals, and wildlife from the effects of climate change in Alaska, existing programs and activities need to be augmented to address these emerging concerns by developing new methods for surveillance and reporting of human and animal diseases.

The goal of the options recommended for this sector is to Improve adaptive capacity to maintain human health and healthy ways of life, reduce current and likely future increases in disease due to a changing climate, and prevent the destruction of gravesites, archaeological sites, and historic sites due to accelerated coastal and river erosion. Four options are recommended.

HC-1 Augment Surveillance and Control Programs for Vector-, Water-, and Food-borne Diseases

This option augments surveillance and control programs for vector-, water-, and food-borne diseases likely to become greater threats because of climate change. In addition, it develop educational programs for the public, health care providers, environmental staff, and others on approaches to reduce emerging disease threats.

HC-2 Community Health Impact Evaluations

This option develops a tiered approach to evaluate recommended adaptation and mitigation options to determine whether they could result in adverse health impacts and, if so, recommends approaches to reduce these risks.

HC-3 Assess Sanitation and Infrastructure Risks from Climate Change

This option assesses sanitation infrastructure and practices at risk from flooding, thawing permafrost, and other risks, or that are otherwise subject to changing conditions that significantly reduce performance in environmental health protection. This option would consider modification, rebuilding, or relocation of sanitation infrastructure to protect human and environmental health.

HC-4 Assess, Protect, and Develop Plans for Archaeological Sites and Gravesites

In cooperation with appropriate local, regional, and statewide entities, the state would assess archaeological sites and gravesites at risk from accelerated coastal and river erosion; convene archaeologists, anthropologists, Alaska Native elders, and others to discuss how best to address and prioritize sites at risk; and develop a plan for the protection or recovery of important at-risk sites. This option would also assist in identifying and opening new gravesites; convening a respectful discussion about gravesites while exploring best practices; and providing assistance for the relocation of existing at-risk gravesites.

Common Themes

Across the sectors, a number of common themes emerge for types of actions that will be needed to assist Alaska in adapting to climate change. These themes include needs for improving access to data, for community assistance, for coordination, and for education. Most of these themes are as relevant to mitigation as they are to adaptation. The recommendations fill a variety of needs that will greatly assist Alaskan efforts to address and respond to climate change. Four options that represent common themes across the sectors were developed.

CT-1 Establish an Alaska Climate Change Knowledge Network

This option recommends establishing an Alaska Climate Change Knowledge Network (ACCKN) to provide an effective, collaborative means to manage data and foster its use for adaptation. Where appropriate, the ACCKN would organize, consolidate, integrate, and archive data, information, and knowledge related to climate change. The network would serve as a point of coordination for National Oceanic and Atmospheric Administration's (NOAA's) proposed Regional Climate Center in Alaska.

CT-2 Coordinate Implementation of Alaska's Efforts to Address Climate Change

This option recommends that Alaska's efforts to address climate change continue to be coordinated internally to ensure synergy among State agency efforts, unified and strategic interaction with federal agencies, and effective outreach and education.

CT-3 Community Climate Impact Assistance

An array of state, federal, and regional entities are responsible for delivering services to Alaskan villages, rural communities, and urban centers, but specific policies and regulatory constraints produce conflicting directives that prevent the coordinated delivery of vital services that will enable endangered villages, traditional culture, and vulnerable communities to adapt in the face of climate change. There is a need to establish a coordinating

entity with the ability to navigate these multiple bureaucracies and to leverage their resources to support vulnerable communities in emergency response, relocation, subsistence concerns, and other priorities.

CT-4 Promote Climate Change Science through K-12 Education

This option promotes development of curriculum and training to support climate change education in grades K-12.

CHAPTER 1. INTRODUCTION AND OVERVIEW

> *"Scientific evidence shows many areas of Alaska are experiencing a warming trend. Many experts predict that Alaska, along with our northern latitude neighbors, will continue to warm at a faster pace than any other state, and the warming will continue for decades. Climate change is not just an environmental issue. It is also a social, cultural, and economic issue important to all Alaskans. As a result of this warming, coastal erosion, thawing permafrost, retreating sea ice, record forest fires, and other changes are affecting, and will continue to affect, the lifestyles and livelihoods of Alaskans." (Administrative Order 238).*

To address the impacts of climate change on Alaska, Governor Palin signed Administrative Order 238 (AO 238 (2007)) on September 14, 2007, which established and charged the Alaska Climate Change Sub-Cabinet to advise the Office of the Governor on the preparation and implementation of a comprehensive Alaska Climate Change Strategy. To accomplish its goals, the Sub-Cabinet formed a Mitigation Advisory Group (MAG) to recommend measures that could be undertaken in Alaska to reduce emissions of greenhouse gases, and an Adaptation Advisory Group (AAG) to evaluate and address impacts of climate change. The Sub-Cabinet also created two work groups: (1) an Immediate Action Work Group to address the early assessment and development of an action plan to address impacts on coastal and other vulnerable communities in Alaska and (2) a Research Needs Work Group to identify important areas for research, assessment, and mapping, in order to support the goals of the advisory groups, as well as other research that might be needed.[1] In addition, Technical Work Groups (TWGs) were developed to support the AAG's development of recommended policy options and actions in four impact categories, or sectors.

This report details the process, analyses, and recommendations of the AAG. Following this introduction, which provides background on the process and structure of the Sub-Cabinet, the report is divided as follows:

- Chapter 2 provides an overview of climate change projections and impacts for Alaska
- Chapter 3 presents a brief overview of Alaska's strategy to adapt to climate change
- Chapters 4 through 8 present the AAG's recommendations clustered into the impact categories represented by the four TWGs (Public Infrastructure, Natural Systems, Other Economic Activities, Health and Culture) and a fifth set of recommendations, representing common themes that cross-cut the sectors
- Appendices A though D contain references, acronyms, the Administrative Order forming the Sub-Cabinet, and lists of members of the AAG and TWGs
- Appendices E through I contain additional, more detailed information on the recommended options in each impact category, as well as the recommendations representing common themes across the sectors.

The remainder of this introduction provides information on the process and goals of Alaska's Climate Strategy, and indicates how the process of developing the adaptation recommendations fits into Alaska's overall climate strategy.

[1] Additional Information on the activities of these advisory and work groups can be found at http://www.climatechange.alaska.gov/rn.htm

Early Actions: Alaska Climate Impact Assessment Commission

The Alaska State Legislature established the Alaska Climate Impact Assessment Commission (ACIAC) by Legislative Resolve 49 in 2006 (HCR 30). The Commission was charged with assessing the effects of climate change that could impact the citizens, resources, economy, and assets of the State of Alaska. The Commission was composed of two state House members, two state Senators, and seven public members appointed to specifically-defined seats. After holding a series of public hearings throughout the state, the Commission concluded that climate change presents "unavoidable challenges to the citizens of Alaska." A set of recommendations is outlined in their March 17, 2008 report to the Alaska State Legislature (ACIAC 2008).

The Commission found that climate change presents unavoidable challenges to the citizens of Alaska. They noted that the most striking impacts are those associated with village relocation in Western Alaska, with the convergence of immediate threats, substantial human need, and prohibitive costs presenting challenges to decision-makers at all levels of government. The Commission also identified potential positive eventualities, such as commercial shipping expansion in the high Arctic and a longer and warmer summer tourism season. They indicated that climate change will generate new responsibilities for the State of Alaska and public entities, and for private interests and individuals. The Commission concluded that continued identification of potential challenges, threats, and responses was needed within the Administration.

Administrative Order 238 and Alaska Climate Change Sub-Cabinet

The Climate Change Sub-Cabinet was established by Administrative Order 238 in 2007 (AO 238 2007). The Sub-Cabinet was tasked with conducting an early assessment and action plan to address the most urgent needs of coastal and other vulnerable communities in Alaska, and to develop a proposed Climate Change Strategy (The Strategy). The Strategy focuses on mitigation options and recommendations to reduce greenhouse gas (GHG) emissions within the state and adaptation recommendations to help Alaskans prepare for a warming climate. Figure 1-1 displays the organization of the Sub-Cabinet and supporting advisory and work groups.

Alaska Climate Change Sub-Cabinet

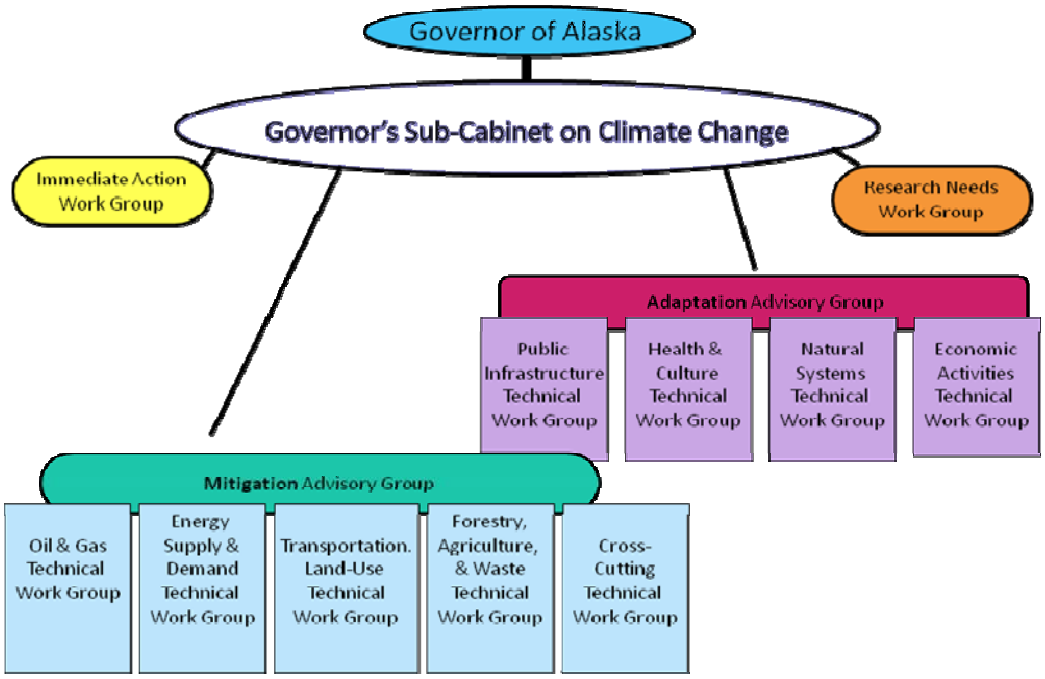
Sub-Cabinet members were appointed by the Governor and comprised Commissioners of the Department of Environmental Conservation (ADEC), the Department of Natural Resources (ADNR), the Department of Commerce, Community, and Economic Development (ADCCED), the Alaska Department of Fish and Game (ADF&G), and the Department of Transportation and Public Facilities (ADOT&PF). Representatives from the Governor's Office and the University of Alaska serve as official liaisons. The Sub-Cabinet has held a number of organizational and informational meetings beginning in early 2007.

Sub-Cabinet Work Groups

The Sub-Cabinet established advisory and technical work groups to bring a wide spectrum of expertise to bear in the primary focus areas. These consisted of the following groups:

- ***Immediate Action Work Group (IAWG)***–This group represented a federal and state-led interagency effort to address near term needs of the most vulnerable communities. Risks, primarily from flooding and erosion, which are heightened due to warming conditions, in many cases necessitate relocation, migration, or protection-in-place.

Figure 1-1. Organization of the Advisory and Work Groups Supporting the Climate Sub-Cabinet



- ***Adaptation Advisory Group (AAG)***–Selected by the Sub-Cabinet, this group consisted of individuals with a wide spectrum of expertise from multiple state and federal agencies, local governments, the Alaska Native community, the University of Alaska, industry, and non-governmental organizations (NGOs). They were tasked with recommending adaptation options in the following areas:
    - Public Infrastructure **(PI)**
    - Health and Culture **(H&C)**
    - Natural Systems **(NS)**
    - Other Economic Activities **(EA)**
- ***Mitigation Advisory Group (MAG)***–Selected by the Sub-Cabinet, this group consisted of individuals with a wide spectrum of expertise from multiple state and federal agencies, local governments, Alaska Native community, the University of Alaska, industry, and NGOs. They were tasked with developing or recommending mitigation options in the following areas:
    - Oil and Gas **(O&G)**
    - Energy Supply and Demand **(ESD)**
    - Transportation and Land Use **(TLU)**
    - Forestry, Agriculture and Waste **(FAW)**
    - Cross-Cutting **(CC)**

- ***Research Needs Work Group (RNWG)***–Also selected by the Sub-Cabinet, the Research Needs Work Group was tasked with identifying research needs associated with climate change. The group looked at gaps in monitoring and observation, research, availability and accessibility of data and information, technology development, engineering standards, support tools, and other derivative products.

The Process of Developing Recommendations from the MAG and AAG

Developing recommended options and the reports to the Sub-Cabinet has been an open, consensus-building process. This process has combined the expertise, knowledge, and concerns of a broad spectrum of Alaskans in a series of public meetings and publicly available interim products. A series of meetings of the TWGs supporting both mitigation and adaptation commenced May 2008. The advisory groups each met in seven formal meetings (supplemented as needed by teleconferences) to direct, review, and approve the work of the TWGs and to provide strategic and technical guidance in the selection and development of the policy recommendations and options. TWG members and facilitators attended the advisory group meetings and presented material, as needed, on the progress of the TWGs and the recommendations being developed.

The process sought, but did not require, consensus to bring a recommendation forward. Where unanimous support could not be achieved, barriers to full support were identified. Where those barriers could not be eliminated through further discussion and modification, dissenting opinions and the context of the dissention were noted in the appendices to the Final Report from each Advisory Group. For each of the advisory groups, nearly all of the recommended options received unanimous support.

The AAG and MAG held final meetings in person (and by teleconference) late in the summer of 2009 to finalize reports for submittal to the Sub-Cabinet from each of the respective advisory groups.

Reports to the Climate Change Sub-Cabinet and Next Steps

The IAWG released its first report on April 17, 2008 (IAWG 2008) and a second, more in-depth analysis in March 2009 (IAWG 2009). This interagency group has proven effective in prioritizing needs and in harnessing and leveraging a variety of resources. The Sub-Cabinet is in the process of taking steps to draft a Memorandum of Understanding to enable this effort to move forward and build on its early success.

The Mitigation and Adaptation Reports will be finalized and submitted to the Sub-Cabinet in 2009. The Research Needs Draft Report is also being submitted for the Sub-Cabinet's review. Its recommendations track the TWGs and their identified needs.

Following the submission of these final reports, the Sub-Cabinet will solicit additional input as needed, review the recommendations, and subsequently distill the recommendations of all the Advisory and Work Groups into a Climate Change Strategy for the Governor's consideration. In developing an integrated strategy, the Sub-Cabinet will consider alignment with other state plans and initiatives, existing programs, federal legislation, and other complementary efforts.

CHAPTER 2. CLIMATE CHANGE AND ALASKA

The *Arctic Climate Impact Assessment (ACIA)*, a comprehensive assessment conducted by hundreds of scientists and indigenous peoples, projects increases in temperature, glacial melt, permafrost temperature, ocean acidification, and continued loss of sea ice extent and thickness in Arctic regions (ACIA 2004 and 2005).

This chapter is not a product of the Adaptation Advisory Group. The information in this chapter provides a scientific backdrop for the recommendations and options for adaptation in each sector. It presents findings from the scientific community regarding observed and projected climatic changes for Alaska, and attendant potential impacts on the Alaskan economy and lifestyles.

Over the past 50 years, Alaska has warmed at more than twice the rate of the rest of the United States (Karl et al. 2009). As a result, climate change impacts are much more pronounced than in other regions. Higher temperatures are already contributing to earlier spring snowmelt, reduced sea ice, widespread glacier retreat, and permafrost warming. These observed changes are consistent with climate model projections of greater warming over Alaska, especially in winter, as compared with the rest of the country (Karl et al. 2009). Warmer temperatures are expected to be accompanied by overall drier conditions and reduced soil moisture, changes in sea level, and other changes.

Changes in climate will pose challenges for Alaskans and the Alaska economy. Climate change will also provide economic opportunities due to a longer summer tourism season, increased navigation potential, and other changes. Addressing these challenges and taking advantage of the opportunities requires understanding the likely changes in climate that Alaska is to experience, and the concomitant changes in natural resources, infrastructure, and other human and natural systems on which urban and rural communities depend. This chapter summarizes relevant literature on projected climate for Alaska and potential impacts on natural and human systems.

Climate Change Science and Projections for Alaska

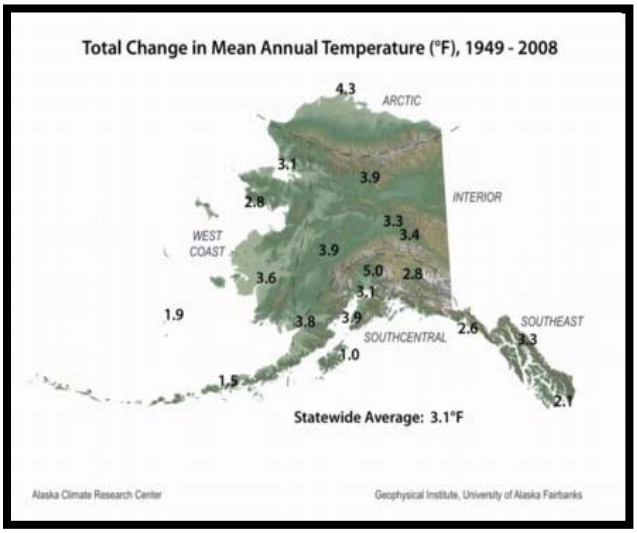
Climate has historically played a key role in shaping Alaska's natural environment, a vast and varied land spanning 586,400 square miles with over 33,000 miles of coastline. Current and projected changes in climate are occurring rapidly with impacts to society, the environment, infrastructure, and economic drivers throughout the state. While natural variability spread over many centuries is well-documented, the present rate of change and global mean surface temperature are higher than during any similar period since 1600 AD (Overpeck et al., 1997). Alaska's climate is particularly sensitive to these changes. Temperature and precipitation in Alaska are driven in large part by the state's high latitude and corresponding seasonal extremes in solar radiation, the influence of ocean waters and sea ice, and variations in elevation (ACRC 2009). A general understanding of projected conditions is critical to planning for the future and anticipating the types of adaptation measures that should be developed.

Temperature

Despite the considerable interannual and interdecadal influence of large-scale regime shifts, most notably the Pacific Decadal Oscillation (PDO), average annual temperatures in Alaska have risen by 3.1° F in the past 60 years (ACRC 2009). This is consistent with the general warming trend observed throughout the circumpolar Arctic. The distribution across Alaska is displayed in Figure 2.1.

An analysis of mean seasonal and annual temperature data for Alaskan communities over the past 60 years shows the greatest changes occurring during the winter months as depicted in Figure 2.2. Multiple communities have experienced increases of greater than 8° F in the winter months. This poses significant implications to the natural ecosystems and the built environment in Alaska.

Figure 2-1. Total Change in Mean Annual Temperature (°F), 1949-2008



Source: ACRC 2009.

Precipitation and Hydrology

Atmospheric temperature is positively correlated with the amount of precipitable water (PW) in the atmosphere, and thus the potential for precipitation. During 1979 to 2005, precipitable water in the atmosphere at the northern latitudes increased by approximately 5 to 10% per decade during spring, increased 5% per decade in summer, and declined (over land masses) in autumn and winter (White et al. 2007). Available precipitation gauge data from across the northern latitudes (between 55° and 85°N) suggests precipitation has increased during winter and spring, with a slight decrease during autumn (e.g., Serreze et al. 2000).

Snow distribution and redistribution data is difficult to gather and the stations that gather such data provide only sparse coverage across Alaska. Increases in

Figure 2-2. Total Change in Mean Seasonal and Annual Temperature (°F), 1949 -2008

Total Change in Mean Seasonal and Annual Temperature (°F), 1949 - 2008

Region	Location	Winter	Spring	Summer	Autumn	Annual
Arctic	Barrow	6.5	4.4	2.8	3.4	4.3
Interior	Bettles	8.5	4.6	1.8	1.1	3.9
	Big Delta	9.2	3.5	1.2	-0.2	3.4
	Fairbanks	7.7	3.8	2.3	-0.4	3.3
	McGrath	7.4	4.8	2.7	0.6	3.9
West Coast	Kotzebue	6.6	1.8	2.5	1.6	3.1
	Nome	4.4	3.6	2.5	0.6	2.8
	Bethel	6.6	5.0	2.3	0.1	3.6
	King Salmon	8.1	4.7	1.8	0.6	3.8
	Cold Bay	1.5	1.8	1.8	0.9	1.5
	St Paul	1.0	2.4	2.8	1.3	1.9
Southcentral	Anchorage	6.8	3.6	1.6	1.4	3.1
	Talkeetna	8.9	5.4	3.1	2.4	5.0
	Gulkana	8.1	2.4	0.9	0	2.8
	Homer	6.3	4.0	3.4	1.7	3.9
	Kodiak	0.9	2.3	1.2	-0.4	1.0
Southeast	Yakutat	4.9	3.1	1.8	0.3	2.6
	Juneau	6.6	3.1	2.1	1.4	3.3
	Annette	3.9	2.5	1.7	0.2	2.1
	Average	6.0	3.5	2.1	0.9	3.1

Alaska Climate Research Center Geophysical Institute, University of Alaska Fairbanks

Source: ACRC 2009

winter precipitation could lead to increased snowpack (Serreze et al. 2000), however, winter melting events and a shortening of the period of snow accumulation could have the opposite effect. If the latter conditions dominated and overall snowpack decreased, Alaska could expect a shorter spring melting period with lower runoff intensity and generally lower summer baseflows. In either event, changes in timing, duration, thickness, and distribution of seasonal snow cover significantly impacts many aspects of the hydrologic cycle including surface runoff, groundwater recharge, and river streamflow (White et al. 2007).

In addition, rain-on-snow events can have a profound impact on wildlife. For example, when a heavy crust forms on snow after a rain event, caribou may be unable to access food and large-scale die-offs may occur. To complicate potential impacts of snowpack and river dynamics, glacial runoff has a significant impact on many Alaskan rivers. For example, Hinzman et al. (2005) found increasing trends in discharge from glacially fed Alaskan rivers and decreasing trends in nonglacially fed rivers. With continued warming, the glacial contribution to rivers could increase. This effect would then decrease with diminishing glaciers.

The potential change in precipitation, snowpack, runoff, and riverflow could have many different effects on Alaskans. Due to the appreciable interannual variability and variation introduced by decadal cycles (i.e., Pacific Decadal Oscillation), longer term trends in precipitation will be difficult to discern and prepare for. However, both decadal variability and longer term trends should be incorporated into long term planning. While most attention is paid to net annual or seasonal precipitation, the nature of the precipitation events is important to human and natural ecosystems. For example, an increase in storminess could have a dramatic impact on erosion and, consequently, on infrastructure. Likewise, midwinter melting events could reduce the potential for spring flooding, particularly flooding caused by ice jams on rivers. As with all climate impacts, changes will be regional in nature.

Warmer spring and fall weather will result in longer growing seasons and a higher number of growing degree days statewide. This in turn will increase water loss from soils through evapotranspiration. This drying effect will generally result in a net loss of moisture, despite increased rainfall.

In the Arctic, drying of wetlands may alter the habitat of many species, and may also impact the oil and gas industry by reducing the availability of water for snow travel and ice roads. In the interior, hydrologic changes are likely to be felt most acutely in terms of the impacts of drying on fire cycles, as described below, as well as on changing drainage patterns as permafrost thaws. In western coastal regions, the greatest risks from changing hydrologic conditions are likely to be erosion (due in part to loss of sea ice and permafrost) and storms, although current models do not provide clear data on potential changes in storm frequency and severity. In southeast Alaska, glacial melt is already occurring, and is likely to continue. This change in conjunction with changes in the timing of spring runoff may affect a wide range of ecosystem functions and human activities, including tourism, hydropower generation, and subsistence harvest.

Sea Level Change

Generally speaking, global sea levels are rising via thermal expansion resulting from warming of the ocean, as well as freshwater input from the melting of a majority of Earth's glaciers and ice sheets. Approximately 47% of Gulf of Alaska freshwater input is derived from glacier melting (Neal et al., in review). Consequently, IPCC models estimate that through the end of the 21st century, global sea levels may rise between 0.6 ft and 1.9 feet (IPCC 2007).

However, these projections do not consider extreme increases in ice-sheet flow velocities or acceleration in the volume and rate of ice loss (Alley et al. 2005; Gregory and Huybrechts 2006; and Hansen 2005). Several recent studies suggest that the IPCC models underestimate ice loss from the Greenland and Antarctic ice sheets (Shepherd and Wingham 2007; Csatho et al. 2008) and ice loss from mountain glaciers (Meier et al. 2007). Further, IPCC results for sea level projections might underestimate sea level rise due to changes in global precipitation (Wentz et al. 2007; Zhang et al. 2007).

Recent glacier retreat in the Gulf of Alaska coastal area of southeast and southcentral Alaska has resulted in the land surface rising as it readjusts to the loss of glacial ice. This isostatic rebound, combined with active regional tectonic deformation, results in a rate of land uplift that is greater than the projected rate of global sea level rise. Thus, over the next century, the relative sea level in these areas will decrease between 2.1 and 3.4 feet (Larsen et al. 2004; Kelly et al. 2007; Pyare 2009).

In contrast, communities in low-lying areas such as the Yukon-Kuskokwim Delta are likely to face increased flooding and changing storm surge and storm tracks. In northwest Alaska, overall, decreasing sea ice extent and resulting increasing wave surge will have greater impact on coastal erosion than will sea level rise.

Ocean Acidification

Ocean acidification, occurring as a result of increasing concentrations of CO_2 in the atmosphere, is considered to be the greatest threat to living marine resources and those who rely on them. The world's largest bodies of water are effective absorbers of both CO_2 and excess heat associated with climate change (Sabine et al. 2004). While this has a mitigating effect on the changes to climate, absorption of CO_2 is making the oceans more acidic posing grave danger to all marine life with calcifying shells. This includes marine plants and zooplankton, the basis of the food chain (Feely 2006).

Acidification processes are more pronounced in colder waters (Orr et al. 2005). Since over 50% of the fish consumed in the U.S. comes from the Bering Sea, this has the potential to significantly alter the conditions that support commercially important species. Even though it has been noted that some stocks are migrating further north and into Arctic waters due to ocean warming, acidification is projected to be a challenge there as well (Orr et al. 2005).

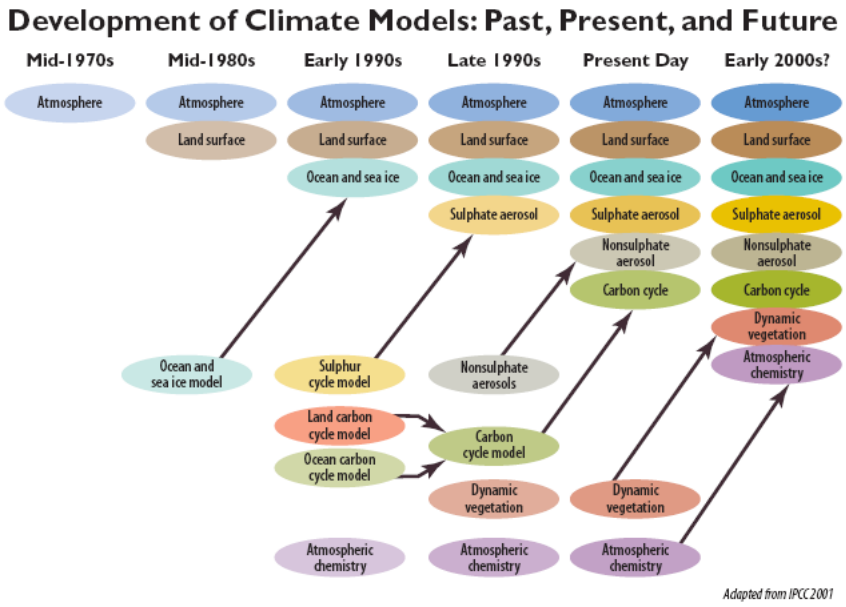
Estimates of future atmospheric and oceanic carbon dioxide concentrations suggest that by the middle of this century, the atmospheric carbon dioxide level could reach more than 500 parts-per-million (ppm), and could rise to over 800 ppm near the end of the century. This would result in an additional surface water pH decrease of approximately 0.3 pH units by 2100 (PMEL n.d.). Box 2-1 describes effects of ocean acidification on marine ecosystems.

Projections – What the Models Predict

Scientists extensively use mathematical models of Earth's climate to examine hypotheses about past and present day climates. These climate simulations provide a framework within which enhanced understanding of climate-relevant processes, along with improved observations, are merged into coherent projections of future climate change (CCSP 2008). Over time, these models have evolved into modern coupled atmosphere-ocean general circulation models (AOGCMs), which incorporate detailed representations of the atmosphere, land surface, oceans, and sea ice (see Figure 2.3). These models form the basis of the projections for temperature, precipitation, and other variables reported in the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment (IPCC 2007).

Predicting the site-specific magnitude of these changes is crucial to interpreting their impacts. In order to produce projections that are useful for impacts analysis at the regional level, the coarse-resolution global climate model output must be "downscaled" to provide higher resolution results. Different methodologies are available for downscaling, with different degrees of success and reliability (CCSP 2008).

Figure 2-3. Historical Development of Climate Models



Source: CCSP, 2008.

For Alaska, the Scenarios Network for Alaska Planning (SNAP) has taken one approach to developing fine-scale projections of future climate. SNAP

Box 2-1 Ocean Acidification and Its Effect on Marine Species

The oceans have absorbed about 50% of the carbon dioxide (CO_2) released from the burning of fossil fuels, resulting in chemical reactions that lower ocean pH. This has caused an increase in hydrogen ion (acidity) of about 30% since the start of the industrial age through a process known as "ocean acidification." A growing number of studies have demonstrated adverse impacts on marine organisms, including:

- The rate at which reef-building corals produce their skeletons decreases
- The ability of marine algae and free-swimming zooplankton to maintain protective shells is reduced
- The survival of larval marine species, including commercial fish and shellfish, is reduced

This research shows that pH will affect the processes by which animals such as corals, mollusks and crustaceans make their support structures. Because these organisms depend on calcium carbonate, increasing acidity threatens their survival. Pteropods, small planktonic mollusks critically situated at the bottom of the food chain and a key food source for salmon and other species, are particularly vulnerable to increasing acidity in Alaska's marine waters. Other marine organisms at risk from increasing acidification include corals and coralline algae commonly found in reef communities. Cold water coral communities along the Aleutian Islands form important fish habitat. Forminifera and coccolithophorids, planktons that are abundant in most surface waters, are also at risk. Some commercial species like clams and crabs will be directly impacted by reductions in calcium carbonate. Others, like most fish populations, will be affected indirectly as acidification impacts their key prey species.

Continued in next text box…

Box 2-1 Ocean Acidification and Its Effect on Marine Species (continued)

Ocean Acidification Will Impact Polar and Sub-Polar Regions First

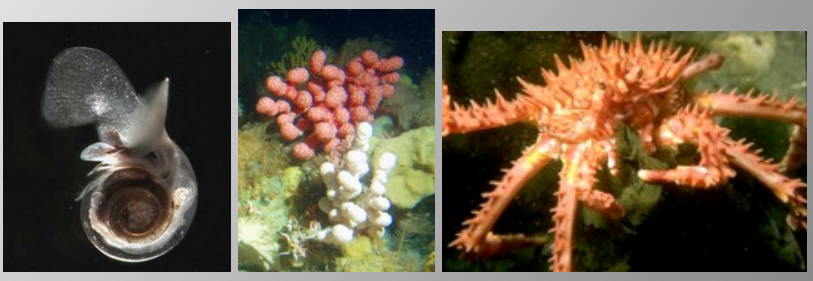
Ocean acidification is likely to alter the biodiversity of the world's marine ecosystems and may affect the total productivity of the oceans. New findings indicate that an increasingly acidic environment could cause problems in high-latitude marine ecosystems within just a few decades. Currently, the oceans' surface water layers have sufficient amounts of calcium carbonate for organisms to use (known as saturated conditions). This calcium carbonate rich layer is deeper in warmer regions and closer to the surface in colder regions. Because calcium carbonate is less stable in colder waters, marine life in the polar oceans will be affected by calcium carbonate loss first. A study published in *Nature* by 27 U.S. and international scientists stated, "Some polar and sub-polar waters will become under-saturated [at twice the pre-industrial level of CO2, 560 ppm], probably within the next 50 years (Orr et al., 2005)."

What Are the Potential Socio-Economic Consequences of Ocean Acidification?

Ocean acidification will have long-term implications for the global carbon cycle and climate, although the range and magnitude ofbiogeochemical and biological effects and their socio-economic impacts are currently too uncertain to accurately quantify. However, we do know that such impacts are likely to be substantial.

Feedback to Climate Changes

As the oceans absorb more and more CO2 from the atmosphere, their capacity to continue to sequester greenhouse gases diminishes, thereby limiting their ability to reduce the greenhouse effect. This then inhibits their potential to reduce subsequent warming.



Sources (including photos and chart): PMEL, 2008 and Alaska Marine Conservation Council, n.d.

projections are based on downscaled global models used by the IPCC. The IPCC used fifteen different GCMs to prepare its Fourth Assessment Report (IPCC 2007). Each model was created by a different nation or group

using slightly different data and assumptions. Thus, models can be expected to perform with varying degrees of accuracy in any particular region.

To downscale IPCC results to Alaska, SNAP investigators compared model output for past years to actual climate data for the same time period, and analyzed how well each model predicted monthly mean values for three different climate variables (surface air temperature, precipitation, and sea level air pressure) over four overlapping northern regions (Alaska, Greenland, latitude 60-90˚N, and latitude 20-90˚N) for the period from 1958–2000 (Walsh et al. 2008). They noted that models that performed well in one northern region tended also to perform well in others. SNAP climate models rely on output from the five models that provided the most accurate overall results. Results are scaled down to match local conditions using data from Alaskan weather stations and various analytical tools.

Results of SNAP modeling efforts are used to inform the predictions for the changes to human and natural systems described below, including vegetation and wildlife species shifts, changes in fire cycles, and loss of permafrost. Data can be accessed via the SNAP website (www.snap.uaf.edu).

Additional linked models connecting climate data to variables such as transportation and construction parameters, hydrologic shifts, or optimal conditions for tourism, recreation, hunting, and fishing will improve the connections between SNAP climate data and landscape changes of concern to Alaskans (Walsh et al. 2008).

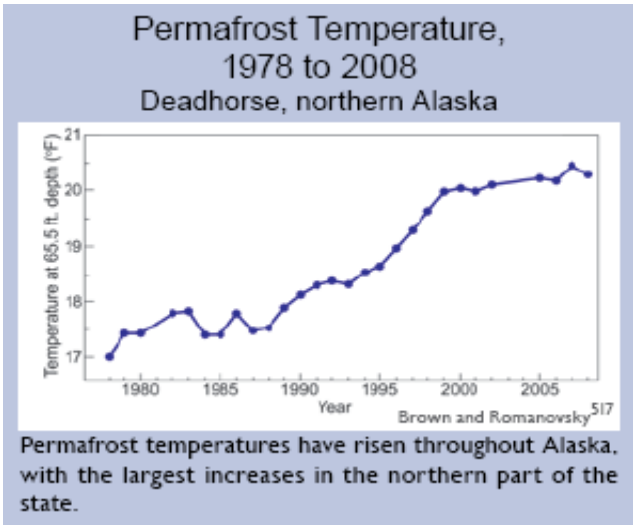
Impacts on Human and Natural Systems in Alaska

Alaska is already experiencing climate warming, with key effects occurring to permafrost and sea ice, forests and other vegetation, coastline communities and infrastructure, marine ecosystems and fisheries, and subsistence livelihoods (NAST 2000). Over the past three decades, Alaska has experienced a sharp reduction in snow-cover extent and duration, shorter river- and lake-ice seasons, melting of mountain glaciers, sea-ice retreat and thinning, permafrost retreat, and increased depth of summer thaw (Weller 2005). The climatic and other changes associated with warming will not only affect the environment, but will also affect the economy and daily life and culture in Alaska (see Box 2-2).

Permafrost Thawing and Sea Ice Melting

Permafrost underlies most of Alaska. Air temperature, snow cover, and vegetation affect the temperature of the frozen ground and the depth of seasonal thawing. Recent decades of warmer temperatures have produced extensive warming and thawing of permafrost (Brown and Romanovsky 2008), as illustrated in Figure 2.4. This warming and thawing has resulted in increased coastal erosion, landslides, high elevation rock and ice avalanches, and sinking of the ground surface, and consequent disruption and damage to forests, buildings, infrastructure,

Figure 2-4. Permafrost Temperature, 1978 to 2008.



Source: Karl et al. 2009

Box 2-2. Impacts on the Economy and on People's Lives

The effects of climate change on the environment in Alaska will have consequences for natural resources and production that may affect the Alaskan economy and the lives and livelihood of indigenous and non-indigenous populations.

Impacts on the Economy

Climate change may affect the economy via effects on natural resources and on transportation and other infrastructure. Large oil and gas reserves exist in Alaska along the Beaufort Sea coast in the Mackenzie River/Beaufort Sea area of Canada. While climate change impacts on this industry have been minor thus far, in the future both negative and positive effects are likely. For example, offshore oil exploration and production is likely to benefit from less extensive and thinner sea ice (Weller 2005). Conversely, ice roads, now used widely for access to offshore activities and facilities, are likely to be less safe and usable for shorter periods (Weller 2005). The thawing of permafrost, on which buildings, pipelines, airfields, and coastal installations supporting oil development are located, is very likely to affect these structures adversely and greatly increase the cost of maintaining or replacing them. (Weller 2005). One study (Larsen et al, 2007, 2008) suggests that strategic adaptation to different future scenarios of climate change could add $3.6–$6.1 billion (+10% to +20% above normal wear and tear) to future costs for public infrastructure from now to 2030, and $5.6–$7.6 billion (+10% to +12%) from now to 2080.

It is difficult to project impacts on the lucrative Bering Sea fisheries because many factors other than climate are involved (Weller 2005). However, large northward changes in the distribution of fish and shellfish are likely with a warmer climate, which might result in substantial costs to relocate infrastructure supporting commercial fishing (Weller 2005). Warmer waters are likely also to lead to increase primary production in some regions, but a decline in cold-water species such as salmon and pollock.

Other economic sectors in this region, including forestry and agriculture are less developed and less important economically than oil and gas and fish and wildlife. Impacts on these other economic sectors are difficult to assess. For example, impacts on tourism will depend on how the Alaskan features that draw tourists change; large undeveloped landscapes will not be directly affected by climate change, whereas marine mammal populations and accessible glaciers are likely to experience major changes. Impacts on agriculture are also difficult to predict. Growing-degree days have increased by 20%, with benefits for agriculture and forest productivity on some sites, and reduced growth on others (Weller 2005, ACIA 2004).. Moreover, the benefits of a longer growing season will be balanced against the negative effects of decreased soil moisture (Karl et al. 2009).

Impacts on People's Lives

Traditional lifestyles are already being threatened by the environmental effects associated with climate change, including reduced or displaced populations of marine mammals, seabirds, and other wildlife, and reductions in the extent and thickness of se ice, making hunting more difficult and dangerous (Weller 2005). Climate change is likely to have significant impacts on the availability of key marine and terrestrial species used as food sources, by shifting the range and abundance of species such as salmon, herring, char, cod, walrus, seals, whales, caribou, moose, and various species of seabird (Weller 2005). Such changes will require major local adjustments in harvest strategies (Weller 2005). These activities play important roles in the lives of many indigenous populations, including making significant contributions to diet and nutrition, providing opportunities for physical activity, contributing monetary income, and providing other important social and cultural functions (Weller 2005).

Impacts have already been observed on lifestyles in indigenous villages and communities in Alaska and Canada that depend heavily on fishing and hunting. Such impacts included reduced access to tundra and offshore food resources, decreases in the anadromous fish stocks and marine mammals harvested for food; threats to villages resulting from coastal erosion, and infrastructure affected by thawing permafrost. Other impacts are likely to occur in the future, due to decreasing area of pack ice, further changes in habitat and migration routes, zoonotic diseases posing a greater threat to humans and wildlife, lower water levels, and other changes.

and coastal communities (NAST 2000; Nelson et al. 2003). Land subsidence associated with the thawing of

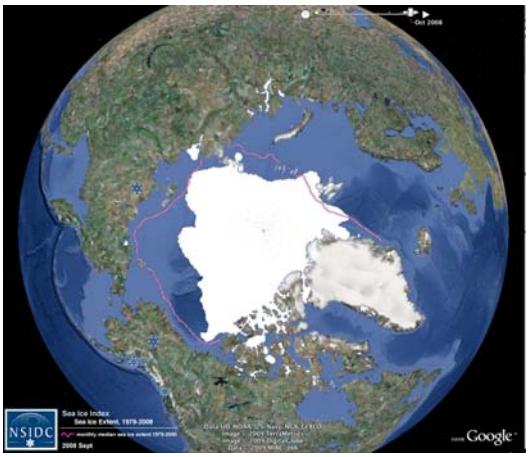
permafrost presents substantial challenges to engineers attempting to preserve infrastructure in Alaska (Nelson et al. 2003; Karl et al. 2009; Larsen et al. 2008).

Public infrastructure at risk of damage includes roads, runways, and water and sewer systems (Karl et al. 2009), as well as local, municipal, Borough, State and Federal buildings. While most permafrost-related damage to infrastructure is due to the heat of the infrastructure itself, many mitigation measures rely on sufficiently cold winter temperatures to balance the heating. Many industrial activities (such as oil and gas exploration which requires travel on the tundra) depend on frozen ground surfaces, and many northern communities rely on ice roads for transport of groceries and other materials. Continued warming will further impair transport by shortening the seasonal use of ice roads (ACIA 2004). Thawing is projected to accelerate under future warming, with as much as the top 10 to 30 feet of discontinuous permafrost thawing by 2100 (NAST 2000; Romanovsky et al. 2007; Romanovsky 2009).

All components of the cryosphere in the Arctic are experiencing change, including snow cover, mountain and valley glaciers, permafrost, sea ice, and lake and river ice (Parson et al. 2000). For example, most glaciers in Alaska, as throughout the Arctic, have been retreating for many decades. Many small lower elevation glaciers have melted away, while most large valley glaciers are thinning several feet per year.

Sea ice off the Alaskan Coast is retreating and thinning, with widespread effects on marine ecosystems, coastal climate, human settlements, and subsistence activities. Recent studies estimate arctic-wide reductions in annual average sea-ice extent of about 5-10% and a reduction in average thickness of about 10-15% over the past few decades (ACIA 2004). Figure 2-5 depicts the extent of sea ice in September 2008. The magenta line represents median sea ice extent between 1979 and 2008. The annual maximum sea ice extent typically occurs in March. This annual maximum level has been gradually declining since 1979, and experienced a record low in 2006, with a slight rebound since the low (Richter-Menge et al. 2008). Retreat of sea ice allows larger storm surges to develop, increasing the risk of inundation and increasing erosion on coasts already made vulnerable by permafrost thawing (NAST 2000). Loss of sea ice also causes large scale changes in marine ecosystems, and threatens populations of marine mammals and polar bears that depend on ice (NAST 2000).

Figure 2-5. Sea Ice Extent in 2008 and 1979



Source: Richter-Menge et al., 2008

At the same time, the continued reduction of sea ice is very likely to increase the navigation season, and seasonal opening of the Northern Sea Route is likely to make trans-arctic shipping feasible during summer months. This could occur within several decades, although increasing ice movement will initially make shipping more difficult in some channels of the Northwest Passage.

Lakes are also declining in area. Across the southern two-thirds of Alaska, the area of closed-basin lakes (lakes without stream inputs and outputs) has decreased over the past 50 years (Karl et al. 2009). This is likely due to the greater evaporation and thawing of permafrost that result from warming (Karl et al. 2009). Continued decline in the area of surface water would present challenges for the management of natural

resources and ecosystems on National Wildlife Refuges in Alaska (Karl et al. 2009). These refuges, which cover 77 million acres (21 percent of Alaska) and comprise 81 percent of the U.S. National Wildlife Refuge System, provide breeding habitat for millions of waterfowl and shorebirds that winter in the lower 48 states (Karl et al. 2009).

Threats to Coastal Communities, Habitats, and Fishing Fleets

Alaska has more coastline than the other 49 statescombined (Karl et al. 2009). Coastal erosion is causing the shorelines of some areas to retreat at average rates of tens of feet per year (Karl et al. 2009). Frequent storms in the Gulf of Alaska and the Bering, Chukchi, and Beaufort Seas already affect the coasts during much of the year (Karl et al. 2009). Alaska's coastlines, many of which are low in elevation, are increasingly threatened by a combination of the loss of their protective sea ice buffer, increasing storm activity, and thawing coastal permafrost (Karl et al. 2009). Increases in the frequency and intensity of storm surges have triggered increased coastal erosion that is threatening a number of coastal villages (see Figure 2-6). A recent report from the Government Accountability Office (GAO) indicated that, since 2003, federal, state, and village officials have identified 31 villages that face imminent threats (see Box 2-3).

Figure 2-6. Coastline Erosion in Shishmaref, Alaska.

Shishmaref, where the coastline has eroded 100-300 feet in the past 30 years. Source: The Nome Nugget

Storm surges have also reduced the protection that barrier islands and spits provide to coastal habitats. Commercial fishing fleets and other marine traffic are also strongly affected by Bering Sea storms. High–wind events have become more frequent along the western and northern coasts (Karl et al. 2009). The same regions are experiencing increasingly long sea-ice-free seasons and hence longer periods during which coastal areas are vulnerable to wind and wave damage (Karl et al. 2009).

Forest and Vegetation Changes

The Arctic region, particularly Alaska, is already experiencing major ecological impacts of warming. Rising temperatures have caused northward expansion of boreal forest in some areas, significant increases in fire frequency and intensity, and unprecedented insect outbreaks (Weller 2005; ACIA 2004). During the 1990s, for example, south-central Alaska experienced the largest outbreak of spruce beetles in the world, attributable to the combination of rising temperatures speeding up the life cycle of the beetle and extended drought weakening the trees (Karl et al. 2009). Large areas of dead trees, such as those left behind by pest infestations, are highly flammable and more vulnerable to wildfire than living trees (Karl et al. 2009).

Climate plays a key role in determining the extent and severity of wildfires, as well as insect outbreaks (Karl et al. 2009). The amount of boreal forest in North America that burned annually tripled from the 1960s to the 1990s, and half of the severe fire years on record have occurred since 1990 (Kasischke and Turetsky 2006).

Fire in Alaska is tightly linked to climate (Duffy 2005) and the average area burned per year in Alaska is projected to double by the middle of this century (Balshi et al. 2008). Under a moderate projection of climate change, by the end of this century, the total area burned by fire is projected to triple (Karl et al. 2009). Current projections suggest that, due to increases in burn area per decade, the tundra-dominated landscape on Seward Peninsula will eventually be replaced by deciduous forest (ACIA 2004). In other areas, forested areas are likely to convert to bogs as permafrost thaws (ACIA 2004). Coupled trajectories of future climate and demographics are expected to directly increase the near-term threats to life and property from wildfire in Alaska (Trainor et al. 2009).

Box 2-3 Alaska Native Villages: Limited Progress Has Been Made on Relocating Villages Threatened by Flooding and Erosion

In December 2003, GAO reported that most of Alaska's more than 200 Native villages were affected to some degree by flooding and erosion (GAO, 2003). Since 2003, state officials have identified the growing impacts of climate change, increasing the urgency of federal and state efforts to identify imminently threatened villages and assess their relocation options.

Since 2003, federal, state, and village officials have identified 31 villages that face imminent threats. The U.S. Army Corps of Engineers' (Corps) March 2009 Alaska Baseline Erosion Assessment identified many villages threatened by erosion, but did not assess flooding impacts. At least 12 of the 31 threatened villages have decided to relocate—in part or entirely—or to explore relocation options.

Federal programs to assist threatened villages to prepare for and recover from disasters and to protect and relocate them are limited and unavailable to some villages. In the absence of a lead entity, federal agencies individually prioritize assistance to villages on the basis of their programs' criteria. These criteria do not necessarily ensure that the villages in greatest peril get the highest priority, and although the Corps has assessed erosion threats, there is no lead federal entity to prioritize and coordinate assistance using this information.

Of the 12 villages exploring relocation options, Newtok has made the most progress in its relocation efforts. The Newtok Planning Group, formed in 2006 by federal, state, regional, and village partners, has helped to accelerate the relocation process that the village proactively initiated in 1994. In 2007, the Newtok Planning Group reported that the lack of designated federal and state lead entities to guide, coordinate, and fund assistance impeded village relocation efforts and created uncertainty regarding the fulfillment of environmental analysis requirements under the National Environmental Policy Act. In 2008, the state designated a lead agency for village relocation assistance, and federal, state, and village officials told GAO that a similar lead federal entity is needed. Lead authority could be provided to an existing agency or commission, or a new entity could be formed for this purpose.

Source: GAO, 2009

Sensitivity of Marine Ecosystems and Fisheries

The Gulf of Alaska and Bering Sea support marine ecosystems of great diversity and productivity. Alaska leads the United States in the value of its commercial fishing catch, and most of the nation’s salmon, crab, halibut, and herring come from Alaska (Karl et al. 2009). One of the most productive areas for Alaska fisheries is the northern Bering Sea off Alaska’s west coast (Karl et al. 2009). Recent climate-related impacts observed in the Bering Sea include significant reductions in seabird and marine mammal populations, unusual algal blooms, abnormally high water temperatures, and low harvests of salmon on their return to spawning areas

(Weller 2005). While the Bering Sea Fishery has become one of the world's largest, the area has been undergoing change for several decades. The abundance of Stellar sea lions has declined by between 50% and 80%, and northern fur seal pups on the Pribilof Islands – the major Bering Sea breeding grounds – declined by 50% between the 1950s and 1980s (Weller 2005, ACIA 2004). Populations of some seabird species, including common the murre, have also declined significantly (Weller 2005).

Differentiating among the various factors affecting the Bering Sea ecosystem is a major focus of current and projected research (Weller 2005). However, future projections for the Bering Sea suggest productivity increases at the base of the food chain, poleward shifts of some cold-water species, and negative effects on ice-dwelling species (Weller 2005; ACIA 2004). Warmer temperatures will also affect commercial fisheries, with large northward shifts of fish and shellfish species, associated declines in production of cold-water species such as salmon and pollock, and increased production of other species (ACIA 2004).

Changes In the Diversity, Ranges, and Distributions of Species

The Arctic sub-region that includes Alaska, Chukotka, and the Western Canadian Arctic is home to over 70 percent of the rare plant species that occur only in the Arctic, and home to a number of plant and animal species already classified as "threatened" (ACIA 2004). Species concentrated in small areas, such as Wrangell Island, are particularly vulnerable to the direct effects of climate change combined with competition from migrating non-native species (ACIA 2004).

Increased Stress on Subsistence Livelihoods and Lifestyles

Subsistence makes an important contribution to livelihood in many isolated rural communities, especially but not exclusively for native peoples. Livelihoods that sustain indigenous communities include hunting, trapping, gathering, and fishing. These activities not only make significant contributions to the diet and health of many indigenous populations, but also play large and important social and cultural roles (ACIA 2004). Reduced or displaced populations of marine mammals, seabirds, and other wildlife, together with continuing thinning of sea-ice, have affected the safety, and the dietary and economic well-being of subsistence communities (ACIA 2004). Over the course of this century, the most productive commercial fisheries are likely to become more distant from existing fishing ports and processing infrastructure (Karl et al. 2009). These changes will also affect the ability of native peoples to successfully hunt and fish for food. Particularly for rural communities, adapting to climate change will pose some complex challenges (see Box 2-4).

Technical Working Groups Supporting Alaska's Adaptation Advisory Group

Prior to establishing Technical Work Groups (TWG) to help the Adaptation Advisory Group (AAG) formulate options, the Sub-Cabinet conducted an inventory of the potential ecological and socioeconomic impacts of climate change on Alaska. A thorough analysis of peer-reviewed literature, such as the Arctic Climate Impact Assessment (ACIA 2005), was conducted along with a review of impacts identified by appropriate state agencies, and the compilation put together by the Alaska Climate Impact Assessment Commission (ACIAC 2008). This laid the groundwork for categorizing the impacts into sectors that formed focal points for the TWGs. The AAG formed the TWGs to develop options to address potential impacts in four sectors: Health and Culture, Public Infrastructure, Natural Systems and Other Economic Activities. The four sectors are not

entirely discrete; over the course of the strategy development process, the AAG and TWGs dealt with a number of issues in defining the scope and addressing potential overlaps among the impact categories.[1]

Health and Culture

This sector focuses on the human health, cultural, recreational, and quality-of-life impacts of climate change on Alaskans. Climate change is projected to be associated with increases in some diseases that flourish in warmer temperatures (such as paralytic shellfish poisoning). Water quality and availability—a decrease in quality of potable water due to drought, saltwater intrusion, and other issues—will also have health consequences. The health and culture of subsistence lifestyles are especially at risk, due to diminishment or change of the subsistence diet, due, in part, to reduced availability of traditional food supplies (waterfowl, fish, marine mammals, sea vegetables, berries, and plant medicines). Injuries, due to thinning and other changes in ice, wildfires, and insect bites and stings, are also likely to increase.

Box 2-4. Vulnerability to Climate Change and the Arctic

The majority of the Arctic's residents live in small to medium-sized communities, in many cases located in remote regions and dependent on climate-sensitive livelihoods, including hunting, fishing, herding, and forestry. This dependence on climate-sensitive resources and infrastructure will make the Arctic particularly sensitive to climate change. Climate change is already threatening activities such as hunting while raising questions about the long-term sustainability of traditional way.

In the Arctic, adaptation is increasingly prominent in policy discussions, with national and regional governments, non-governmental organizations, communities, and national and international research bodies stressing the need to strengthen the ability of communities, regions, and economic sectors to adapt to current and future climate change.

To identify adaptation needs and inform the development of policies to reduce the negative impacts of climate change, it is crucial to identify and characterize vulnerability. Vulnerability can be thought of as the capacity to be wounded: it is a measure of the susceptibility to harm in a system in response to a stimulus or stimuli. In this context, the stimuli are climate-related risks, and the "system" can range from an individual or household unit to the national state. In turn, vulnerability is related to both exposure and sensitivity to climatic risks and the adaptive capacity to deal with those risks.

Non-climatic factors can amplify or attenuate vulnerability to climatic stress. These include sources of livelihoods, assets, access to resources, globalization, institutional networks, education, gender, race, ethnicity, and poverty. These determinants are influenced by social, economic, cultural, and political conditions. Identifying viable options for adaptation requires both identifying technological and engineering-based responses and also understanding and applying the lessons of vulnerability science to the Arctic.

Source: Ford and Furgal, 2009.

Natural Systems and Associated Economies

This sector examines the impacts of climate change on biodiversity, ecosystem health, and associated human economic activity. In general, climate is projected to result in changes in growing seasons, and changes in the distribution, quantity, and ranges of many species. Consequently, this sector comprises a wide range of subsectors, including agriculture; boreal and temperate forests and dependent species; tundra and alpine ecosystems and dependent species; freshwater ecosystems and dependent species; marine, sea ice, coastal

[1] Additional information on the initial characterization of sectors can be found on Alaska's Climate Change Web site, associated with the first meeting of the AAG: http://www.climatechange.alaska.gov/aag/aag.htm

environments, and dependent species; other warm temperature impacts on animals; commercial and sport fishing; subsistence hunting, trapping, and gathering; and sport hunting, tourism, and wildlife viewing.

Public Infrastructure

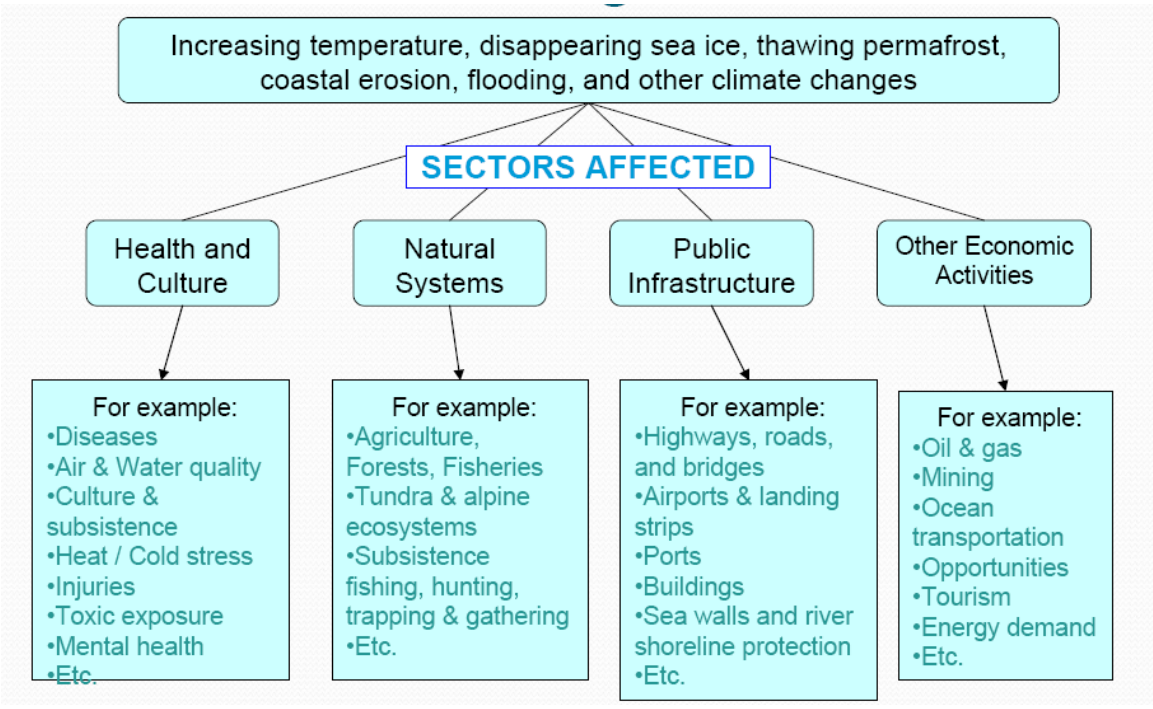
This sector addresses the physical impacts of climate change on Alaska's built environment and transportation options. Infrastructure includes both publicly- and privately-owned infrastructure (the word public refers to "use" rather than "ownership"). Types of infrastructure considered by this sector include road transportation (highways, roads, and bridges), air transportation (airports and landing strips), sea walls and shoreline protection, utility and fuel infrastructure, landfills, sewage and septic systems, and water systems. As discussed above, impacts from thawing permafrost, increased freeze-thaw cycles, and erosion all pose challenges to road infrastructure and buildings. Other forms of infrastructure are similarly susceptible to these and other changes, including increased fire risk, increased coastal fog (affecting flying conditions), and other impacts.

Other Economic Activities

This sector focuses on Alaskan economies affected by a changing climate that are not directly dependent on living ecosystems. Key industries initially examined by the TWG included oil and gas, mining, ocean transportation and other transportation, tourism, and other business impacts and opportunities. The types of impacts addressed by this sector include the effects of climate change on industries such as oil and gas, which are expected to be negatively affected by difficulties in tundra ice travel and effects of sea level rise and erosion on buried or above-ground oil and gas pipelines. The sector also focuses on economic opportunities, such as increased shipping opportunities.

Figure 2-7 provides an overview of the four sectors and the issues covered by each TWG.

Figure 2-7. Effects of Climate Change on Each Sector.



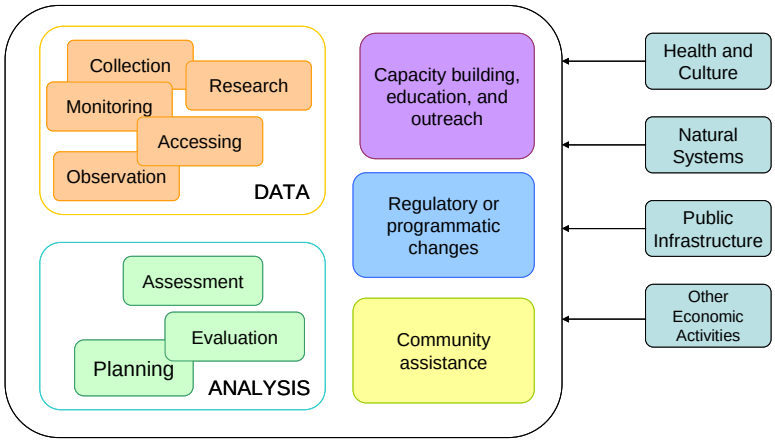
CHAPTER 3. OVERVIEW OF ALASKA'S ADAPTATION STRATEGY

Climate change presents both potential impacts and opportunities for Alaska and the Alaska economy. Developing a viable set of policy and other recommended actions for addressing these impacts and opportunities faces a number of challenges: These challenges include:

- Actions to address impacts cut across the jurisdictions of different agencies at all levels of government
- Decision-makers need access to science that is accurate, relevant, and understandable
- Current regulations and legislation may limit Alaska's ability to take some adaptive actions
- Decision-making powers and authority are decentralized within state government
- Information is decentralized and housed in the government, at universities, and within the traditional knowledge of rural communities
- Implementation of the strategy will happen in a resource-constrained financial environment
- Different adaptation options can conflict with each other or with broader state goals and objectives
- Immediate, near-term, and long-term actions are all needed.

The recommendations presented in this report are designed to address these challenges in a number of ways. First, as illustrated in Figure 3-1, recommendations focus on developing and making data accessible, evaluating and assessing baseline and changing conditions in both natural and human systems, building capacity, and examining regulatory or programmatic challenges. The recommendations developed by the Research Needs Work Group (RNWG), which include and were informed by the recommendations developed by the Adaptation Advisory Group (AAG), also help to ensure that data and analysis needs are met. Box 3-1 summarizes some of the recommendations of the RNWG, which have applicability beyond those specific sectors. Identified research needs are also discussed in the individual sector chapters.

Figure 3-1. Improving Alaska's Adaptive Capacity



Second, in addition to sector-specific recommendations, the AAG developed a number of recommendations that represented broader considerations, referred to as "Common Themes." These recommended actions address coordination across and between state government and other governmental and non-governmental entities, provide for the delivery of services and information to communities, and promote the coordination of state efforts to evaluate and address climate changes in ways that cut across agencies' jurisdictions.

Box 3-1. Broad Recommended Research Needs

The Research Needs Work Group (RNWG) has emphasized several needs both to assist implementing the recommendations of the advisory groups and to help the State of Alaska better understand the impact of climate change on its economy and livelihoods. As with the research needs identified in Box 8-4 in Chapter 8, a number of these research needs have broad applicability across the sectors. The following is a list of some of these broad research needs:

- Develop regional economic models to quantify climate change impacts on communities and provide input to the National Environmental Policy Act (NEPA) process.
- Revise flood risk maps.
- Develop sea level rise projection maps for coastal areas throughout Alaska, accounting for local isostatic rebound in conjunction with global sea level rise predictions.
- Downscale climate modeling projections to the local or regional level to aid communities in planning.
- Conduct a comprehensive inventory of the wide range of data collection, monitoring efforts, and research projects underway or planned in relation to the impacts of climate change on the environment.
- Use the SPOT satellite data system or others to track changes in permafrost extent and work to develop projection maps for changes in extent over the next 100 years, based on climate change projections.
- Refine general circulation models for better understanding of regional variations within Alaska.
- Assess the degree and rate of thawing of submarine permafrost deposits in coastal areas due to warming sea temperatures.

For additional information on each recommendation, and for a broader set of identified needs, see Research Needs Work Group (2009). See also the broad research needs identified in Chapter 8, Common Themes.

Third, the recommendations developed by the AAG represent a combination of near-term and long-term actions, including the development of baseline information and studies to promote action in the long-term. In combination with the actions undertaken and policy options recommended by the Immediate Action Work Group (IAWG), the AAG recommendations strive to meet the immediate needs of rural communities as well as the near- and long-term needs of all Alaskans.

Last, the recommendations emphasize the broad principles of coordination and cooperation, integrating climate change into existing practices and decisions, and building on existing programs and activities. The recommendations were also selected to meet a number of important evaluation criteria, such as effectiveness in reducing the potential impacts of climate change and costs of the actions (see Box 3-2).

Box 3-2. Criteria Used to Identify High Priority Recommendations

Significance: Magnitude/extent of economic / sectoral impacts, irreversibility of impacts.

Benefits and Effectiveness: Effectiveness of recommended option in adapting to climate change by reducing adverse impacts or taking advantage of opportunities, as well as producing other, ancillary benefits.

Costs: Magnitude of public and private sector costs relative to benefits (initial costs and costs over time).

Feasibility: Realistic to implement (within state authority; legal, administrative, financial, technical and other resources exist)?

Timing: How urgent is adaptive action, given timing of impacts, planning and implementation periods for action, and other factors?

Adaptive Capacity: How well can natural and human systems adapt to climate change in the absence of the recommended action?

CHAPTER 4. PUBLIC INFRASTRUCTURE

The Public Infrastructure sector addresses the observed and projected impacts of climate change on Alaska's infrastructure and recommends priority adaptation actions that the State of Alaska should take to address the vulnerabilities associated with these impacts. Box 4-1 summarizes the mission statement for the sector.

Box 4-1. Public Infrastructure Mission Statement

Develop a system to increase likelihood that Alaska has sustainable infrastructure to support communities in an uncertain environment.

Overview of Public Infrastructure Options		
	Option Name	Level of Support
PI-1	Data Collection, Analysis, and Sharing	Unanimous
PI-2	Current Best Practices	Unanimous
PI-3	Build to Last; Build in Resiliency	Unanimous

Impacts and Vulnerabilities

Infrastructure is the platform upon which society functions. Public Infrastructure is defined to include essential facilities and utilities under public, cooperative, or private ownership that deliver goods and services to communities. Common examples in Alaska include, but are not limited to:

- Highways and bridges, railways
- Airports, landing strips
- Harbors, docks, and ports
- Public buildings (schools, fire stations, health clinics, post offices, etc.)
- Seawalls and river shoreline protection
- Water, sewer, stormwater and solid waste facilities and systems including related piping and utilidors, sewage lagoons, and dumps/landfills
- Publicly owned or essential utilities and communication facilities, distribution systems, and power grids
- National defense infrastructure, military installations

Climate change in Alaska is creating the following potential impacts to public infrastructure, with significant regional variation (ACIA 2004):

- Increased storm surges, flooding, and erosion
- Decreased duration (cold season) and extent (warm season) of shore fast sea ice
- Increasing freeze/thaw cycles
- Changing wind and precipitation
- Increased storm frequencies and duration
- Warming and thawing permafrost
- Increased fire risk

These changes are impacting infrastructure in a number of ways.

Problems associated with thawing permafrost, including effects on the foundations of buildings and roads, are well documented and often dramatic (Larsen et al. 2008). (Also see, for examples, ACIA 2005; Nelson et al. 2003; and Robinson et al., (in prep); IAWG 2009; Stephani et al. 2008). As frozen ground thaws, existing public buildings, roads, bridges, coastal structures, pipelines, utilidors, and airports are likely to be destabilized, requiring substantial maintenance, rebuilding, and investment. Thawing permafrost can disrupt community drinking water supply. For example, the community drinking water source lake in Kwigillingok disappeared in June 2005 when the permafrost liner was lost and the lake drained overnight. The same risk of rupture exists for sewage lagoons. The added risk of contamination of surrounding areas is also a concern if the impermeable barrier for a sewage lagoon is lost. Increased failure rates and dramatically increasing operations and maintenance costs result from changing freeze/thaw cycles that cause shifting soils in once permanently frozen ground. Transportation routes and pipelines are particularly susceptible and are already being disrupted and disturbed in some places by thawing ground, and this problem is likely to expand. Future development will require new design elements to account for ongoing warming (see recommendation PI-3).

The Alaska Department of Transportation and Public Facilities (ADOT&PF) Northern Region is currently spending approximately $10 million to combat the effects of warming permafrost on Alaska's highway system. Increased thaw and warming permafrost related to warming temperatures will increase the amount of funding required to address the problem. ADOT&PF has already had to relocate entire airports due to flooding/erosion, and there are several other airports that are being studied for relocation.

Utilities have reported that telecommunication towers are settling due to warming permafrost. United Utilities, for example, has stated that "warm permafrost is a result of global warming" and is seeking funds for cost overruns in the Yukon-Kuskokwim Delta (see Hamlen 2004).

Changes such as declines in river flows and water levels, higher water temperatures, storm surges, and heavier short duration rainfalls may produce a decline in hydroelectric power, declining water supplies, water quality problems, flash floods, and overtaxing of drainage facilities. The U.S. Army Corps of Engineers (USACE) reports that increasing erosion along the Bering Sea coast means the villages of Shishmaref, Kivalina, and Newtok in western Alaska will need to be moved in the next 10 to 15 years, at an estimated cost of up to $455 million (see Larsen et al. 2007)

The U.S. Government Accountability Office (GAO) has reported that "flooding and erosion affect 184 out of 213, or 84 percent, of Alaska Native villages to some extent. While many of the problems are longstanding, various studies indicate that coastal villages are becoming more susceptible to flooding and erosion caused in part by rising temperatures.

Coastal storms threaten infrastructure critical for community viability (harbors, docks, schools, fuel tanks, runways, power plants, water/sewer provisions, and more) by eroding sea walls and other shoreline protection and exposing infrastructure to erosion, flooding, and storm surge. In December 2004, a storm surge contaminated the drinking water supply of Nunam Iqua with salt water, creating an emergency that required drinking water to be flown into that community.

In May 2009, eastern interior Alaska saw record high temperatures that quickly melted snow, pushing water into the Yukon River. That, combined with a winter of heavy snowfall and thick river ice made perfect conditions for ice jams that can act as dams that flood riverside. In Eagle and Eagle Village, an old Native cemetery was flooded, power and phones were turned off, the clinic and Village Public Safety Officer (VPSO) office were lost, and all buildings and houses along the riverfront in the old village were flooded.

Reduced sea ice allows higher waves and storm surges to reach the shore. It will enhance ocean access to northern coastlines. Communities and infrastructure are already threatened; some are being forced to relocate, while others face increasing risks and costs (ACIA 2004 and ACIA, 2005).

Ongoing erosion and flooding concerns have caused problems for a number of years in Kivalina. The geotextile bag seawall installed in 2006 was ineffective at arresting erosion and was severely damaged, with some sections completely destroyed during its first minor storm event of 2006. Erosion is threatening the waste storage containment area located at the dump site. This is a potential environmental catastrophe for the surrounding water bodies (IAWG 2008). A partially completed USACE project is providing armor rock protection for portions of the shoreline (IAWG 2008).

Erosion, flooding, and fires are threatening Koyukuk. The entire village of Koyukuk lies within the floodplain of the Yukon River. Erosion occurs anytime the river is open and especially during high flow events on the Yukon River. These events happen throughout the year, including floods during spring breakup ice jam events; spring/summer/fall significant rainfall events; wind; and permafrost thaw at Koyukuk and upstream. These floods are often severe, inundating a majority of the village and sometimes requiring evacuation of citizens to other villages. These problems have been persistent and serious enough—often flood warnings provide only a two hour window to evacuate—that the community has begun planning efforts to relocate themselves to higher ground above the floodplain of the Yukon River upon nearby Koyukuk Mountain (IAWG 2008).

Newtok facilities—both public and private—have already been severely damaged by erosion and storm surge flooding due to lack of sea ice, and with continued erosion and destruction of public and private facilities anticipated to be imminent. Problems endemic to many rural Alaska communities, such as lack of adequate drinking water, and sanitary sewage disposal, and available usable land space have been worsened by the erosion and flooding (IAWG 2008).

Shishmaref has been threatened by erosion for many years with recent increases due to the lack of sea ice during the fall storm season. A partially completed USACE project is providing armor rock protection for portions of the shoreline (IAWG 2008).

Problems associated with increased rates of coastal erosion are the result of storm activity and wave action eroding shorelines once protected by shore-fast sea ice. The photo on the next page shows how coastal storms have eroded the foundations of structures in western Alaska. This problem is expected to become chronic as the climate warms, sea ice retreats, and coastal storms become more frequent.

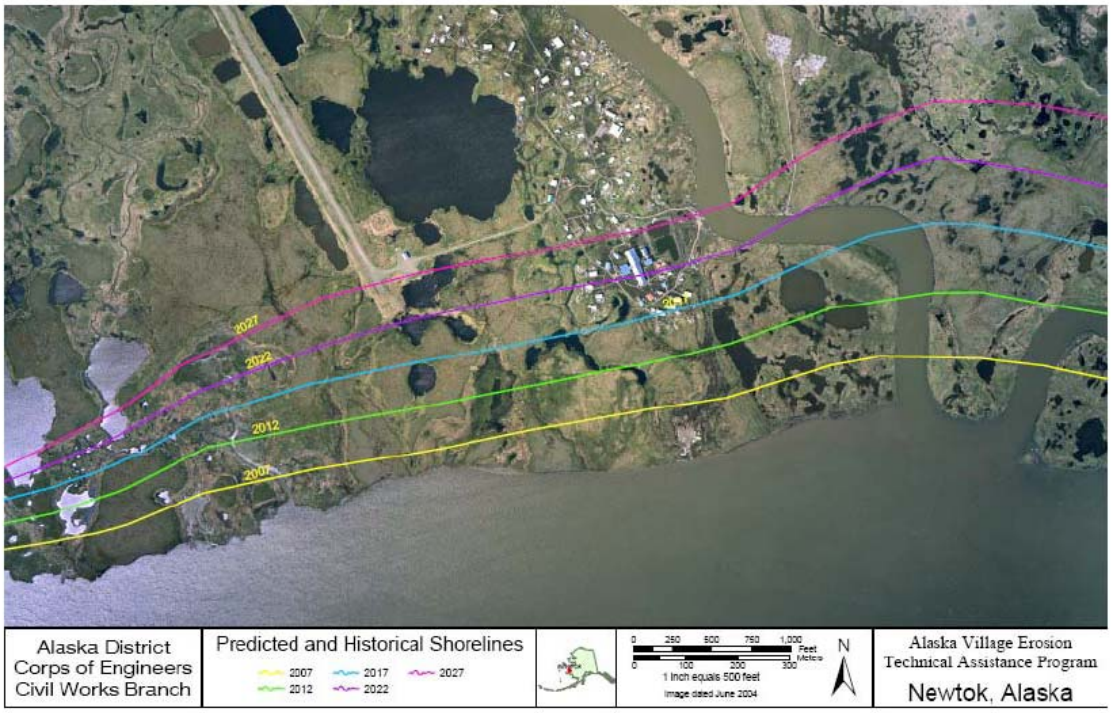


Image Source: Bruce Sexauer, U.S. Army Corps of Engineers, Alaska 2006

Projected Coastal Erosion at Newtok, Alaska through 2027 (Larsen et al. 2007)

The Vulnerability of and Risk to Public Infrastructure is Growing. Most of these impacts are not new to Alaska. What is new is the increased magnitude, rapid development and progression, and increasing geographic extent of these impacts and affected communities. In some locations, entire Alaskan villages are at immediate risk. In other locations, critical roads and public buildings are at risk. The immediacy and level of risk varies by region and locally within regions, adding challenges that are difficult to address.

Reliable and sustainable infrastructure is the foundation upon which the future of Alaska will be built. To ensure that Alaska is prepared to optimize investment opportunities and demonstrate that the return on investment for Alaska's current and future infrastructure provides good value for the state and the nation, an ongoing, aligned statewide effort to monitor, analyze, and proactively adapt to Alaska's changing environment is required. Larsen et al., (2008) found that undertaking plausible adaptation strategies in the near-term could reduce the net amount of infrastructure at risk by over 40% over the course of several decades.

Adaptive Capacity for Existing Infrastructure is Low; New Construction Provides More Opportunity to Incorporate Adaptive Techniques. The adaptive capacity of public infrastructure is generally quite low. Most public infrastructure is hard and fixed (for example, roads, airport runways, bridges, buildings) and cannot easily alter its alignment, elevation, or structural foundation to accommodate coastal erosion or increased flood risk. When modification is possible it is typically very expensive. There is high potential for adaptive capacity in new infrastructure and construction through planning for projected climatic changes and updated design and siting.

Increased Communication and Coordination is Critical. Alaska needs an entity that can increase communication and coordination in public infrastructure climate change adaptation across agencies, communities, and scientific and applied researchers. Impacted and potentially impacted communities, agency funders, and researchers often do not know about each other's planning efforts; infrastructure improvement projects; funding opportunities; or research, materials testing, and demonstration project results. Information is not being shared with all whom could benefit. The lack of routine coordination and information sharing raises costs, creates redundancies, and adds inefficiencies to efforts to adapt Alaskan infrastructure. An entity is needed to facilitate communication both horizontally among partner agencies and vertically among the various layers of government and organizations.

Left: Impacts from thawing permafrost on Alaska Highway north of Beaver Creek (Source: Prof. Billy Connor, University of Alaska Fairbanks 2009, Permafrost and the Alaska Highway) Below: Storm surge undercutting western Alaskan coast (Source: IAWG Final Report)

Photo courtesy U.S. Army Corps of Engineers, Alaska

"Sink hole" on shoulder of Goldstream Road 5 mi N. of Fairbanks (Source: Prof. Vladimir Romanovsky, University of Alaska Fairbanks; UCAR 2007)

Thermokarst depression on the edge of the Geophysical Institute UAF parking lot (Fairbanks, Alaska). Surface disturbance related to the parking lot construction triggered the permafrost degradation and ground ice melting. This created a subsurface void within the ground. The roof of this void collapsed when surface and ground waters saturated the soils during spring and beginning of summer. Photo by Prof. Vladimir Romanovsky, University of Alaska Fairbanks.

Bluff erosion & permafrost thaw, Shishmaref (c 2002) Kawerak

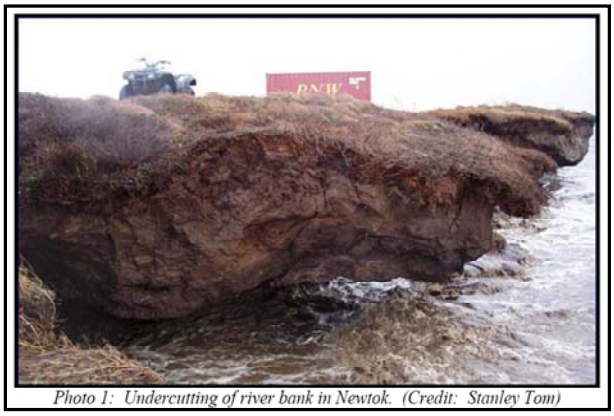


Photo 1: Undercutting of river bank in Newtok. (Credit: Stanley Tom)

Photo 5: Flooding during coastal storm in Newtok. (Credit: Stanley Tom)

Four-story apartment building (not public infrastructure) in Cherski, Russia, North-East Yakutia (upper Kolyma River) was destroyed because of permafrost thawing and differential settlement in its foundation. It took only several days between the appearance of first cracks in the walls and the partial collapse of the building. Photo by Prof. Vladimir Romanovsky, University of Alaska Fairbanks.

Public Infrastructure Adaptation Strategy

Box 4-2. Overview of Public Infrastructure Recommendations

This is a systems approach to reduce the impacts of climate change on Alaska's public infrastructure by accomplishing actions under three policies/programs:

PI-1: Create a Coordinated and Accessible Statewide System for Key Data Collection, Analysis, and Monitoring

Baseline data on the condition of current infrastructure and on regional and local environmental conditions needs to be collected. The locations and characteristics of the problems need to be identified as well as information on what is working and what is not working. Based on the best science and collected empirical data, Alaska needs to predict its future. The Environmental Atlas of Alaska must be updated. The resulting information needs to be available to all interested parties.

PI-2: Promote Improvements that Use the Current Best Practice

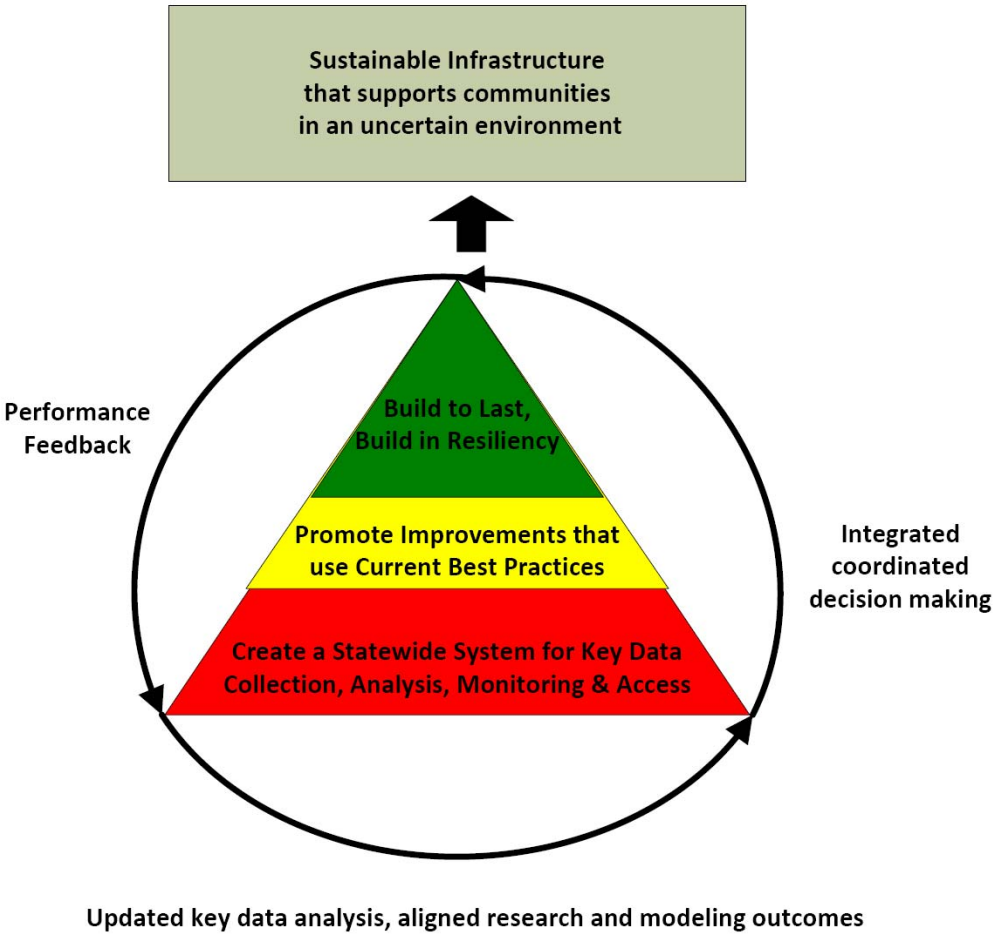
Managing the risks and/or reducing the uncertainties associated with climate change will take time. Promoting sustainability, reducing operating costs, and protecting/extending the service life of existing infrastructure is always worthwhile. Simultaneous with PI-1, improvements to existing infrastructure that are worth doing regardless of climate change effects should be enacted.

PI-3: Build to Last; Build Resiliency into Alaska's Public Infrastructure

As PI-1 and PI-2 are enacted and we learn more as a result, new and upgraded infrastructure needs to be sited, planned, designed, and built to be resilient and sustainable in an uncertain environment. Systematic feedback with a performance review and analysis needs to be integrated into public infrastructure funding, development, construction, and operations so that planners and builders use "what works" and codes and standards are assessed and improved as needed to achieve the best results.

Box 4-2 summarizes the recommendations for Alaska's public infrastructure. The recommended adaptation options are designed as an integrated system (Figure 4-1). The three policies (in the triangle) build upon and support one another. Continued, routine communication and feedback is essential to adapt and refine actions taken over time.

Figure 4-1



Required Actions. The Public Infrastructure Technical Work Group (PI TWG) policy system to adapt Alaska's public infrastructure to a changing climate requires that four actions take place for both short and long term success.

1 **There must be across-the-board improvement in the collection, coordination, and accessibility of information**. This includes information on the condition of existing infrastructure and the environment where it is located; information on updated forecasts and trend analysis (such as rate of erosion, permafrost thaw, flooding); and ready access to community plans and infrastructure design.

2 **A program partner should be identified with the capability to organize and host an information center or clearinghouse. Collection, coordination, and communication of pertinent information needs to start immediately.** The center would standardize, coordinate, and link data among the many differing sources to enable queries and integrated use. It would also track and index readily available and cost-effective infrastructure development techniques (those that are working and those that have not worked), materials development and testing results, design development, and contact information.

3 **Create/designate an Immediate Action Work Group (IAWG)-like entity to assume a coordinating role now.** We recommend this group be permanent and be action-oriented, focusing on aligning and coordinating (not regulating) decisions. Impacted and potentially impacted communities, agency funders, and researchers frequently do not know about each other's planning efforts, infrastructure improvement projects, or funding opportunities. The proposed entity is needed to coordinate communication horizontally among partner agencies and vertically among levels of government and other stakeholders. It will streamline processes, eliminate duplicate efforts, minimize unnecessary effort, and minimize transaction costs of developing and carrying out a statewide system. A State of Alaska Executive Order is likely needed to establish this entity or structure. A senior-level executive should be manager. Implementation will be through existing agencies and authorities.

4 Standing still while waiting for improved climate change data and forecasts is not an option, therefore **systematically use current best practice when retrofitting existing and building new infrastructure.** Many of these improvements will be worth doing regardless of climate change effects.

The PI TWG 3-policy system to achieve sustainable infrastructure that supports communities in an uncertain environment is predicated upon these actions.

Research will be a critical part of these recommendations, as described in Box 4-3. The recommendations are also intended to build on existing public and private sector programs and activities as described in Box 4-4. Both of these boxes appear at the end of this chapter.

		Type of option										Implementation				
		Coordination														
Option (number)	Short option name	State interagency coordination	Community response and assistance	Data management	Access to data and "knowledge" sharing	Data collection (research, monitoring, observation, etc.)	Regulatory / programmatic change or addition	Assessment, evaluation, or planning	Capacity building , education, outreach	Direct or indirect financial assistance (e.g., tax incentives)	Capital improvements	Requires new institutions/ government agency	Requires new staffing	Requires funding	Requires new legislative authority	Lead role for state government
PI-1	Data Collection, Analysis & Sharing	✓		✓	✓	✓	✓	✓	✓			New IAWG-like coordinating entity and new clearinghouse needed. A senior-level manager for each needed.			?	Yes, with partners.
PI-2	Current Best Practices	✓	✓		✓		✓		✓		✓				?	
PI-3	Build to Last, Build in Resiliency	✓				✓	✓		✓		✓					

Description of Public Infrastructure Recommendations

This section describes the options recommended for the Public Infrastructure sector.

PI-1 Create a Coordinated and Accessible Statewide System for Key Data Collection, Analysis, and Monitoring

The goals of Public Infrastructure Policy 1 (PI-1) are to establish a coordinated and integrated system to:

- Observe, collect, catalog, and disseminate data on the existing condition of public infrastructure and the environmental conditions where it is located.
- Use this information to prepare forecasts and trend analysis yielding up-to-date rates of erosion, permafrost thaw, and flooding etcetera by region.
- Systematically assess the vulnerability of Alaska's public infrastructure in communities to establish the local level of risk.
- Share information in a useable format with communities to enhance understanding of climate change and the effect on the community and to facilitate and coordinate project planning and development.

Actions needed to achieve these goals include:

1 Standardize information to be gathered. Establish a baseline and benchmarks so that data from differing sources can be compared and analyzed over time, regional geographic areas, and across agencies/parties. Set up system to consolidate and link data to enable queries and integrated use.

2 Gather two types of data: on the condition of existing infrastructure and on regional and local environmental conditions. Specific environmental data to gather routinely are:

- soil temperature
- air temperature
- precipitation
- surface runoff
- shore-fast sea ice duration (cold season) and extent (warm season)
- coastal wind speed and duration

Organize data around designated climatic regions that are based on geopolitical boundaries. Identify and fill data gaps over time. Use data to run predictive models. Prepare scientifically sound projections of climatic conditions and local environmental conditions including up-to-date rates and maps for:

- soil temperatures
- coastal and riverine erosion
- event intensity
- 100 year floodplain

This information should also be used concurrently to update the “Environmental Atlas of Alaska."

3 Vulnerability assessments. Review agency infrastructure plans for consistency and resilience to climate change to identify and conduct systematic hazard analysis based on up-to-date regional climate data and projection of future conditions. Produce local vulnerability assessments to rank the risk level or vulnerability of existing infrastructure in communities. Determine the status, capability, and vulnerability of current infrastructure. Determine the useful life of current infrastructure. Share this information in an easy-to-understand format to facilitate its use by local, tribal, state, and federal users. Distribute results to:infrastructure designers; engineers and professional organizations; and municipal/tribal governments, state/federal agencies, and non-governmental organizations (NGOs). The environmental data and modeling completed in this step is also needed to update engineering designs and codes (policy PI-3) to reflect changing conditions.

4 Review agency infrastructure plans for consistency and resilience to climate change to identify and resolve discrepancies. Ensure future plans for use of current best practices to repair, renovate, retrofit, replace, or relocate.

5 Use a performance feedback loop to improve policy coordination; update analyses based on new information on weather, economic assumptions, or demographic changes, and integrate results of research, foundation, and material testing. Continually improve data alignment, scenarios, and assumptions for future infrastructure policies and plans.

6 A ”go to” center or clearinghouse is needed to standardize, coordinate, and link data among the many differing sources to enable queries and integrated use. The State of Alaska can play a coordinating role to bring state and federal agencies, university resources, professional organizations, local and tribal stakeholders and NGOs together. A coordinating agency must determine what technology is needed for systems to “talk” to each other and what funding is needed to systematically identify, collect, analyze, and disseminate data.

These efforts are scalable; they can expand (or shrink) over time as resources are available. Work can begin immediately using existing resources and data—a starting place is to target a region or location known to be at high risk with vulnerable public infrastructure. Enlarge and build the effort over time.

PI-2 Promote Improvements that Use Current Best Practices

The goal of Public Infrastructure Policy 2 (PI-2) is to use current best practices to make infrastructure improvements that are worth doing regardless of climate change’s effects. This is both critical and practical because Alaska can’t stand still while efforts proceed in gathering and analyzing data and reducing the uncertainties associated with climate change. In the interim, PI-2 focuses efforts on accomplishing actions that promote sustainability, reduce operating costs, and protect/extend the service life of existing infrastructure.

Examples include:

- the use of existing technology such as adjustable and/or mobile building foundation systems,
- building foundations that use thermosiphons or thermopiling,
- protecting facilities from flood or erosion damage,
- providing energy conservation upgrades,

- long-term planning and preparedness,
- building local capacity for operations and maintenance,
- promoting energy-efficient technologies,
- using alternative energy sources, or
- building with better materials.

Implementation of PI-2 can begin immediately by:

1 Routinely gathering and making available information on measures and practices that are, and are not, working to adapt infrastructure. A program partner should be identified with the capability to organize and host an information center or clearinghouse for tracking sustainable and resilient best practices. This center/clearinghouse could index readily available and cost-effective infrastructure development and protection techniques that are working (and those that have not worked), materials development and testing results, development designs, contact information, and more.

2 Integrating factors into agency funding and prioritization formulas (such as Alaska DOT&PF Statewide Transportation Improvement Program-STIP evaluation or Village Safe Water Capital Improvement Project) to reward consideration of climate change and use of current best practices. For example, funding agencies could give higher scores to projects that:

- Including an engineering peer review process incorporating current best practices, as catalogued by the to-be-established information clearinghouse/center (for smaller projects).
- Including a value engineering review process that demonstrates improved performance, reliability, quality and life cycle costs (for larger projects).
- Presenting a project site or community vulnerability assessment to document its location compared to expected hazards.
- Commit to a schedule of reporting environmental data and infrastructure performance (to the to-be-established information clearinghouse/center) following project construction.

By systematically rewarding behaviors that promote the construction of more resilient and sustainable infrastructure, the State will be better prepared for the future.

PI-3 Build to Last; Build Resiliency into Alaska's Public Infrastructure

The goal of Public Infrastructure Policy 3 (PI-3) is to build to last by building resiliency into Alaska's public infrastructure. This can be done by:

- building in locations outside of hazard zones (that have been updated and defined using climate change modeling),
- building infrastructure to withstand the expected forces at the location over the life of the infrastructure, and
- designing and locating public infrastructure to meet acceptable risk limits.

Ultimately, life cycle cost analysis will determine the best value solution. The cost of renovating existing structures within the hazard zone in comparison to relocation or reconstruction at an alternate location outside

the hazard zone will require systematic evaluation of infrastructure capital cost, operating cost, and a risk projection of potential useful life. At existing at-risk locations, a financial investment "tipping point" will need to be calculated after which relocation will become the ultimate solution.

To be successful, decision-makers need updated hazard zone locations; revised data on expected local forces and conditions for which infrastructure must be designed; research and testing of foundation designs and construction methods that can adapt to or withstand expected impacts; and modification of some engineering design standards, building codes, and operation and maintenance practices.

Four points to achieve are:

1. Update/create appropriate design standards, codes, and ordinances.
2. Meet or exceed infrastructure design life.
3. Optimize life cycle costs/asset management practices.
4. Create resilience to withstand expected weather events and a changing environment. Design infrastructure using the best science combined with appropriate building codes and engineering standards.

There are many ongoing applied research and technology projects looking to find ways to better predict climate conditions, more routinely locate infrastructure, and design infrastructure to better adapt to new conditions.

The challenge—and why an entity that can increase communication and coordination is so strongly needed—is that impacted and potentially impacted parties do not routinely know about these and other efforts, nor are the results being routinely shared with all who could benefit. The lack of routine coordination and information sharing raises costs which creates redundancies and adds inefficiencies to efforts to adapt Alaskan infrastructure. **To be successful in implementing PI-1, PI-2 and PI-3, an IAWG-like entity that can assume a coordinating role should be created/designated now.**

Box 4-3. A Sampling of Relevant Current Activities

The examples presented below are not intended to be exhaustive, but rather to illustrate ongoing and proposed initiatives and activities.

There are many ongoing applied research and technology projects seeking to find ways to better predict climate conditions, more routinely locate infrastructure, and design infrastructure to better adapt to new conditions.

A few relevant efforts are listed here:

1. SNAP-UAF (University of Alaska Fairbanks) hosts the Scenarios Network for Alaska Planning (SNAP), a collaborative organization linking the University of Alaska; state, federal, and local agencies; and NGOs. The primary products of the network are (1) datasets and maps projecting future conditions for selected variables, and (2) rules and models that develop these projections based on historical conditions and trends. Improvements to make the system and its results more user friendly are needed.

2. UAF Permafrost Research Project (partners: US Federal Highway Administration, Yukon Highways & Public Works, Alaska University Transportation Center, Transport Canada, Université Laval, Public Works and Government Services Canada). A 10-year project is testing 10 adaptive techniques including: full air convection embankment (ACE), full heat drain embankment, covered ACE shoulder treatment, uncovered ACE shoulder treatment, heat drain should treatment, longitudinal convection culverts, heat drain shoulder treatment with insulation, snow-free side slopes, grass covered side slopes, and light colored bituminous surface treatment (BST).

3. Cold Climate Housing Research Center –Sustainable Northern Shelters Project was developed to address the needs of sustainable rural housing for northern climates.

4. Institute of Social and Economic Research-University of Alaska Anchorage (ISER–UAA) development of a preliminary and limited database of existing public infrastructure created to project the added cost (above normal wear and tear) from the effects of climate change on infrastructure at risk. See Larsen et al. (2008) and Foster and Goldsmith (2008).

5. Alaska Sea Grant Marine Advisory Program (MAP) has regional agents and specialists in 10 coastal communities statewide. MAP works in partnership with the AK Cooperative Extension Service (CES). These university organizations combine outreach and extension to residents with the intent to reach marine dependent businesses and other stakeholders, including fishing, tourism, transportation, subsistence, recreation and lifestyle users, local gov'ts, etc. They are presently in the early phases of developing an initiative for community-based climate change adaptation outreach.

Box 4-4. Public Infrastructure Recommended Research Needs

The Research Needs Work Group identified several needs both to assist in implementing the recommendations and to help the State of Alaska better understand the impacts of climate change on its public infrastructure:

OVERARCHING RESEARCH NEEDS

PI/RN-1.1 Down-scale to increase the spatial and temporal resolution of climate projections.

PI/RN-1.2 Improve access to authoritative, defensible, and timely information to support analysis and decision-making for climate change adaptation.

PI/RN-1.3 Develop a strategic plan for collection and evaluation of data to economically plan, develop, and manage public infrastructure in a sustainable manner.

SPECIFIC RESEARCH NEEDS

PI/RN-2.1 Update engineering and building codes, standards, and practices for infrastructure and other structures in vulnerable areas.

PI/RN-2.2 Establish an integrated baseline inventory on the location and condition of public infrastructure and continue to monitor and analyze post-construction performance.

PI/RN-2.3 Integrate national and international research and products into infrastructure research and planning in Alaska.

HC/RN-8.2 Update the Environmental Atlas of Alaska and Engineering Design Information System (AEDIS).

For additional information on each recommendation, and for a broader set of identified needs, see Research Needs Work Group (2009). The numbering system above refers to the last two subsection numbers in the appropriate chapter in the report.

CHAPTER 5. NATURAL SYSTEMS

The Natural Systems sector addresses the observed and projected impacts of climate change on Alaska's ecosystems and the services they provide, and recommends priority adaptation actions that the State of Alaska should take to address the impacts and vulnerabilities associated with these impacts. Box 5-1 summarizes the mission statement for the sector.

Box 5-1. Natural Systems Sector Mission Statement

Sustain natural ecosystem services in Alaska that meet society's essential needs, through adaptation to changing environmental conditions.

Overview of Natural Systems Options		
	Option Name	Level of Support
NS-1	Fisheries Management	Unanimous
NS-2	Wildland Fire Management	Unanimous
NS-3	Freshwater Management	Unanimous
NS-4	Invasive and Eruptive Species Prevention & Response	Unanimous
NS-5	Adaptive Fish & Wildlife Management	Unanimous
NS-6	Support Local Sustainable Agriculture	Unanimous

Impacts and Vulnerabilities

Alaskans (as well as humans across the globe) benefit from a multitude of resources and processes supplied by natural ecosystems. Collectively, these benefits are known as **ecosystem services** and they include products upon which humans depend, such as clean drinking water, timber, habitat for fisheries and wildlife, and pollination of native and agricultural plants. Natural ecosystem services can be *provisioning* such as the production of food, clean water, fiber and energy; *regulating*, such as the control of climate and disease; *supporting*, such as nutrient cycling, water purification and plant pollination; *cultural*, such as spiritual and recreational benefits; and *preserving*, such as maintaining ecological diversity and the resilience and stability it brings.

In the past three decades, Alaska has warmed at a rate approximately twice the global average, and additional warming of 5-13°F is projected over the next 100 years. Rapid warming has substantially affected Alaska's marine, terrestrial, and freshwater ecosystems (ACIA, 2004). The resilience and ecological integrity of these ecosystems varies, depending on the sensitivity of the physical environment to warming and the capacity of the current dependent-species to adapt or move in response to environmental changes. Warming also brings the arrival of new species (including invasives) that can modify natural ecosystems in ways that challenge their resilience to environmental change.

Key impacts and vulnerabilities for the natural systems sector include:[1]

Marine Ecosystems: The seas around Alaska are responding to warming in ways that substantially influence circulation patterns, sea ice, food webs, and productivity regimes. In addition, independent of the effects of warming, carbon dioxide from human emissions is causing about a 30% increase in the acidity of the oceans worldwide, an effect projected to increase substantially by the end of this century. Impacts will be significant in the Arctic Ocean, Bering Sea and the Gulf of Alaska, including changes in fish and wildlife species' diversity, ranges, distribution and abundance; elimination of some species from Alaskan seas; introduction of new species (including invasive species and pathogens); and loss of habitat for sea-ice-dependent species. Alaskans will face impacts to commercial, subsistence, and sport fisheries; changes in traditional modes of travel, fishing, and hunting in areas historically covered by sea ice; and other effects. Communities and industries reliant on marine-based fisheries will be particularly affected, as will individuals and communities dependent on subsistence harvest of marine fish and wildlife as essential elements of their food supply and cultural well-being (ACIA, 2004; Anderson et al., 1999; Brodeur et al., 1992; Grebmeier et al., 2006; Hunt et al., 2002; Sarmiento et al., 2004).

Terrestrial Ecosystems: Although effects will vary in different regions of the state, Alaska's terrestrial ecosystems are generally expected to experience warmer and drier conditions with climate change. Thawing permafrost and increases in the active soil layer will alter the hydrologic regime. In southeast Alaska, changing seasonality is expected to shift temperatures across the freezing threshold, significantly impacting the amount of precipitation that falls as rain vs. snow and impacting ecosystem water availability. Vegetation zones in Alaska are likely to shift, with tree line moving northward and to higher elevations, and forests replacing a significant fraction of existing tundra. Animal species' diversity, ranges, distribution, and abundance will change, with new species arriving (including invasives) and some current species no longer able to thrive. Impacts of warmer and drier conditions may include increased area and frequency of wildland fire, increased insect outbreaks, retreat of inland glaciers, decrease in the area of continuous and discontinuous permafrost and lakes, and an expanded growing season. These potential changes—some negative, some beneficial—will substantially affect a wide range of human uses of terrestrial resources, including forestry and subsistence harvest of fish and wildlife (ACIA, 2004; Werner et al., 2006; USDA Forest Service, 2008; Juday, 2008).

Freshwater Ecosystems: While effects will vary regionally, impacts to Alaska's freshwater ecosystems are generally expected to include reduced summer and fall stream flows, increased winter flooding, warmer summer stream temperatures, loss of perched lakes and other surface water sources underlain by permafrost, and potential water quality changes. Changes to freshwater species will occur, as species that have adapted to colder conditions find it more difficult to thrive and species that have adapted to warmer water temperatures benefit (including invasives). These impacts will have major effects on people who access and harvest the fish and wildlife that depend on freshwater habitat, as well as entities seeking freshwater appropriations for community, industrial, or other purposes (ACIA, 2004; White et al., 2007; Wrona et al., 2006).

[1] Climate change is expected to drive significant ecosystem changes in Alaska in the coming decades. The Natural Systems Technical Work Group (NS TWG, 2008) summarized changes to Alaska's ecosystems and expected future trends in www.climatechange.alaska.gov/aag/docs/AAG4a_NSTWG_DftOptnsCtlg_17dec08.pdf.

Natural Systems Adaptation Strategy

Climate change is already altering the natural ecosystem services that provide life requisites and cultural well-being in Alaska. **The Natural Resources Adaptation Strategy recommends actions that the State of Alaska should take to sustain the natural ecosystem services that meet society's essential needs, through adaptation to changing environmental conditions.** To sustain ecosystems services, the State must adaptively manage its biotic natural resources by managing negative impacts and capitalizing on new opportunities, in coordination with others who manage or benefit from these resources.

The State of Alaska has an essential leadership role in adapting to natural systems change. State government is a primary manager of Alaska's natural biotic resources—with management authority and responsibility for fish and wildlife conservation and harvest, forest and wildland fire management, freshwater appropriations, Alaskan agriculture, infrastructure development, and use of State lands and other resources. The State must be fully prepared to adapt its management policies, strategies, and actions to respond flexibly to the effects of climate change on natural ecosystem services and the human use of those services. The State's planning and response actions must also be fully coordinated with the federal government, local communities, tribes, industry, non-governmental organizations (NGOs), universities, and the public.

The six adaptation options recommended for the NS sector are **targeted to sustaining the natural ecosystem services that meet Alaskan's essential needs for food, water, renewable resource economies, community stability and safety, and cultural well-being.** Box 5-2 summarizes the NS recommendations.

Box 5-2. Overview of Natural Systems Recommendations

NS-1 Fisheries Management

Incorporate climate change into fisheries assessment and management and assist fishing communities and users in adaptation.

NS-2 Wildland Fire

Review and modify Alaska's wildland fire policy and programs in the context of increased wildfire risk.

NS-3 Freshwater Management

Address the effects of climate change on Alaska's freshwater resources through adaptive management, supported by improved hydrologic data.

NS-4 Invasive and Eruptive Species

Reduce introduction and spread of invasive species and eruptive species in the context of climate change.

NS-5 Fish and Wildlife

Improve capability to adapt harvest regulations and monitoring of fish and wildlife to respond to climate change.

NS-6 Sustainable Agriculture

Develop a program to support sustainable agriculture that will improve, secure, and sustain the supply of quality, affordable food

These recommendations build on existing state authorities and programs, and will move Alaska forward substantially in its ability to adapt to climate change impacts. Implementation of these options will require leadership and policy direction, as well as a moderate investment in staffing and funding to complete priority tasks. However, through this work, the State will take a major step forward in integrating adaptive management to climate change over the long-term into the State's resource management programs and practices, so that it becomes a way of doing business—not a suite of separate initiatives.

The NS sector encompasses a wide range of ecosystems, biotic resources, and ecosystem services; yet there are common approaches that will improve the State's capacity for adaptive management across this broad spectrum. Recommended approaches include:

- Organize, coordinate, and facilitate access to research and monitoring data, and identify important data gaps (e.g., data essential to adaptive management of fish and wildlife conservation and harvest; hydrologic data essential to freshwater resource management).
- Review and modify (as needed) resource management policies, practices, and plans to facilitate adaptive management to address climate change impacts (e.g., fishery management plans; wildland fire response practices; water management policies).
- Provide strategic plans and tools to accomplish specific, effective adaptive actions (e.g., regulation change for adaptive management of wildlife harvest; strategic plans for invasive and eruptive species control; plans for community wildfire protection and management of high-risk fire areas).
- Establish and/or fully utilize effective forums for coordination and communication to combine and leverage resources and increase effectiveness (e.g., Invasive Species Council, Alaska Water Resources Board).
- Increase the adaptive capacity of local communities, the public, and others who benefit from ecosystems services (e.g., provide information/technical assistance to fishing-reliant communities; prepare community wildfire protection plans).

These recommendations represent a concise set of feasible actions that the State of Alaska can lead and accomplish, generally in the short- to mid-term, with modest additional funding. The recommendations represent high priority actions, based on criteria that include significance of impacts addressed; anticipated benefits, effectiveness, cost, and feasibility of the adaptation action; timing considerations; and the adaptive capacity of the natural ecosystem and human uses of the ecosystem. Research will be a critical part of these recommendations, as described in Boxes 5-3 and 5-4. The recommendations are also intended to build on existing public and private sector programs and activities as described in Box 5-5. These three boxes appear at the end of this chapter.

In addition to the recommendations presented in this chapter, there is a substantial need for coordination and sharing of data regarding climate change and its effects in Alaska, and assurance that entities that need this data to build their adaptive capacity (e.g., local communities, tribes) can access, understand, and successfully apply these data and findings. This recommendation is presented in Chapter 8, "Common Themes," as Common Themes Option #1, establishment of an *Alaska Climate Change Knowledge Network.* There is also a need to increase climate change education in the Alaska school system, an option that is also presented in Common Themes.

		Type of option										Implementation				
		Coordination														
Option name		State interagency coordination	Community response and assistance	Data management	Access to data and "knowledge" sharing	Data collection (research, monitoring, observation, etc.)	Regulatory / programmatic change or addition	Assessment, evaluation, or planning	Capacity building , education, outreach	Direct or indirect financial assistance (e.g., tax incentives)	Capital improvements	Requires new institutions / government agency	Requires new staffing	Requires funding	Requires new legislative authority	Lead role for state government
NS-1	Fisheries Management	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	possibly	✓
NS-2	Wildland Fire Management	✓	✓			✓		✓	✓				✓	✓		✓
NS-3	Freshwater Management	✓			✓	✓	✓	✓					✓	✓		✓
NS-4	Invasive and Eruptive Species Prevention & Response	✓				✓		✓					✓	✓	✓	✓
NS-5	Adaptive Fish & Wildlife Management	✓	✓	✓	✓	✓	✓						✓	✓		✓
NS-6	Sustainable Agriculture	✓	✓	✓		✓		✓	✓				✓	✓		✓

Description of Natural Systems Recommendations

This section describes the options recommended for the Natural Systems sector.

NS-1 Incorporate Climate Change into Fisheries Management and Assist Fishing Communities and Users in Adaptation

The State of Alaska will take into account climate change impacts when developing fisheries policy and management options for the state's commercial, recreational, subsistence and personal use fisheries. In addition, because of commercial fishing's contribution to Alaska's economy and jobs, the State will develop a program to assist the commercial fishing industry—and the communities and user groups reliant on the industry—in adapting to the impacts from climate change. These actions will improve the adaptive capacity of state managers, the fishing industry, and fishing-reliant communities to changes in fish species ranges, distribution, and abundance while addressing the sustainability and conservation of fisheries. Key elements of NS-1 include:

1. Review of the State's fishing-related statutes, policies, management actions, and programs to determine if and how climate change considerations might be included in these. This review could be conducted by state agencies, or through a combined effort of agencies and a stakeholder group.
2. Comprehensive assessment of existing habitat, fish species, and stock monitoring programs for commercially-fished species to determine program effectiveness and how better information could facilitate meaningful responses to climate change. A panel of agency scientists and independent scientific experts would best accomplish this assessment. This assessment must go hand-in-hand with development of a comprehensive long-term monitoring program that builds upon existing federal and state programs and that also addresses physical and biological components, fisheries abundance and distribution, habitat monitoring, human activity and effects, and socioeconomic data trends.
3. Development of a centralized source of information regarding effects of climate change on marine and freshwater ecosystems and fisheries (see the *Alaska Climate Change Knowledge Network,* proposed as Common Themes Option #1).
4. Development of a long-term strategy to work with fishing-reliant communities and businesses to identify the needs for modified or new fisheries-related infrastructure to meet the changing needs of the industry and fishermen, including possible construction, loans, etc.

Alaska's fisheries are an essential part of the state's economy, food supply, heritage, and culture. The potential negative impacts of *not* being prepared to adapt to changes in the state's fisheries cannot be overstated.

The State of Alaska could realistically implement these actions in the short- to mid-term with the leadership of the Alaska Department of Fish and Game (ADF&G), in cooperation with federal fisheries managers, University of Alaska, fishing-reliant communities, the fishing industry, and other stakeholders. Legislative action would be required only if changes to statutes were identified as required for adaptive management. Completing the assessments and strategic planning described above would not be high cost. However, substantial funding would be needed to implement a more robust marine ecosystem monitoring program (#2 above) or to fund changes to fisheries-related infrastructure (#4). New federal funding sources would likely be required to implement these initiatives (e.g., Ocean Trust Fund).

This recommendation is linked to several high priority research needs, including reviewing effective adaptive management programs from other fishing-reliant countries and states, and developing a comprehensive long-term monitoring program for marine ecosystem changes. As noted above, NS-1 is also linked to Common Themes Option #1.

NS-2 Review and Modify Alaska's Wildland Fire Policies and Programs

The State of Alaska will thoroughly review and modify as appropriate, Alaska's wildland fire policy and programs to address potential climate-induced increases in wildland fire frequency, size, and geographic location. Key elements of NS-2 include:

1. Increase the capacity of communities to initiate, complete, and implement Community Wildfire Protection Plans (CWPP) – providing additional emphasis and funding to a well-established state program.

2 Review selected wildland fire management practices for lands in Alaska, including special consideration of tundra wildfires, which have increased in the last two decades due to warming.

3 Develop a comprehensive fuels management program to treat high-risk areas through fire and mechanical fuel treatment with the goal of minimizing the negative impacts of wildland fire on humans while increasing the beneficial aspects of fire, especially to wildlife habitat.

Taking these actions will benefit public health and safety (life and property), help maintain healthy forest ecosystems, improve homeowner and community preparedness and capacity, provide jobs, supply woody biomass for carbon neutral energy projects, and potentially reduce greenhouse gas (GHG) emissions from wildland fires.

These recommendations build upon programs and coordinating bodies (state, federal, community, NGOs) that are already in place, with coordination by the Alaska Department of Natural Resources (ADNR), Division of Forestry. The actions are highly feasible, could be completed in the short- to mid-term, and are not high in cost. Addition of a CWPP coordinator position and planning funds would be needed to achieve the desired target of completing five new CWPPs each year for the next ten years and keeping all plans updated. Additional funding may also be necessary if a decision were made to implement a higher fire protection status in regions of the state. Federal funding is generally available to support fuels management projects in high-risk areas.

NS-3 Address Effects of Climate Change on Alaska's Freshwater Resources through Adaptive Management, Supported by Improved Hydrologic Data

The State of Alaska will improve the capacity of its freshwater management program to adapt to the impact of climate change to meet the diverse needs for freshwater in Alaska. Key elements of NS-3 include:

1 Advocate for and coordinate with the federal government and others to fill the substantial need for additional, essential data on stream flow and groundwater hydrology.

2 Reestablish the Alaska Water Resources Board to improve coordination among water resource agencies and with the public.

3 Protect water for fish and wildlife habitat through reservation of instream flows, in rivers and lakes for which there is sufficient hydrologic data.

4 Review and adjust water management laws, policies, and practices as necessary to improve adaptive capacity.

Natural ecosystems, communities, residents, industries, and transportation/utility systems all benefit from use of Alaska's freshwater resources. By closing existing substantial data gaps and strengthening its water management structure, the State will be better prepared to develop a strategic approach to water management in the face of climate change, assess risk of water shortage and the need for replacement sources within and between regions, avoid over-appropriation, and protect beneficial uses. These actions would be taken under the leadership of the ADNR Division of Mining, Lands and Water and Department of Environmental Conservation (ADEC).

Alaska's primary water management challenge is the lack of sufficient surface and groundwater hydrologic data. This option recommends a concerted effort to identify sources of data regarding the quantity and quality of Alaska's freshwater sources, crucial data gaps, and a strategic plan for filling gaps. Very substantial funding

would be needed to provide sufficient data for hydrologic modeling and well-informed decisions on water appropriation. Substantial federal funding sources would be needed and data collection would need to be strategically prioritized to use funds to their greatest advantage.

Reestablishment and funding of the public/private Alaska Water Resources Board (the board is authorized, but has not been seated since 1994) would provide needed Cabinet-level emphasis to water resource management issues and programs, including coordination with ADNR regarding improving data and the potential need to adapt Alaska's water management laws, policies and practices, and the water rights adjudication process. Additional state agency funding would be needed to achieve a desired target of completing adjudication of water rights within five years for the fish-bearing streams in South, Central, and Interior Alaska that have adequate hydrologic information.

NS-4 Reduce Introduction and Spread of Invasive and Eruptive Species

The State of Alaska will expand its efforts to be an active partner with all levels of government and other entities in addressing the problem of invasive and eruptive species in Alaska. NS-4 recommends state support for the Legislature's establishment of the Alaska Invasive Species Council (House Bill 12), and state commitment to partnering with others to prevent and control invasive and eruptive species in Alaska.

The combination of changing climate (lengthening growing seasons and warming temperatures) and increasing globalization has dramatically increased the rate of introduction and the spread of non-native, invasive species in Alaska. Invasive plants, eruptive insects and diseases, and invasive marine species have the potential to damage important economic sectors such as fisheries and forestry, as well as to alter fire cycles and subsistence opportunities and to spread disease.

NS-4 recommends that the State of Alaska immediately join in the work underway to address invasive species in Alaska.[2] ADF&G, ADNR, ADEC and Department of Transportation and Public Facilities (ADOT&PF) need to be fully involved. Establishment of the Alaska Invasive Species Council would cement the partnership between the state and other levels of government, and would provide leadership, policy decisions, and leverage and coordination of resources and authorities to implement effective prevention and response actions.

Many actions to prevent introduction of invasives and those to control invasives already in Alaska could be implemented within the short- to mid-term (two to five years). Funding for two state positions (ADOT&PF vegetation management and ADNR plant/wood products inspector) is recommended to address two significant points where invasives can be effectively controlled. It is *much more cost-effective to invest in prevention and early control of invasive and eruptive species* than to combat their spread and their substantial impacts to Alaska's ecosystems and economy in the future.

NS-5 Provide for Adaptive Management of Fish and Wildlife

The State of Alaska will improve its capability to manage fish and wildlife species adaptively in Alaska to assure sustainable management of these important resources under conditions of rapid and substantial climatic change. NS-5 proposes two specific actions under the leadership of ADF&G:

[2] This recommendation would contribute to and build on work underway by the ad hoc statewide Alaska Committee on Noxious and Invasive Plant Management (CNIPM) and the Alaska Invasive Species Working Group (AISWG).

1. Develop and adopt a more timely regulatory process for the harvest of wildlife to adapt and respond to short- and long-term changes in climate that can decrease harvest success under a static harvest season.
2. Develop a coordinated framework that documents existing fish and wildlife monitoring efforts (for both harvested and non-harvested species), identifies priorities for monitoring in the context of climate change, and identifies gaps and potential for collaboration. This option would also include development and use of a common structure for cataloguing and disseminating monitoring information, such as the *Alaska Climate Change Knowledge Network,* proposed as Common Themes Option #1.

Under sub-option #1 above, the Alaska Board of Game would need to delegate regulatory authority to state wildlife managers to adjust wildlife harvest regulations in-season when situations presented by climate change hinder harvest or meat care (e.g., warm, dry conditions reduce access by boat and/or change migration routes). This action could be implemented in the short-term at low cost as a collaborative pilot study with a community or small region. A working group could develop a proposal to the Board of Game for an in-season management option, to determine if there is a management tool that will help respond to climate change impacts on hunting success, and to meet subsistence needs for wildlife. (This recommendation focuses on management of wildlife harvest; note that state fisheries management regulations and practices already provide for adaptive in-season management by state fishery managers).

Under sub-option #2 above, collaboration amongst agencies, scientists, and stakeholders to develop a monitoring framework for fish and wildlife species in Alaska could be accomplished in the short- to mid-term; the cost of this initial product (framework, data coverage, data gaps) is not expected to be high. However, implementation of additional monitoring to fill data gaps would require substantial funding. This recommendation is linked to NS-1, which recommends a similar assessment for monitoring focused on commercially fished species and the habitats that support those species. As noted above, it is also linked to Common Themes Option #1, which addresses coordinated access to data and information regarding climate change.

NS-6 Support Local Sustainable Agriculture in Alaska

Increasing locally grown foods can contribute significantly to Alaskans' efforts to adapt to some consequences of a warming climate. In particular, agriculture can play a critical role in maintaining continuity of food supplies for rural Alaskans who are facing changes in the timing and availability of subsistence foods. It could also reduce the risk of disruptions to transportation systems, which may have consequences for Alaskans in both urban centers and remote communities. In addition, agriculture can take advantage of climate effects that will create a more hospitable environment for some crops, and possibly livestock. Together, actions taken to provide continuity of food supplies (by increasing reliance on locally produced foods) and to take opportunity of potential benefits of climate change can work to create a more sustainable agricultural system while dovetailing with recommendations to reduce emissions contained in the companion report from the advisory group focused on mitigation.

Under this option, the State of Alaska will develop a program to support sustainable agriculture in Alaska that will improve, secure, and sustain the supply of quality, affordable food for all Alaskans by responding to new challenges and opportunities presented by a changing climate and other future changes (e.g., increasing food

transportation costs to and within Alaska). NS-6 recommends four key actions to increase food security, to be led by the ADNR Division of Agriculture:

1. Encourage community-based agriculture and practices that optimize the use of the land and resources available.
2. Research the magnitude and composition of food consumption in the state.
3. Research the sources of food supply and the risk associated with high reliance on imported foods.
4. Develop, in cooperation with stakeholders, a strategic Alaska food policy to increase reliance on locally produced food sources through agriculture, seafood harvesting, and subsistence activities, including enhanced intrastate marketing of Alaska-grown products.

Enhancing food security through locally sustainable food sources can address potential interruptions in current sources, increase availability of quality, affordable food for Alaskans, increase business opportunities, improve nutrition and health, and provide socio-cultural benefits.

These actions fit within the framework of the Division of Agriculture's 2008 Strategic Plan—which calls for addressing climate change effects on Alaska's agriculture sector and increasing local sustainable agriculture—and could be implemented in the short- to mid-term. Funding for two positions in the Division of Agriculture is recommended to lead and accomplish these tasks; as well as moderate funding for research on Alaska's food supply and to support meetings of the Alaska food coalition.

Box 5-3. Natural Systems Recommended Research Needs: *Overarching Research Needs*

The Research Needs Work Group identified several overarching needs to help the State of Alaska better understand the impacts of climate change on its natural systems:

NS/RN-1.1 Develop improved hydrology data and models statewide.
NS/RN-1.2 Identify permafrost thaw hazards and incorporate into engineering guidelines.
NS/RN- 3 Identify laws, policies, and regulations that could be modified to better support adaptation.
NS/RN- 4 Implement local climate change scenario planning workshops in communities across Alaska (Coastal, Arctic, Interior, etc.).
NS/RN-5 Identify and assess health and safety hazards resulting from climate change
NS/RN-6 Coordinate data integration.
NS/RN-7 Fill gaps in geospatial data coverage, aerial photography, digital elevation models (DEM), and remote sensing data that are needed to assess and forecast climate change impacts.
NS/RN-8 Conduct coastal mapping and shoreline characterization.
NS/RN-9 Assess, model, and monitor coastal impacts of changes to sea level and ice.
NS/RN- 10 Develop and refine down-scaled climate models.
NS/RN-11 Coordinate climate and ecosystem monitoring programs among agencies, organizations, and institutions.
NS/RN-12 Work with communities to determine appropriate indicators of climate change and community impacts. Improve monitoring of key climate change indicators & effects, with emphasis on effects having large societal impacts. Monitor climate change indicators and their societal impacts.
NS/RN-13 Conduct research on protecting community water supplies and instream flows.
NS/RN-14 Expand research and monitoring of contaminants deposition and bioavailability under changing climate.
NS/RN-15 Acquire or produce vegetation maps that are usually compiled from satellite imagery. Ortho rectified imagery would show human improvements and vegetation. A base map is needed for the state.
NS/RN-16 Assess and improve communications strategies for climate change information.

For additional information on each recommendation, and for a broader set of identified needs, see Research Needs Work Group (2009). The numbering system above refers to the last two subsection numbers in the appropriate chapter in the report.

Box 5-4. Natural Systems Recommended Research Needs: *Specific Research Needs*

The Research Needs Work Group identified research necessary to assist in implementing specific natural systems recommendations.

FISHERIES

NS/RN-2.1 Synthesize current information about climate change impacts on fisheries and assess its reliability and degree of uncertainty.

NS/RN-2.2 Conduct Arctic Ocean fisheries assessments to prepare for potential changes due to changes in both climate and commercial fishing patterns.

NS/RN-2.3 Increase real-time monitoring and forecasts of physical ocean conditions (winds, waves, sea ice, currents, temperature, salinity, pH, etc.).

NS/RN-2.4 Assess the applicability of alternative government approaches to integrating climate change considerations into fisheries policy.

NS/RN-2.5 Conduct physical, biological, and socioeconomic monitoring to understand environmental change, distribution and abundance of freshwater, marine and, anadromous species as well as societal impacts.

NS/RN- 2.6 Consider need for protected fish conservation areas in response to impacts on fisheries.

WILDLAND FIRE

NS/RN-3.1 Expand modeling of wildland fire, fuel, and smoke.

NS/RN-3.2 Review and coordinate wildland fire policies with Canadian counterparts.

NS/RN-3.3/6.1 Research and monitor Tundra and forest response after fire disturbance and develop measures to reduce impacts.

INVASIVE SPECIES

NS/RN-4.1 Identify and develop methods to assess and control invasive and eruptive plant, animal, and diseases that are likely to become established, expand their range, or be intentionally introduced in Alaska due to climate change.

NS/RN-4.2 Provide effective monitoring, forecasting, and response to marine invasive species.

FISH AND WILDLIFE

NS/RN-5.1 Improve data and access regarding wildlife and fisheries populations and harvest rates.

NS/RN-5.2 Project likely changes to wildlife habitat due to climate-driven impacts on landscape, vegetation cover, wildfire frequency and intensity, permafrost thaw, and fragmented migratory corridors.

NS/RN-5.3 Improve methods for enumerating caribou and moose populations, to assist subsistence communities.

NS/RN-5.4 Assess disjoint between calendar dates for legal harvest and timing of biological behavior.

NS/RN-5.5 Identify how "sentinel" ecosystems are changing to provide long-term trend information.

SUSTAINABLE AGRICULTURE

NS/RN-7.1 Research agricultural products and practices suitable for changing conditions

NATURAL HAZARDS

NS/RN-8.1 Assess effects of climate on safe access for hunting, fishing and other subsistence activities.

NS/RN-8.2 Update the Environmental Atlas of Alaska and Alaska Engineering Design Information System (AEDIS).

For additional information on each recommendation, and for a broader set of identified needs, see Research Needs Work Group (2009). The numbering system above refers to the last two subsection numbers in the appropriate chapter in the report.

Box 5-5. A Sampling of Relevant Current Activities

The examples presented below are not intended to be exhaustive, but rather to illustrate ongoing and proposed initiatives and activities.

Many ongoing research and management programs are relevant to the effects of climate change on Alaska's natural systems and ecosystem services. The most effective adaptation actions by the State of Alaska will be those that partner with, contribute to, leverage, and build upon these types of existing efforts.

NS-1 Fisheries and NS-5 Adaptive Management of Fish and Wildlife

There are many government agencies, universities, and NGOs involved in monitoring the status of Alaska's fish and wildlife, their habitats, and the effects of climate change on these important resources.

NS-2 Wildland Fire

The existing Alaska Wildland Fire Coordinating Group is a highly-effective interagency mechanism for adaptive management of fire response and management. The Community Wildfire Protection Plan program is an existing, but not well-funded program. State, federal and university mapping projects provide essential baseline information (e.g., vegetative land cover).

NS-3 Freshwater Management

Relevant programs include the State's existing management authorities for water quantity and quality; hydrologic data collection by federal agencies, and other programs through the University of Alaska, private sector, and others. There is occasionally ad hoc coordination regarding water management and hydrologic issues at the agency staff level (e.g., Interagency Hydrology Committee for Alaska).

NS-4 Invasive and Eruptive Species

Several federal agencies have recently developed effective invasive species programs in Alaska. Ad hoc agency groups have been operating (Alaska Committee for Noxious and Invasive Plant Management, Alaska Invasive Species Working Group), but are hampered by lack of consistent State participation.

CHAPTER 6. OTHER ECONOMIC ACTIVITIES

A changing climate could potentially affect all sectors of Alaska's economy (Box 6-1 gives the mission statement for the sector). Some of Alaska's major economic activities, such as tourism and shipping, are highly dependent on weather conditions and/or the natural environment, both of which can be significantly affected by climate change. Some activities, such as mining and oil and gas exploration, rely on engineered infrastructure that is also potentially affected by climate, weather, and underlying environmental conditions. For example, permafrost thaw could threaten the stability of oil pipelines in Alaska, and shorter winters would reduce the utility of seasonal ice roads for off-road navigation.

Box 6-1. Other Economic Activities Mission Statement

To identify adaptive actions and options that contribute to the ability of sectors of the Alaska economy not directly supported by living systems (e.g., fishing) to adapt to the effects of climate change and ensure the sustainability of a robust Alaskan economy based on the responsible development of its natural resources.

At the same time, a changing climate could create economic development opportunities in existing and new sectors. This chapter focuses on the impacts and vulnerabilities facing sectors of the Alaska economy that are not dependent on living systems. The recommendations are designed to assist these economic sectors in adjusting to a changing climate to ensure a continued healthy economy for Alaska. Measures to adapt the economy to a changing climate may also contribute to building resiliency in Alaska's economy to other external factors.

Overview of Economic Activities Options		
	Option Name	Level of Support
EA-1	Assess Arctic Capability Needs	Unanimous
EA-2	Develop Alaskan Economic Scenarios	Unanimous
EA-3	Improve Availability of Data	Unanimous

Impacts, Vulnerabilities, and Opportunities

Climate change could have numerous effects on the Alaska economy. Potential vulnerabilities, impacts, and opportunities within different sectors, as a result of climate change, include the following:

Oil & Gas: Oil and gas is the leading sector in the Alaska economy, generating more than 85% of State revenue from royalties and taxes as well as significant employment. Alaska's economic future will depend largely on maintaining robust oil and gas production. With thawing permafrost and changing weather patterns, oil and gas operations are likely to see impacts both on- and off-shore. This includes potential impacts to infrastructure such as pipelines, ice roads, and waste pits. Already, shorter and warmer winters have resulted

in reduced operation windows for exploration and development, and warmer summers have resulted in reduced efficiency of gas compression and reinjection. Engineering focused on proactively addressing challenges of the changing climate is already essential. Decreased sea ice creates the potential for impacts to North Slope oil fields. Increased local, national, and global energy demands may increase the need for and economic viability of oil and gas operations.

Mining: Mining is another important sector of Alaska's natural resource based economy (not dependent on living systems), especially in remote rural areas of the state where employment opportunities are limited. Mining is expected to face similar challenges and opportunities as the oil and gas sector. Currently, exposed permafrost and warmer temperatures have resulted in increased erosion and less stability in mining sites. Engineering challenges will arise as thawing permafrost and other climatic conditions affect existing and planned infrastructure and transportation related to mining. The same climate changes, however, may also highlight new mining opportunities and allow expanded seasons for exploration, development, and operations.

Tourism and Recreation: Tourism and recreation are also important industries in Alaska and are tied closely to the diversity and condition of the natural environment. Climate change may impact many of the natural resources that attract tourists to Alaska. Increased temperatures could lead to changes in seasons that support various activities (e.g., skiing, hiking, camping). Some regions of the state may experience increases in summer tourists due to a longer and warmer season. This could create more seasonal job opportunities in areas and times where they do not currently exist. Less ice in the Arctic Ocean may mean increased cruise and land-based tourism opportunities throughout the region, with requirements for additional infrastructure to support the industry.

Ocean Transportation: Less ice in the Arctic Ocean will have significant impacts for trade and ocean transportation for all countries in the Arctic region. New shipping lanes are likely to open and be available for longer periods, and there would be increased access to the Ocean's natural resources, such as fish, oil and gas, and minerals. Increased ocean transportation and activity will require increased vigilance for safety and environmental protection (e.g., oil spills) and may also lead to more disputes around boundaries and ownership of natural resources.

Boundaries and Ownership: Changes in sea ice and glaciers, with potential concomitant erosion and sedimentation including river erosion and sedimentation, can result in changes in boundaries and issues about ownership in the Arctic. Receding glaciers will likely result in post-glacial rebound of lands previously submerged or covered by glaciers. Boundary and ownership disputes can affect a number of sectors, such as mining, oil and gas, tourism and recreation, fishing as well as locations of boroughs, municipalities, and villages.

Energy Production and Demand: Activities that address the needs of Alaskans for affordable energy are likely to be significantly affected by climate change. Changes in weather will affect how Alaskans generate energy and when they demand energy, with potential decreased demands in winter and increased demands in summer (for cooling). In addition, global demands and federal and state regulations could affect oil, gas, and coal operations. While global energy demand is expected to increase, requirements to reduce greenhouse gas emissions may affect the sources and costs of energy supplied, with increased interest in and opportunities for the use of alternative and renewable sources of energy.

Economic Activities Adaptation Strategy

The recommendations in this sector focus on broad issues relevant to the Alaska economy as a whole, rather than actions designed to address the individual concerns of a particular economic group or industry. Box 6-2 summarizes the EA recommendations. These recommendations represent high priority actions based on a number of criteria, including:

- Significance: the importance of the option to the State's economy, including tangible and intangible variables such as social justice and the viability of small communities.
- Benefits and effectiveness: consideration of the vulnerability of the economy if the option is not carried out and whether benefits are long- or short-term.
- Costs: expenses up-front and over time.
- Feasibility: ease and possibilities of implementing the option, including speed of implementation.
- Timing of impact: assessment of when the option must be undertaken (e.g., in response to immediate impacts or longer term). Shorter term needs were given higher priority.
- Adaptive capacity: ability of the system (e.g., economic sectors) to cope with the consequences of climate change.

Box 6-2. Overview of EA TWG Adaptation Options

EA-1: Evaluate Capability Needs for Potential Expansion of Arctic Economic Activities

This option recommends that the State recognize and address the potential for increased Arctic economic activities and identify gaps in infrastructure and the ability to provide an adequate presence in the Arctic coastal region to protect environmental resources, human health, and safety.

EA-2: Develop and Evaluate Scenarios for the Alaskan Economy

Components of the Alaska economy will experience varying impacts due to potential effects of climate change. An assessment of economic strengths, weaknesses, opportunities, and threats by sector is needed to better understand current and potential future components of the economy. This understanding will aid state agencies and other stakeholders in identifying and acting on optimum adaptive strategies and policies to help address future conditions. This option recommends conducting and managing a project to develop and evaluate possible economic scenarios for the State, based on potential climate change effects.

EA-3: Improve Availability of Mapping, Surveying, Charting, and Imagery Data

Accurate, timely information about the distribution and magnitude of changes is needed to better address economic challenges and opportunities. This option recommends improving the availability of data, specifically real-time mapping, digital elevation model, and imagery, to better track and understand the impacts of climate change. This option would build on the work of the Statewide Digital Mapping Initiative and aid in transitioning between locations at the water-land interface.

Assisting the Alaska economy to adapt to climate change requires meeting several broad needs: 1) improved understanding of the current Alaskan economy and identification of opportunities and risks for the future, 2) better data and improved access to data for decision-making, and 3) enhanced capabilities to respond to

climate change in specific environments that may experience significant changes in economic activities (such as the Arctic). The three EA options address these needs.

The three options are focused on state agency activities in conjunction with other parties to gather and analyze additional information to better understand potential economic challenges and opportunities from climate change. The rationale is that climate change adaptation actions and options specific to individual sectors are best addressed by industries within those sectors (as they are currently doing). State and federal agencies can assist by (1) improving available data about physical changes in the landscape (option EA-3), and (2) developing a deeper understanding of the potential impacts of climate change to the current economy how to maintain a robust economy in future climatic conditions (option EA-2). Option EA-3 calls for significant investments in new data collection. Option EA-2 requires funding to conduct additional scenario development and analyses. Option EA-1 is an assessment of likely needed state and federal support for safety and environmental protections as economic development occurs in the Arctic. Funding is needed to assess and evaluate these needs. Characteristics of the options are described in the table below.

		Type of option										Implementation				
		Coordination														
Option	Option name	State interagency coordination	Community response and assistance	Data management	Access to data and "knowledge" sharing	Data collection (research, monitoring, observation, etc.)	Regulatory/programmatic change or addition	Assessment, evaluation, or planning	Capacity building , education, outreach	Direct or indirect financial assistance (e.g., tax incentives)	Capital improvements	Requires new institutions/government agency	Requires new staffing	Requires funding	Requires new legislative authority	Lead role for state government
EA-1	Assess Arctic Capability Needs	✓	✓	✓	✓	✓	✓	✓			✓			✓		✓
EA-2	Develop Alaskan Economic Scenarios	✓	✓	✓	✓	✓		✓						✓		✓
EA-3	Improve Availability of Data	✓		✓	✓	✓					✓			✓		✓

In addition to the recommendations presented in this chapter, there is also a need for better coordination of knowledge-sharing relative to Arctic activities, including participation in meetings and development of policies. This option is presented in Chapter 8, "Common Themes," as Common Themes Option #1, establishment of an *Alaska Climate Change Knowledge Network*. Research will also be a critical part of these recommendations, as described in Box 6-3. The recommendations are also intended to build on existing public and private sector programs and activities as described in Box 6-4. Both these boxes appear at the end of this chapter.

Description of Other Economic Activities Recommendations

This section describes the options recommended for the Other Economic Activities sector.

EA-1 Evaluate Capability Needs for Potential Expansion of Arctic Economic Activities

Many scientific models predict that Arctic sea ice will continue to retreat, creating longer ice-free summers along the Alaska Arctic coast. This will result in growth of maritime economic activities in the region such as shipping, mining, fishing, tourism, and oil & gas exploration. The oil & gas industry is estimated to have the greatest potential for substantial economic growth in the Arctic. To support increased economic activity, ports, infrastructure, and other facilities are expected to develop as warming temperatures result in longer seasonal access. This will bring increased ship traffic and a greater human presence, not only creating job and business opportunities, but also requiring investments to ensure essential government functions such as safety, security, and environmental protection are provided. Potential gaps may exist in emergency response and regulatory oversight capabilities. This option recommends that the potential for increased Arctic economic activities be recognized as well as the need to address potential gaps in infrastructure and the ability to protect environmental resources, human health, and safety.

To implement this option, the EA TWG recommends that a Capital Improvement Project (CIP), managed by the Alaska Department of Transportation and Public Facilities (AKDOT&PF) and involving other stakeholders, be undertaken to plan for and collaboratively identify the infrastructure and capabilities required to address response and regulatory needs concerning the Arctic maritime industry. Implementing this option will provide the State with needed information to plan for services and capabilities to support future economic growth, including better positioning the state to compete for federal funding. Moreover, extending government programs into the Arctic is resource intensive. Tremendous opportunities exist to share costs, facilities, equipment, and responsibilities, thus increasing efficiency and strengthening interagency partnerships. An adequate understanding of the capabilities available is needed before these opportunities can be fully explored.

EA-2 Develop and Evaluate Scenarios for the Alaskan Economy

Components of the Alaska economy could experience varying impacts due to potential effects of climate change. Better understanding the potential range of economic impacts based on possible climate changes, as well as other ancillary effects such as growth or loss of jobs, is needed to anticipate challenges and opportunities. This understanding will aid state agencies and other stakeholders in identifying and acting on optimum adaptive strategies and policies to help address future conditions.

This option recommends that Alaska provide funding to conduct and manage a project that develops and evaluates economic scenarios for Alaska, based on potential climate change effects. Scenarios will be developed that take current variables and conditions (e.g., socio-economic-demographic) as a starting point and examine the effects of various future conditions, such as changes in climate, land use, energy use, water availability, regulations, demographics. Future economic scenarios will examine both challenges in terms of economic variables such as possible job losses, economic investments staying or leaving Alaska, sustainability, etc. and opportunities that may result in both existing and new sectors. The scenarios developed would provide potential ways to maintain a robust economy based on responsible natural resource development. They will consider the future of the Alaskan economy and aid in planning and investment decisions in response to the needs and opportunities to adapt to climate change.

EA-3 Improve Availability of Mapping, Surveying, Charting, and Imagery Data

Accurate, timely, and high resolution information about the distribution and magnitude of topographic changes resulting from climate change is needed to better address economic challenges and opportunities. To assess change, a good baseline of existing conditions is needed along with real-time updating of rapidly changing conditions, such as shorelines and coastal areas.

This option proposes that the State of Alaska and others invest in an accurate and high-resolution statewide digital base map that includes a digital elevation model and an acquisition system for imagery. The State also must ensure that the associated data are available to all users. This option would improve the availability of real-time mapping, surveying, charting, digital elevation models, and imagery data to provide means to better track changing conditions and understand economic impacts of climate change and opportunities to address the impacts. Additionally, this option would provide support for ongoing management and distribution of this spatial information through a geographic information system and open standards web service. This option recommends using the existing program that is creating a digital basemap, the Statewide Digital Mapping Initiative (SDMI), as a vehicle of implementation, as well as continued coordination with University of Alaska (UA) Research Centers, the U.S. Coast Guard, and the National Oceanic Atmospheric Administration (NOAA).

6-3. Economic Activities Recommended Research Needs

The Research Needs Work Group identified several needs both to assist implementing the recommendations and to help the State of Alaska better understand the impact of climate change on its economy.

IMPACTS AND OPPORTUNITIES

EA/RN-2,3,4,7 Analyze the potential rise or decline of various industries and consequent impacts on state revenues.

EA/RN-1.7 Assess new or expanded economic opportunities that may become available with climate change

EA/RN-5,6,8 Assess impacts, opportunities, and adaptation needs for ocean, road, rural-non-road, and other forms of transportation and transportation infrastructure

BOUNDARIES AND OWNERSHIP

EA/RN-9.1 Improve mapping and surveying to accurately and efficiently establish boundaries, address boundary disputes as needed, and aid charting for safe navigation.

ENERGY DEMAND

EA/RN-10.1 Assess how climate change will impact application of federal, state, and local laws, regulations, and policies on energy demand and use.

EVOLVING ALASKA'S JOBS AND ECONOMY

EA/RN-11.1 Assess how climate change will impact application of federal, state, and local laws, regulations, and policies on economic development activities.

INFORMATION COLLECTION AND DISSEMINATION

EA/RN-12.2 Identify climate trends and downscale models leading to establishing environmental information, analysis tools, and design criteria for use in adapting to climate change.

EA/RN-12.3 Provide resources for good Digital Elevation Model (DEM) and GIS data, and current and high resolution imagery to establish a more robust information infrastructure to plan and adapt.

EA/RN-12.4 Invest in monitoring and data dissemination programs to enhance information available for safe and efficient resource development.

For additional information on each recommendation, and for a broader set of identified needs, see Research Needs Work Group (2009). The numbering system above, in general, refers to the last two subsection numbers in the appropriate chapter in the report, except for single digit numbers.

Box 6-4. A Sampling of Relevant Current Activities

The examples presented below are not intended to be exhaustive, but rather to illustrate ongoing and proposed initiatives and activities.

EA-1: Evaluate Capability Needs for Potential Expansion of Arctic Economic Activities

The U.S. Coast Guard, 17th District (Alaska), has conducted an Arctic capabilities analysis. In addition, the U.S. Arctic Research Commission has developed an Arctic Marine Shipping Assessment that explores some of the infrastructure and service needs with a more navigable Arctic Ocean. The Institute of the North is coordinating several programs relating to current and future Arctic industry. Finally, Alaska's FY10 funding proposal has $0.5 million set aside for a long term harbor study, which may be matched by the Denali Commission.

EA-2: Develop and Evaluate Scenarios for the Alaskan Economy

Decision makers in Alaska need data and information on projected changes in climate and associated impacts, on socioeconomic conditions, and on the likelihood of these changes, to support taking adaptive action. Future climate scenarios can be developed in a number of ways, including using downscaled data from General Circulation Models (GCMs) (as described in Chapter 2 of this report), using historical analogues, and trend data. One relevant effort that is underway is occurring at the University of Alaska - Fairbanks Scenarios Network for Alaska Planning (SNAP) program, which is developing predictions for Alaskan climate.

EA-3: Improve Availability of Mapping, Surveying, Charting and Imagery Data

Currently, the Statewide Digital Mapping Initiative (SDMI) is underway and would be a vehicle of this option. A related effort for this option is NOAA's GRAV-D program is an airborne gravity survey to improve the accuracy of the vertical datum, by mapping the mean sea level elevation, which, for Alaska, can be several meters off with the current data. Alaska is the top priority to be mapped under this program, but it will need federal funding.

CHAPTER 7. HEALTH AND CULTURE

Climate change is being linked to increases in the geographic range and incidence of certain infectious and non-infectious diseases, new problems in sanitation and solid waste management, and contaminant exposures in Alaska. Current programs are insufficient to identify and control these changes. To protect the health of humans and animals (both domestic and wildlife) from the effects of climate change in Alaska, existing programs and activities need to be augmented by developing new methods for surveillance and reporting of human and animal diseases. Box 7-1 summarizes the mission statement for the sector.

Box 7-1 Health and Culture Mission Statement

Improve adaptive capacity to maintain human health and healthy ways of life, reduce current and likely future increases in disease due to a changing climate, and prevent the destruction of gravesites, archaeological sites, and historic sites due to accelerated coastal and river erosion.

Overview of Health and Culture Recommendations		
	Recommendation Name	Level of Support
HC-1	Infectious Disease and Surveillance Control	Unanimous
HC-2	Community Health Impact Evaluation	Supermajority*
HC-3	Sanitation Infrastructure and Practices	Unanimous
HC-4	Archeological Sites and Gravesites	Unanimous

*Supermajority reflects one objection. One AAG member objected to creation of a system because it would add an unnecessary layer of oversight. Additional costs in time and resources should be estimated and compared to that which is presently directed to assist communities in adapting their public health and water and sanitation infrastructure to warming.

Impacts and Vulnerabilities

Climate change poses risks to the health of all Alaskans, but particularly those living in rural communities with limited public health and health care capacity. Climate change also poses risks to cultural traditions and traditional ways of life.

Problem and Significance:

***Health**:* Climate change poses real health risks (Ebi et al. 2008). Climate change is projected to increase the frequency and intensity of heatwaves and other extreme weather events (floods and droughts), change the geographic range and incidence of climate-sensitive vector-, food-, and waterborne diseases, and increase

diseases associated with air pollution and aeroallergens. Climate change is often not the sole cause of increases in the burden of climate-sensitive health outcomes, but it interacts with other public health stresses. The increasing extent and rate of climate change means it is expected to be a major health issue for decades to come (Confalonieri et al. 2007).

There are indications that vector-borne and enteric diseases in Alaska may be changing their geographic range as a consequence of climate change, with adverse consequences for human health (McLaughlin 2008). Climate is a primary determinant of whether a particular location has the environmental conditions suitable for the transmission of several vectorborne diseases. A change in temperature may hinder or enhance vector and parasite development and survival, thus lengthening or shortening the season during which vectors and parasites survive. Small changes in temperature or precipitation may cause previously inhospitable altitudes or ecosystems to become conducive to disease transmission (or cause currently hospitable conditions to become inhospitable). Examples of human diseases that have already been or might soon be linked to climate change in Alaska include botulism, echinococcosis, giardiasis, paralytic shellfish poisoning, rabies, tick-borne encephalitis, venomous insect events, and West Nile virus infection. West Nile virus is of particular concern because it is spreading across Canada and is now one degree south of Juneau (McLaughlin 2008). Examples of animal diseases that have already been or might soon be linked to climate change in Alaska include leptospirosis; parasitic infestations in caribou, muskoxen, and moose; toxoplasmosis in sea otters; tularemia; and winter tick infestation in moose (Gerlach 2008).

An example of the type of response that would be expected with climate change is a retrospective review of three independent patient databases in Alaska that reported a statistically significant trend in patients seeking care for insect reactions over fourteen years (Demain et al. 2009). In Fairbanks, there was a four-fold increase in patients in 2006 compared to 1992-2005. In Anchorage, there was a three-fold increase in patients between 1999-2002 and 2003-2007. A review of the Alaska Medicaid database from 1999 to 2006 also showed statistically significant increases in medical claims for insect reactions in five of six regions, with the largest percentage increases occurring in the most northern areas. Since 1950, average annual and winter temperatures in Alaska increased 3.4°F and 6.3°F, respectively. Average winter temperatures increased at least 6°F in regions reporting a significant increase in bite or sting events; warmer temperatures may have been a contributing factor.

Increasing numbers of cases of food- and waterborne disease also are of concern to Alaskans. Most of these pathogens are enteric and transmitted by the fecal-oral route, and many are sensitive to ambient temperature. Control of these pathogens requires not just effective water treatment and food production and handling, but also sanitation and solid waste management. Enteric diseases of concern include *salmonella*, *campylobacter* and *cryptosporidium*. While the outcome of many gastrointestinal diseases is mild and self-limiting, they can be fatal or significantly decrease fitness in vulnerable populations, including young children, the immuno-compromised, and the elderly. Children ages 1-4 and older adults (>80 years) each constitute more than 25% of hospitalizations involving gastroenteritis, but older adults are 85% of the associated deaths (Gangarosa et al. 1992). Climate may affect food- and waterborne pathogens directly by influencing their growth, survival, persistence, transmission, or virulence in ways that could increase the number of cases with increasing ambient temperature (Fleury et al. 2006; Naumova et al. 2006).

Vibrio parahaemolyticus, the leading cause of seafood-associated gastroenteritis in the US, is typically associated with the consumption of raw oysters gathered from warm-water estuaries. In 2004, an outbreak occurred in Alaska where the consumption of raw oysters was the only significant predictor of illness; the

attack rate among people who consumed oysters was 29% (McLaughlin et al. 2005). All oysters associated with the outbreak were harvested when mean daily water temperatures exceeded 15.0°C (the theorized threshold for the risk of *V. parahaemolyticus* illness from the consumption of raw oysters). Between 1997 and 2004, mean water temperatures in July and August at the implicated oyster farm increased 0.21°C per year; 2004 was the only year during which mean daily temperatures did not drop below 15.0°C. The outbreak extended by 1000 km the northernmost documented source of oysters that caused illness due to *V. parahaemolyticus.* Rising temperatures of ocean water appear to have contributed to one of the largest outbreaks of *V. parahaemolyticus* in the U.S.

***Culture*:** Marine and terrestrial ecosystems are changing substantially with complex feedbacks that alter habitat and the mix of fish, marine mammals, terrestrial mammals, and vegetation. Sea ice, the prime habitat of walrus and seals and the hunting grounds for many coastal villagers, is forming later and at differing rates in the winter and breaking up earlier in the spring. This combined with the overall dramatic rate of sea ice loss is impacting people with loss of traditional knowledge and extended periods without access to traditional foods (Huntington and Fox 2005). Similar ecosystem and resource impacts are affecting Native cultures throughout the state, challenging their subsistence way of life and posing significant cultural challenges. Subsistence hunters in these areas must now travel increasingly large distances to hunt marine mammals, such as bearded, spotted, ringed, and ribbon seals, whose reproduction and survival rates are known to fluctuate with climate changes (Ferguson et al. 2005; Stirling 2005). This hunting occurs in unsafe, frigid waters in boats for which gasoline costs more than $9/gallon (ADCRA 2009), a high price to pay in communities whose per capita income is one third that of urban Anchorage. Rural villagers also confront population shifts, declines, and loss of quality in other subsistence species including fish, moose, caribou, wild berries, and other native plants.

Many aspects of the traditional and subsistence way of life are now more difficult, more dangerous, and more expensive. The cost of store bought foods, heating oil, and other daily living expenses interact with climate-related challenges to create circumstances that make survival in rural villages increasingly difficult. More than one in five individuals is below the poverty threshold, three times that of their urban counterparts (Callaway and Smith 2008). Stresses to traditional practices—including a way of life tied to being on the land and providing for one's community—is combining with rising cost of rural living to raise the potential of serious social impacts. Other outcomes can be subtler. For example, Alex Whiting from northwest Alaska notes that the youth and elderly depend on strong ice in fall to ice fish for saffron cod and smelt. Late freeze up and a concomitant shorter ice-fishing season lessens the opportunity for elders to pass on traditional knowledge and ethical values (Whiting 2002).

Beyond the social and cultural impacts of climate change, many villages are now facing erosion, flooding, engulfment, and disappearance of their community infrastructure. Shismaref, a community of 150 households on the northern Bering Sea, faces relocation at a cost of $93 - $179 million dollars (USACE 2004). A recent report from the Government Accountability Office (GAO 2004) found 213 predominantly Native villages—historically situated along rivers and coasts—at risk, with potential relocation costs of $34 billion. Several existing communities have begun the relocation process and others are seriously evaluating the risk to their communities and may follow suit in the near future. Beyond the communities themselves, many culturally important sites are currently at risk from erosion, including archaeological sites and gravesites.

Need for action: The coordinated delivery of services to rural communities supports many Health and Culture objectives. Currently an array of state, federal, and regional entities are responsible for delivering services to rural Alaskan villages, but specific program policies and regulatory constraints cause conflicting directives,

resulting in bottlenecks in the ability to achieve a coordinated delivery of vital services and outcomes that will enable villages and traditional culture to adapt to climate change. Chapter 8, “Common Themes,” includes a recommendation that addresses the need for community assistance, which is more far reaching than simply health and culture but also includes natural systems, public infrastructure, and other needs.

Agencies within the state currently tasked with the responsibility for surveillance and control for human and animal diseases include the Alaska Department of Health and Social Services (ADHSS), the Alaska Department of Environmental Conservation (ADEC), the Alaska Native Health Consortium (ANTHC), and the Alaska Department of Fish and Game (ADF&G). Although programs and activities are in place, there is evidence that they are insufficient to address the additional health risks from climate change.

Actions taken to mitigate greenhouse gas emissions or to adapt to the current and projected impacts of climate change can benefit or harm human health. Without prior evaluation, adaptation and mitigation policies and programs might cause morbidity and mortality that would have been prevented, often by simple and inexpensive adjustments to the implementation plan.

Increases in global temperatures have led to new and exacerbated existing problems in sanitation and solid waste management that are anticipated to negatively impact the health of communities. Facility and program performance design is based on historical environmental factors. However, these design factors are shifting due to climate change. Current community sanitation policies are insufficient to address these risks and need to be modified. Not identifying and implementing effective and efficient modifications to sanitation and solid waste management will lead to additional cases of waterborne, vector-borne, and hygienic diseases, as well as environmental toxic exposure to humans and wildlife.

Alaska’s gravesites, archaeological sites, and historic sites are becoming increasingly exposed and impacted through anthropogenic and natural processes, including global climate change. Coastal sites are particularly vulnerable. The sea level rise projected to occur over the next few decades will alter the shape of coastline and speed of erosion, submerging or destroying many graves and cultural sites. For inland areas, warming temperatures have led to the melting of ice fields thousands of years old, exposing organic artifacts such as arrows to the elements. Warming temperatures are also causing lake and stream levels to become higher or lower than normal, exposing or inundating sites. In some areas, the onslaught of the bark beetle has had an effect on sites and structures.

Challenges:

Sufficient evidence exists that implementation of additional surveillance and monitoring for climate-sensitive infectious diseases will provide significant benefits in detecting cases of disease early enough to take action to reduce additional cases of disease. This information is critical for determining targeted public health control needs. Implementing additional surveillance is highly feasible as no new legislative authority is needed and the basic governmental structure already exists for implementation with minimal cost in terms of capital infrastructure and personnel services support.

Implementing an option to assess adaptation and mitigation options recommended by all sectors would require at least authorizing regulations. Existing personnel in the Division of Public Health (DPH) could probably meet the professional needs, but part-time support staff would be needed. It is anticipated that the number of mitigation and adaptation options selected by the State will not be large enough at any one time to make additional full-time professional staff a requirement.

Addressing climate change-related risks to sanitation and solid waste management will require augmentation of existing programs. Implementation of these changes will require increased human and material resources, including methods and tools, within existing programs as well as new and augmented partnerships with the public and private sectors. Additionally, these recommendations will require an update of existing environmental data sets (temperature and climate projections) in order that facilities can be constructed and/or renovated to meet future changed environmental conditions.

There is scientific support for a relationship between global climate change and the environmental changes that are causing the destruction of gravesites, archaeological sites, and historic sites. Collection of baseline data and monitoring efforts are required to identify, assess, and prioritize threatened sites and develop plans for mitigating these threats. Examples of cemeteries and cultural sites that have been wholly or partially destroyed by changing weather patterns are widespread throughout Alaska. Programs within the state have the authorities, infrastructure, and expertise to coordinate identification, assessment, and mitigation of adverse effects to these resources, but do not have adequate staff or funding to perform the duties.

Health and Culture Adaptation Strategy

The four adaptation options recommended for the Health and Culture sector address issues where current climate variability and change have increased risks of adverse health and culture outcomes, with increasing impacts expected over the short- and long-term. Failure to implement the recommended modifications to current programs and activities is expected to increase disease burdens. Climate change also is adversely affecting Alaska's culture and history through observed and projected increase in the destruction of

Box 7-2. Overview of Health and Culture Recommendations

HC-1: Augment Surveillance and Control Programs for Vector-, Water-, and Foodborne Diseases

Augment surveillance and control programs for vector-, water-, and foodborne diseases likely to become greater threats because of climate change. Develop educational programs for the public, health care providers, environmental staff, and others on approaches to reduce emerging disease threats.

HC-2 Community Health Impact Evaluations

Develop a tiered approach to evaluate recommended adaptation and mitigation options to determine whether they could result in adverse health impacts and, if so, to recommend approaches to reduce these risks.

HC-3: Assess Sanitation and Infrastructure Risks from Climate Change

Assess sanitation infrastructure and practices at risk from flooding, thawing permafrost, and other risks, or that are otherwise subject to changed conditions that significantly reduce performance in environmental health protection. Consider modification, rebuilding, or relocation of sanitation infrastructure to protect human and environmental health.

HC-4: Assess, Protect, and Develop Plans for Archaeological Sites and Gravesites

In cooperation with appropriate local, regional, and statewide entities, assess archaeological sites and gravesites at risk from accelerated coastal and river erosion; convene archaeologists, anthropologists, Alaska Native elders, and others to discuss how best to address and prioritize sites at risk; and develop a plan for the protection or recovery of important at-risk sites. Assist in identifying and opening new gravesites; convene a respectful discussion about gravesites and explore best practices; and provide assistance for the relocation of existing at-risk gravesites.

gravesites, archaeological sites, and historic sites due to accelerated coastal and river erosion. Box 7-2 summarizes the recommendations for Health and Culture.

Implementation of the recommendations would not only decrease vulnerability now, but would also build the capacity to increase future resilience to climate change. The recommendations would establish processes and data collection programs to support future actions to address additional climate change-related risks. The human and financial resources required for implementation would be significantly less than the benefits that would accrue; the overall resources needs are modest.

Research will be a critical part of these recommendations, as described further in Box 7-3. The recommendations are also intended to build on existing public and private sector programs and activities as described in Box 7-4. Both these boxes appear at the end of this chapter.

		Type of option										Implementation				
		Coordination														
Option (number)	Short option name	State interagency coordination	Community response and assistance	Data management	Access to data and "knowledge" sharing	Data collection (research, monitoring, observation, etc.)	Regulatory / programmatic change or addition	Assessment, evaluation, or planning	Capacity building , education, outreach	Direct or indirect financial assistance (e.g., tax incentives)	Capital improvements	Requires new /institutions / government agency	Requires new staffing	Requires funding	Requires new legislative authority	Lead role for state government
HC-1	Infectious Disease Surveillance and Control	✓		✓	✓	✓		✓					✓	✓		✓
HC-2	Community Health Impact Evaluation	✓	✓		✓		✓	✓	✓					✓		✓
HC-3	Sanitation Infrastructure and Practices	✓	✓	✓	✓	✓		✓	✓		✓		✓	✓		✓
HC-4	Archeological Sites and Gravesites	✓		✓	✓	✓		✓	✓				✓	✓		✓

Description of Health and Culture Recommendations

This section describes the options recommended for the Health and Culture sector.

HC-1 Augment Surveillance and Control Programs

Augment surveillance and control programs for vector-, water-, and foodborne diseases likely to become greater threats because of climate change. Public health surveillance is the ongoing and systematic collection, analysis, and interpretation of data essential to the planning, implementation, and evaluation of public health practice. Improving surveillance will allow more robust tracking and identification of trends in order to expeditiously and effectively respond to and control emerging public health threats. Surveillance and control

are necessary because they are the mechanisms by which public health practitioners prevent, prepare for, and respond to disease threats.

The State of Alaska agencies currently tasked with the responsibility for surveillance and control for human and animal diseases are the ADHSS, the ADEC, and ADF&G. The recommendations presented in this option will require augmentation of existing surveillance and control efforts performed by programs within these agencies. Implementation of the option recommendations will require increased human and material resources, including methods and tools within existing programs as well as new and augmented partnerships with the public and private sectors, including memoranda of understanding to collect the necessary data.

The targets of the option include:

- Improve surveillance for vectors and vectorborne diseases in vectors;
- Expand and improve ADHSS hospital discharge and emergency room databases to improve detection of climate change-related diseases;
- Improve health care provider education around infectious disease reporting;
- Create a reporting system for sanitation/wastewater integrity disruptions within ADEC;
- Improve interagency notification of drinking water and wastewater violations between Municipality of Anchorage (MOA), ADHSS, ADEC; and
- Provide surveillance and control program updates to stakeholders through a variety of means.

HC-2 Evaluate Recommended Adaptation and Mitigation Options

Evaluate recommended adaptation and mitigation options to determine whether they could result in adverse health impacts. Actions taken to mitigate greenhouse gas emissions or to adapt to the current and projected impacts of climate change in a wide variety of sectors may benefit or harm human health. These auxiliary health effects are generally unintended, and can range from minor to highly significant. At present, there is no established mechanism for a brief, structured, and rapid professional evaluation of a proposed mitigation or adaptation measure to identify potential adverse or positive influences on health. This option would create such a mechanism to identify where health effects were unlikely, minor, few, or significant. Such an evaluation would facilitate the design and implementation of necessary additional measures, including monitoring to maximize benefits and to reduce potentially likely and significant adverse effects. This option proposes a Community Health Impact Evaluation (CHIE) initiative to rapidly and efficiently screen proposed mitigation and adaptation activities to determine whether there may be associated health benefits or harms and to identify additional actions to maximize the benefits and reduce potential adverse impacts.

The CHIE would require a Project Review Committee (PRC) with primary responsibility for examination and evaluation of each mitigation and adaptation measure recommended for implementation. To optimize efficiency and ensure rapid response, the PRC would have a core team that includes the DPH, representatives from relevant state agencies, and public health professionals from other organizations. Implementing this option would not require the hiring of new professional staff, but would need part-time staff support.

The PRC would follow these steps:

- The state agency responsible for the mitigation or adaptation measure would develop a tiered approach to determine which actions merit further analysis. The potential impacts associated with the actions under consideration will be the determining factor that dictates the level of review: Mini, Desktop, or Full.
- If further evaluation is warranted, a request would go to the PRC chair for an evaluation, along with a full description of the measure.
- The PRC Chair would convene the core PRC members, with at least one representative from the responsible state agency. The proposed measure would be reviewed by the PRC to determine the possible need for an in-depth review. A detailed evaluation would be recommended if (1) multiple likely mechanisms for adverse health effects were identified, (2) one mechanism was identified with a high likelihood of adverse effect, or (3) the initial evaluation suggested that there was likely to be a public perception of possible adverse effects.
- If the PRC evaluation concluded that there was a negligible likelihood for any adverse health effect, a report from the PRC would be issued to the responsible state agency.
- If the PRC decided an in-depth evaluation was advisable, an appropriate group of additional consultants, agency personnel, and citizen members would be convened and a process followed to: (1) ascertain the possible pathways or mechanisms of potential adverse effects or benefits, (2) identify all aspects of effect mechanisms, positive and adverse, and suggests measures to mitigate adverse effects and maximize benefits, (3) align measures designed to minimize adverse impacts and measures designed to maximize benefits, with outcome monitoring indicators to create the most efficient monitoring strategy, and (4) and submit a final report within 4-6 working weeks.

HC-3 Assess Sanitation and Infrastructure Practices

Assess sanitation infrastructure and practices at risk from climate-related impacts. Sanitation and solid waste management are intended to prevent the outbreak of waterborne, vector-borne, and hygienic diseases; limit environmental toxic exposure to humans and wildlife; and improve quality-of-life. Facility and program performance design is based on historical environmental factors. Increases in global temperatures have led to new and exacerbated existing problems in sanitation and solid waste management that are anticipated to negatively impact the health of communities. This option is intended to adapt program and facility design so that public health continues to be adequately addressed in the face of current and anticipated environmental changes. Current rural sanitation policies are insufficient to address these changes and need to be modified. The objective of this option is to protect the health of humans and wildlife from the effect of climate change in Alaska by improving the capacity of the rural sanitation and solid waste management systems to respond to and/or control anticipated new and exacerbated disease and toxic exposures. The goal is to prevent or at least ameliorate acute and chronic health problems in the population.

There is a growing scientific consensus that climate change has affected the distribution, including incidence and geographic range, of infectious and non-infectious diseases that sanitation systems are intended to minimize. Additionally, changes in water quality—such as acidification and temperature that can affect human and wildlife toxic exposures—are occurring in Alaska. Changes in drinking water supply (both quality and quantity) and location may occur with the changing hydrology regime. Permafrost, utilized in some cases as a waste liner for sewage lagoons and solid waste facilities, and riverbanks that support treatment cells and infrastructure are eroding. Additionally, permafrost laden soils, in some cases, serve as structural elements in

the foundation of water storage tanks, buildings that are part of the community sanitation infrastructure, and/or earthen berms that may contain fresh water for drinking or coral effluent from a sewage collection system. These phenomena are a concern as rural sanitation differs from urban and semi-rural facilities.

The agencies currently tasked with the responsibility for rural sanitation and solid waste management include the ADEC, the ANTHC, regional tribal health organizations, local environmental programs, U.S. Department of Agriculture (USDA), and U.S. Environmental Protection Agency (EPA). Alaska DHSS, ADF&G, and U.S. Fish and Wildlife (USFWS) are indirectly involved in identification and control for human and aquatic life negative health outcomes that may emanate from inadequate system performance.

The recommendations presented in this option will require augmentation of existing sanitation and waste management or human and aquatic life health efforts performed by programs within these agencies. Implementation of the option recommendations will require increased human and material resources, including methods and tools, within existing programs as well as new and augmented partnerships with the public and private sectors. Additionally, these recommendations will require an update of existing environmental data sets (temperature and climate projections) in order that facilities can be constructed and/or renovated to meet future changed environmental conditions.

A number of these recommendations, while focused on health-related concerns, also overlap with public infrastructure.

Targets include:

- Provide a portion of distressed community operation & maintenance (O&M) costs in order to adequately protect system investment, via annuity or other mechanism. Non-traditional approaches such as the Alaska Rural Utilities Collaborative may be considered for more wide spread utilization.
- Collaborate with statewide sanitation and environmental health entities currently conducting infrastructure inspections to design inspection/evaluation protocols addressing severity, nature, and timing of climate change impacts.
- Review existing Class III solid waste management guidelines (for rural and remote, non-hub communities) to adapt the regulations, recommendations, and community outreach to anticipate continued climate change impacts.
- Review the State of Alaska Capital Improvement Project (CIP) list for solid waste projects and priority classifications in relation to substantial and relevant climate change issues.
- Make available financial resources or incentives for development of more efficient and lower-cost systems (e.g., Alaska-based manufacturing of road mats, modular treatment systems).
- Establish a Memorandum of Understanding (MOU) between agencies related to responsibilities.
- Assure to the extent possible that existing sanitation facilities are protected against system failure due to climatic events such as flooding, wind, erosion, permafrost melt, etc.
- Plan and design for new sanitation facilities to account for potential future climate changes that could damage or destroy these facilities

HC-4 Assess Archeological Sites at Risk from Accelerated Coastal and River Erosion

The State should convene archaeologists, anthropologists, Alaska Native elders, and others to discuss how best to address and prioritize cemetery, archaeological, and historic sites at risk, and develop a plan for the protection or recovery of important at-risk sites. This process should (1) include a statewide assessment of the gravesites most at risk, (2) assist in identifying and opening new gravesites, (3) convene a respectful discussion about gravesites and explore best practices, and (4) provide assistance for the relocation of existing at-risk gravesites. The objective of this option is to identify, assess, prioritize, and mitigate adverse effects of climate change on gravesites, archaeological sites, and historic sites through the development of dedicated program areas within existing state authorities. This will provide for the coordination of efforts to identify, assess, prioritize, and develop mitigation plans to address the effects of climate change, and will enable the State to rapidly respond to threats as necessary.

This option addresses the observed and projected increase in the destruction of gravesites, archaeological sites, and historic sites due to the effects of global climate change. Programs within the state have the authorities, infrastructure, and expertise to coordinate identification, assessment, and mitigation of adverse effects to these resources, but do not have adequate staff or funding to perform the duties. Appropriate responses to these challenges require augmentation to existing infrastructure.

The state agency tasked with preservation and protection of archaeological and historical sites on state lands, including tidelands and submerged lands, is the Office of History and Archaeology (OHA). Housed within the ADNR, Division of Parks and Outdoor Recreation (DPOR), OHA carries out the policy of the State to “preserve and protect the historic, prehistoric, and archeological resources of Alaska from loss, desecration, and destruction so that the scientific, historic, and cultural heritage embodied in these resources may pass undiminished to future generations...” (AS 41.35.10). OHA also fulfills the responsibilities of the State Historic Preservation Office, a federally funded program that carries out the mandates of the National Historic Preservation Act of 1966 *(16 U.S.C. 470)* for a wide range of historic preservation activities, including maintenance of the official restricted-access statewide inventory of archaeological and historic sites. With regard to gravesites and human remains, OHA has provided forensic anthropology consultation to the State Medical Examiner (SME) under reimbursable services agreements since 1988. In 2004, OHA initiated a Memorandum of Understanding with the SME and Alaska State Troopers (AST) that provides interagency guidance on the discovery and treatment of human remains.

Targets include:

- Establish a new program area within OHA, with a dedicated archaeologist/anthropologist position and funding for travel and equipment to coordinate and facilitate cemetery issues. Duties would include coordination of studies to assess the effects of climate change and provision of technical advice. Modeled somewhat after a successful program in Wisconsin, the proposed “Alaska Burial Sites Preservation Program” would coordinate closely with the Alaska State Troopers (AST), the Alaska State Medical Examiners Office, tribes, and other stakeholders. The position should be supplemented as necessary to carry out specific program activities through the use of paid college interns or non-permanent state positions. The position would serve as OHA liaison with law enforcement agencies, the State Medical Examiner’s Office, and the Bureau of Vital Statistics (BVS) (for burial transit permits and disinterment/re-interment permits). The position would also facilitate communication with tribal representatives on matters involving human remains.

- Establish a new program area within OHA, with a dedicated archaeologist position and funding for travel and equipment, to coordinate and facilitate studies for addressing the effects of climate change on Alaska's archaeological and historic sites.
- Pursue funding to create a benefit for private landowners who actively protect listed cemeteries/gravesites, and archaeological or historical sites on their land.

Box 7-3. A Sampling of Relevant Current Activities and Entities

The examples presented below are not intended to be exhaustive, but rather to illustrate ongoing and proposed initiatives and activities.

Center for Climate and Health (CCH), Alaska Native Tribal Health Consortium (ANTHC)

The CCH combines engineering, environmental health, and community health expertise to provide the Alaska Tribal Health System with a comprehensive approach to local climate challenges: http://anthc.org/chs/ces/climate.

A number of programs within state agencies presently offer services that provide expertise or have the potential to further engage in collaborative efforts to carry out the options recommended by the AAG. Some of these include:

- Environmental Public Health Program, ADHSS
- Infectious Disease Program, ADHSS
- Office of the State Veterinarian Program, ADEC
- Drinking Water Program, ADEC
- Wastewater Program, ADEC
- Solid Waste Program, ADEC
- Wildlife Conservation Program, ADF&G

Box 7-4. Health and Culture Recommended Research Needs

The Research Needs Work Group identified research necessary to both assist implementing the recommendations and to help the State of Alaska better understand the impacts of climate change on its health and culture.

- HC/RN-2.1 Assess impacts and socio-economic effects of decline and migratory shifts of major subsistence species and vegetation.
- HC/RN-2.2 Standardize ADF&G harvest surveys.
- HC/RN-4.1 Evaluate current monitoring and surveillance programs to ensure effectiveness in detection and control of new pathogens or contaminants from source water.
- HC/RN-4.2 Assess sanitation and solid waste disposal infrastructure and practices impacted by climate change.
- HC/RN-4.3 Estimate the impact from potential release of methane hydrates in the Arctic.
- HC/RN-4.4 Study the potential increase in bioavailability of trans-boundary pollutants.
- HC/RN-4.5 Study the interaction of increased UV exposure on humans, animals, and vegetation in conjunction with projected climate changes.
- HC/RN-5.1 1. Assess archaeological sites most at risk and develop a protection or recovery plan. 2. Complete a statewide assessment of, and response to, gravesites most at risk.

For additional information on each recommendation, and for a broader set of identified needs, see Research Needs Work Group (2009). The numbering system above refers to the last two subsection numbers in the appropriate chapter in the report.

CHAPTER 8. COMMON THEMES

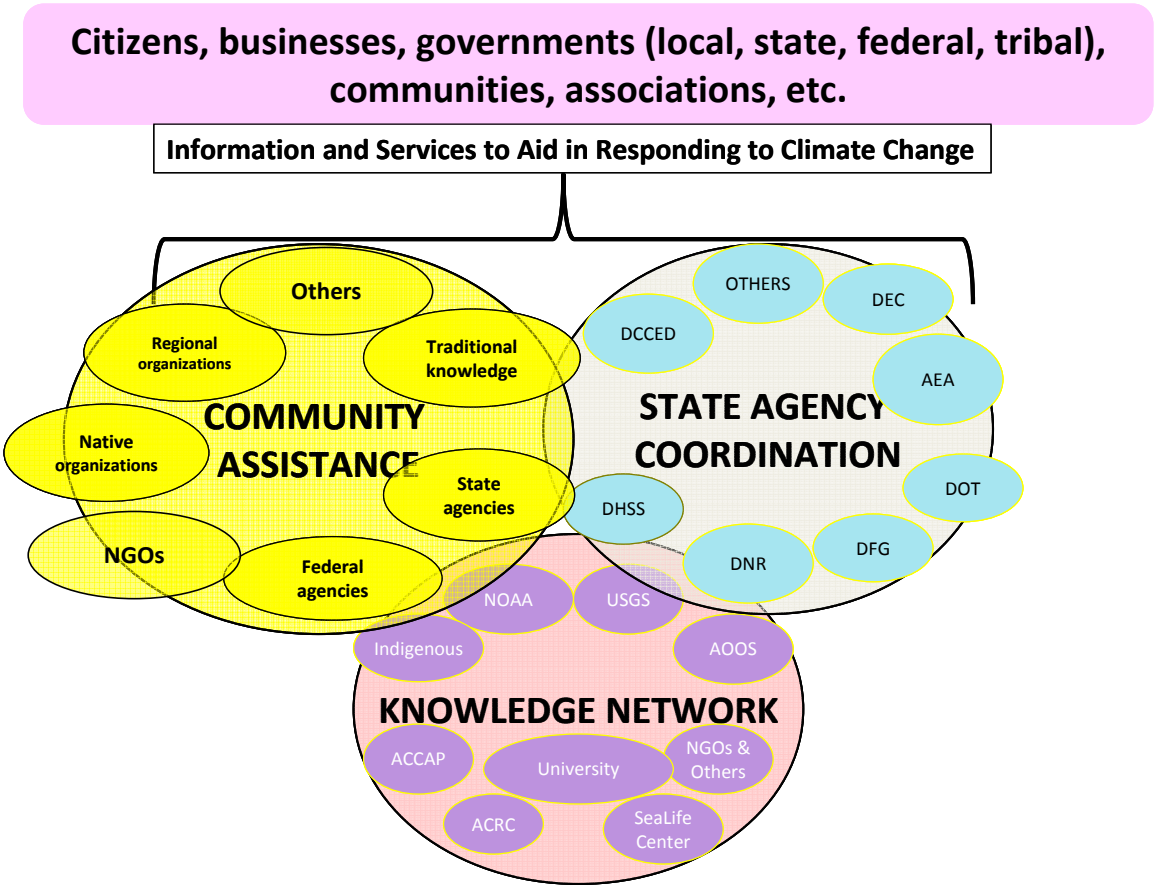
Across the sectors, a number of common themes emerged for types of actions that will be needed in order to assist Alaska in adapting to climate change. These themes included needs for improving access to data, for community assistance, for coordination, and for education. Most of these themes are as relevant to mitigation as they are to adaptation.

Overview of Common Themes		
	Option Name	Level of Support
CT-1	Establish an Alaska Climate Change Knowledge Network	Unanimous
CT-2	Coordinate Implementation of Alaska's Efforts to Address Climate Change	Supermajority*
CT-3	Community Climate Impact Assistance	Unanimous
CT-4	Promote Climate Change Science through K-12 Education	Unanimous

*Supermajority reflects one objection. One AAG member voiced support for the option but felt it imperative that the State Coordination function expand beyond the coordination of internal state efforts to a more active and explicit role in providing communities with assistance. The suggestion was that CT-2 and CT-3 be combined, to avoid creating a new entity.

		Type of option										Implementation				
		Coordination														
Option	Short Option name	State interagency coordination	Community response and assistance	Data management	Access to data and "knowledge" sharing	Data collection (research, monitoring, observation, etc.)	Regulatory/programmatic change or addition	Assessment, evaluation, or planning	Capacity building , education, outreach	Direct or indirect financial assistance (e.g., tax incentives)	Capital improvements	Requires new institutions/government agency	Requires new staffing	Requires funding	Requires new legislative authority	Lead role for state government
CT-1	Establish a Knowledge Network	✓	✓	✓	✓			✓						✓		✓
CT-2	Coordinate Implementation	✓	✓					✓						✓		✓
CT-3	Community Climate Impact Assistance	✓	✓		✓	✓	✓	✓	✓	✓	✓			✓	✓	✓
CT-4	Promote Climate Change Science	✓			✓				✓					✓		✓

The recommendations fill a variety of needs that will greatly assist Alaskan efforts to address and respond to climate change, as illustrated in the figure below. In addition, the table above identifies how each of these recommendations helps to meet those needs.



Description of Common Themes Recommendations

Box 8-1 provides an overview of the recommendations, which are described in more detail below. Research will be a critical part of these recommendations, as described in Boxes 8-2 and 8-3. The recommendations are also intended to build on existing public and private sector programs and activities as described in Box 8-4. Boxes 8-3 and 8-4 appear at the end of this chapter.

Box 8-1. Overview of Common Theme Recommendations

CT-1 Establish an Alaska Climate Change Knowledge Network - This option recommends establishing an Alaska Climate Change Knowledge Network (ACCKN) to provide an effective collaborative means to manage data and foster its use for adaptation. Where appropriate, the ACCKN would organize, consolidate, integrate, and archive data, information, and knowledge related to climate change. They would serve as a point of coordination for NOAA's proposed Regional Climate Center in Alaska.

CT-2 Coordinate Implementation of Alaska's Efforts to Address Climate Change - This option recommends that Alaska's efforts to address climate change continue to be coordinated internally to ensure synergy among state agency efforts as well as unified and strategic interaction with federal agencies and outreach and education activities.

CT-3 Community Climate Impact Assistance - An array of state, federal, and regional entities are responsible for delivering services to Alaskan villages, rural communities, and urban centers, but specific policies and regulatory constraints produce conflicting directives that prevent the coordinated delivery of vital services that will enable endangered villages, traditional culture, and vulnerable communities to adapt in the face of climate change. Therefore, there is a need to establish a coordinating entity with the ability to navigate these multiple bureaucracies and to leverage their resources to support vulnerable communities in emergency response, relocation, subsistence concerns, and other priorities.

CT-4 Promote Climate Change Science through K-12 Education – Promote development of curriculum and training to support climate change in education in grades K-12.

CT-1 Establish an Alaska Climate Change Knowledge Network

Numerous activities are underway in various arenas to obtain data relevant to climate change in Alaska. Many agencies, organizations, and offices have responsibility for collecting, generating, and organizing data. Examples of these include: the Alaska Marine Ecosystem Forum, the Alaska Ocean Observing System (AOOS), the Alaska Center for Climate Assessment and Policy, the Alaska Climate Research Center, the National Oceanic and Atmospheric Administration (NOAA), the U.S. Geological Survey (USGS), the Alaska SeaLife Center, etc. Some of the existing data are maintained in online archives, while others are stored in file cabinets or boxes, with no easy way to access and integrate the datasets and research. Additionally, numerous forums, meetings, and events take place that generate information, knowledge, and ideas among the participants about specific geographic areas (e.g., the Arctic) or specific thematic areas (e.g., ocean acidification), but finding, integrating, and making use of this information is very challenging. Overall, there is a large amount of information that scientists, decision-makers, and others need about climate change and its effects that could be more accessible, better integrated, and more valuable to communities, agencies, businesses, universities, and individuals. Option CT-1 presents one recommended strategy to improve this situation.

The recommendation is that the State of Alaska authorize establishment of an Alaska Climate Change Knowledge Network (ACCKN) to foster coordination among the various entities with responsibilities for collecting, interpreting, and using climate change data in Alaska. The ACCKN will integrate data and gather information by building on existing efforts and responsibilites. The intent is to create a network that leverages current efforts and supports the following functions:

- Organize, archive when needed, and inventory data and other resources pertinent to understanding climate change and its effects in Alaska.

- Promote enhanced online access to the above data, information, and knowledge in ways that facilitate use.
- Identify and communicate (to data and information providers) the needs of communities for information to understand and plan for climate change.
- Share information on specific geographic and/or thematic areas of concern.
- Incorporate community and other entities' (e.g., private, non-profit, and citizen science efforts) data, information, and knowledge about the effects of climate change and feedback on adaptation efforts.
- Integrate and analyze data and information for better understanding of climate change impacts and effects, including identifying gaps where additional data may be needed.
- Provide a point of coordination with federal efforts in Alaska, such as NOAA's activities to develop a Regional Climate Service partnership, and USGS activities related to the proposed Alaska Wildlife Climate Science Center.

This option would establish a focal point for organizing the many data collection efforts to improve access to and use of them. It is expected this focal point will consist of a staff that supports the many tasks outlined below. This staff may be established at a state-university funded site, a non-governmental organization (NGO), within an existing agency, or through some other entity. This staff will bring expertise in both technology to support the infrastructure of the ACCKN and science to understand the content as follows:

- A comprehensive inventory of organizations and programs collecting data relevant to climate change in Alaska.
- Improved access to climate change data and information existing in current databases and centers.
- Improved access to research papers and references, information about successful climate adaptation efforts, information on themes and geographies, etc.
- Forum for integrating and analyzing data.
- A Frequently Asked Questions and Answers list.
- Identification of missing data (data gaps).
- Means for communities and citizens to provide data and measurements and to receive easily understood and locally relevant information for climate change adaptation.
- Forums for discussion on topics of interest.

Various existing data collection entities are interested in initiating this effort as soon as possible, and intend to take short-term actions to coordinate with each other and seek funding. It is recommended that the State of Alaska invest resources and support for this measure, which is critical to establishing a foundation based on sound, shared science.

CT-2 Coordinate Implementation of Alaska's Efforts to Address Climate Change

The ability to implement the breadth of options recommended by the Advisory Groups without duplicating efforts requires coordination among state agencies. Coordination can promote efficiencies and effectiveness to address both mitigation and adaptation efforts on the following fronts:

- Tracking climate change efforts across state agencies in Alaska.

- Communicating between State of Alaska and other efforts (e.g., federal activities).
- Responding to expected federal initiatives on climate change.
- Providing access to information and education resources.
- Improving outreach to citizens and businesses on climate change.

To achieve the above, a coordinating entity is needed within the State. This could be an Alaska Climate Change Coordinating Committee under the Subcabinet or a designated person or office that brings together representatives of state agencies. The intent of this effort is to coordinate the implementation of the recommendations of the Subcabinet among state agencies; ensure that the state agency development of position papers, guidance documents, policies, procedures, and standards to establish and implement federal and state climate change programs are coordinated; provide for consistent outreach and information from state agencies on climate change mitigation technology and regulatory guidance to industry and the public; ensure the State's efforts are coordinated with other related initiatives such as Alaska energy planning, the Alaska Municipal League member actions, industry, the Western Climate Initiative (WCI), and advisory groups working on climate change efforts in Alaska; and provide a primary point of contact for federal agencies addressing climate change in Alaska.

This coordination effort will provide support for various state agency responsibilities, including a greenhouse gas (GHG) emission reporting program and associated inventories; state government partnerships with private citizens, businesses, and local governments; "lead-by-example" actions; and information outreach and education to citizens and businesses on climate change efforts at the state level. This option was identified and developed by the Cross-Cutting Issues Technical Work Group under the Mitigation Advisory Group (MAG) but also brought before the AAG for further endorsement, therefore it is included herein.

CT-3 Community Climate Impact Assistance

This option recommends establishing a permanent, high-level coordinating entity within Alaska to provide tools and assistance to help communities adapt to a changing climate and its impacts on community and individual health. Currently, an array of state, federal, and regional entities are responsible for delivering services to Alaskan villages, rural communities, and urban centers, but specific policies and regulatory constraints produce conflicting directives that prevent the coordinated delivery of vital services that will enable endangered villages, traditional culture, and vulnerable communities to adapt in the face of climate change. A need exists to establish a coordinating entity with the ability to navigate these multiple bureaucracies to leverage their resources in support of vulnerable communities to address emergency response, relocation, subsistence concerns, and other priorities.

The objective of an entity is to create an integrated and coherent process by which state, federal, regional, and local entities can provide rapid, coordinated, and effective relief to communities facing (and experiencing) substantial cultural, health, economic, infrastructure, and subsistence impacts from climate change. The proposed coordinating body will help communities navigate the complexities of requirements and mandates of multiple bureaucracies. Evaluation of existing services and identification of gaps would enable the state to operate as efficiently and effectively as possible. Likewise, inter-agency coordination among multiple state and federal agencies, local governments, NGOs, and others is considered essential in supporting vulnerable communities faced with the complex issues related to climate change.

This policy option is similar to, but provides a slightly different perspective on the Immediate Action Workgroup (IAWG) March 2009 report recommendations. These options should inform each other to create the most cost effective organization to address the problems facing communities.

The specific form and organization of a coordinating body is not specified, as those decisions require additional political perspectives to create an effective coordinating body with the authority, expertise, and community trust necessary to tackle the difficult issues currently threatening Alaskan communities. The primary functions of this coordinating body will be:

- Develop a process for prioritizing and addressing climate challenged communities that is fair and systematic. This may include meetings with at-risk communities, development of strategies under various scenarios, identification of funding options, etc.
- Help communities adapt to flooding and erosion either by relocation or in-place protection. This will include developing a mandate, clarifying responsibilities, identifying and establishing funding, establishing a relocation strategy, addressing National Environmental Policy Act (NEPA) concerns, etc.
- Develop a community-based, flexible, and responsive process to manage and promote traditional ways of life, including subsistence access under changing climatic conditions.
- Develop principles to guide community climate impact assistance activities, including providing resources to ensure cross-cultural communication and understanding within traditional language; reducing community burdens during sensitive times; and providing for local input and community involvement.

Box.8.2 Research Needs Specific to CT-3, Community Assistance

Additional research needs that were identified specific to CT-3, Community Assistance, can be found in the Research Needs Work Group report under Health & Culture. They may also have applicability to other sectors.

HC/RN-1.6 Engage communities in social research on cultural impediments and history of government.

HC/RN-1.7 Conduct social and education research to develop culturally appropriate curriculums for maintaining public infrastructure and community property.

HC/RN-1.8 Perform standardized social network research in select communities to understand potential impacts of relocation on social, sharing, economic and subsistence networks.

HC/RN-3.1-3 Perform regional social impact assessments, including (1) assessments of existing social service infrastructure, staffing, budgets, and delivery; (2) assessments to provide information for Section III of the NEPA process, description of the affected environment; and (3) detailed interviews and oral histories to provide narrative information.

HC/RN-6.1 Community capacity assessment to identify effective cooperative mechanisms to support rural communities in dealing with multiple rules and requirements, and building capacity to design and implement programs.

For additional information on each recommendation, and for a broader set of identified needs, see Research Needs Work Group (2009). The numbering system above refers to the last two subsection numbers in the appropriate chapter in the report.

CT-4 Promote Climate Change Science through K-12 Education

Despite the critical and growing importance of climate change to Alaska's residents, there is a generally a low level of public understanding of the science and impacts of climate change. Successful adaptation to climate change in Alaska requires improved public understanding of these components of climate change. To address this essential need, the State of Alaska should increase emphasis, curriculum, and training for delivery of climate-change science content in grades K-12 and increase coordination among existing programs and entities that address climate-change education in Alaska's schools.

This education will be provided under the framework of the existing Alaska Science Standards. The State will provide training and curricula to teachers on climate change, provide an education specialist to focus on science and climate change education, and increase coordination among existing programs and entities that address climate-change education in Alaska's schools. By emphasizing climate-change education, Alaska will provide adequate educational resources to its residents to enable them to make wise choices about how to minimize the costs and maximize the opportunities that may result from climate change.

Box 8-3. Common Themes Recommended Research Needs

The Research Needs Work Group identified eight overarching needs essential for providing the type of information needed for almost all planning efforts, both mitigation and adaptation. They are as follows.

1. Improve downscaled (local) climate models
2. Expand baseline environmental research and monitoring
3. Improve research infrastructure (computer systems, radar, ships, satellites, personnel, etc.)
4. Improve data integration and sharing
5. Develop multiple level decision-making tools
6. Adapt legal and policy frameworks to incorporate climate change and build in flexibility to address uncertainty
7. Improve baseline mapping
8. Improve climate change-related education and outreach

Additional research needs that were identified specific to CT-3, Community Assistance, can be found in the Research Needs Work Group report under Health & Culture. They may also have applicability to other sectors. For additional broad research themes, see Chapter 3 of this report.

Box 8-4. A Sampling of Relevant Current Activities

The examples presented below are not intended to be exhaustive, but rather to illustrate ongoing and proposed initiatives and activities.

Alaska Center for Climate Action and Policy (ACCAP). ACCAP is one of nine Regional Integrated Sciences and Assessments (RISA) programs nation-wide, funded by the Climate Program Office of NOAA (http://www.uaf.edu/accap/). Started in 2006, ACCAP operates as a collaboration between University of Alaska (AF) campuses and institutes to assist Alaskan businesses, agencies, and citizens in adapting to a changing environment. ACCAP serves as a state-wide resource for climate change information exchange and research design and development. They work closely with the Scenarios Network for Alaska Planning (SNAP) to communicate scientifically credible information about climate change in a form that is useful and usable to decision-makers. Recent projects have included development of tools for decision-making for At-Risk Communities and Fire Prediction and a project to support Cross-Regional Dialog of Local and Indigenous Climate Knowledge and Adaptation. ACCAP also holds monthly Climate Teleconferences/Webinars and is presently working on a Sea Ice Information and Decision-Support Manual.

National Climate Service

Congress is considering legislation to create a National Climate Service, which would enable NOAA and its partners to provide timely production and delivery of useful climate data, information, and knowledge to decision-makers. The goal is to improve everyone's ability to understand, predict, and adapt to climate change.

Alaska Climate Services Partnership

NOAA intends to build on its cooperative efforts with multiple partners (all levels of government, Native communities & organizations, private and public business sectors, research entities, and international bodies) by fulfilling a vision of long-term planning for Alaska by establishing an Alaska Climate Service Partnership by 2015. Plans call for NOAA to identify and share applicable products and to harness existing services to support Alaskan customers in immediate action, adaptation, and mitigation efforts.

National Climate Change and Wildlife Center

The U.S. Geological Survey (USGS), science agency of the U.S. Department of the Interior (DOI), is in early planning stages of establishing a national Climate Change and Wildlife Center to inform adaptation or management of fish and wildlife in the face of climate change. The Center is being designed with input from federal, state, and tribal science and management agencies; NGOs; academia; and others. Mobilization of existing assessment and monitoring capabilities and coordination of interagency and inter-organizational efforts will be tapped for timely forecasting of responses at multiple spatial and temporal scales.