Appendices

APPENDIX 1: CLUSTER 0: OVERALL SKILLS AND ATTITUDES FOR SENIOR 2 SCIENCE*

Overview

Cluster 0 comprises nine categories of specific learning outcomes that describe the skills and attitudes* involved in scientific inquiry and the decision-making process for STSE issues. In Grades 5 to Senior 2, students develop scientific inquiry through the development of an hypothesis/prediction, the identification and treatment of variables, and the formation of conclusions. Students begin to make decisions based on scientific facts and refine their decision-making skills as they progress through the grades, gradually becoming more independent. Students also acquire key attitudes, an initial awareness of the nature of science, and other skills related to research, communication, the use of information technology, and cooperative learning.

In Senior 2, students continue to use scientific inquiry as an important process in their science learning, but also recognize that STSE issues require a more sophisticated treatment through the decision-making process. This process has been delineated in Cluster 0 specific learning outcomes.

Teachers should select appropriate contexts to introduce and reinforce scientific inquiry, the decision-making process, and positive attitudes within the thematic clusters (Clusters 1 to 4) throughout the school year. For example, students will use the decision-making process as they examine an STSE issue related to safe driving conditions in Cluster 3. To assist in planning and to facilitate curricular integration, many specific learning outcomes within this cluster are accompanied by links to specific learning outcomes in other subject areas, specifically English Language Arts (ELA) and Mathematics (Math). There are also links to *Technology As a Foundation Skill Area* (TFS).

Students will...

	Scientific Inquiry	STSE Issues
Initiating	**S2-0-1a Propose questions that could be tested experimentally.** **GLO: C2** **(ELA: S2: 3.1.2)** **S2-0-1b Select and justify various methods for finding the answers to specific questions.** **GLO: C2** **(Math: S2: A-1)**	**S2-0-1c Identify STSE issues which could be addressed.** **GLO: C4** **S2-0-1d Identify stakeholders and initiate research related to an STSE issue.** **GLO: C4** **(ELA: S2: 3.1.2)**

* Reproduced from pages 0.3 to 0.8 of *Senior 2 Science: A Foundation for Implementation, Draft August 2001* (Manitoba Education, Training and Youth, 2001).

Researching

Scientific Inquiry	STSE Issues
S2-0-2a Select and integrate information obtained from a variety of sources. **Include: print and electronic sources, specialists, and other resource people.** **GLO: C2, C4, C6 TFS: 1.3.2, 4.3.4** **(ELA: S2: 3.1.4, 3.2.4; Math: S2-B-1, 2)** **S2-0-2b Evaluate the reliability, bias, and usefulness of information.** **GLO: C2, C4, C5, C8** **TFS: 2.2.2, 4.3.4 (ELA: S2: 3.2.3, 3.3.3)** **S2-0-2c Summarize and record information in a variety of forms.** **Include: paraphrasing, quoting relevant facts and opinions, proper referencing of sources.** **GLO: C2, C4, C6 TFS: 2.3.1, 4.3.4** **(ELA: S2: 3.3.2; MATH: S2-AMA C-1)**	
	S2-0-2d Review effects of past decisions and various perspectives related to an STSE issue. ***Examples: environmentalist and industry group positions on fossil fuel emissions...*** **GLO: B1, C4 TFS: 1.3.2, 4.3.4** **(ELA: S2: 3.2.2)**

Planning

Scientific Inquiry	STSE Issues
S2-0-3a State a testable hypothesis or prediction based on background data or on observed events. **GLO: C2**	**S2-0-3d Summarize relevant data and consolidate existing arguments and positions related to an STSE issue.** **GLO: C4** **TFS: 2.3.1, 4.3.4** **(ELA: S2: 1.2.1, 3.3.1, 3.3.2)**
S2-0-3b Identify probable mathematical relationships between variables. ***Examples: relationship between braking distance, velocity, and friction...*** **GLO: C2** **(MATH: S2-AMA H-3, CMA F-3[11], PCA H-1,2)**	**S2-0-3e Determine criteria for the evaluation of an STSE decision.** ***Examples: scientific merit; technological feasibility; social, cultural, economic, and political factors; safety; cost; sustainability...*** **GLO: B5, C1, C3, C4**
S2-0-3c Plan an experiment to answer a specific scientific question. **Include: materials, variables, controls, methods, safety considerations.** **GLO: C1, C2**	**S2-0-3f Formulate and develop options which could lead to an STSE decision.** **GLO: C4**

<table>
<tr><th></th><th>Scientific Inquiry</th><th>STSE Issues</th></tr>
<tr><td rowspan="2">Implementing a Plan</td><td>S2-0-4a Carry out procedures that comprise a fair test.
Include: controlling variables, repeating experiments to increase accuracy and reliability of results.
GLO: C1, C2 TFS: 1.3.1
(MATH: S2-AMA H-1, 2, CMA F3[11])

S2-0-4b Demonstrate work habits that ensure personal safety, the safety of others, as well as consideration for the environment.
Include: knowledge and use of relevant safety precautions, WHMIS regulations, emergency equipment.
GLO: B3, B5, C1, C2

S2-0-4c Discuss safety procedures to follow in given situations.
Examples: acid or base spill in a lab, use of cleaning products...
GLO: C1, C2

S2-0-4d Interpret relevant WHMIS regulations.
Include: symbols, labels, Material Safety Data Sheets (MSDS).
GLO: C1, C2</td><td>S2-0-4e Use various methods for anticipating the impacts of different options.
Examples: test run, partial implementation, simulation, debate...
GLO: C4, C5, C6, C7</td></tr>
<tr><td colspan="2">S2-0-4f Work cooperatively with group members to carry out a plan, and troubleshoot problems as they arise.
GLO: C2, C4, C7
(ELA: S2: 3.1.3, 5.2.2)

S2-0-4g Assume the responsibilities of various roles within a group and evaluate which roles are most appropriate for given tasks.
GLO: C2, C4, C7
(ELA: S2: 5.2.2)</td></tr>
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Observing, Measuring, Recording	Scientific Inquiry	STSE Issues
	S2-0-5a Select and use appropriate methods and tools for collecting data or information. **GLO: C2 TFS: 1.3.1** **(MATH: S2-AMA: H-1, CMA: F-3,1, PCA: H-3)** **S2-0-5b Estimate and measure accurately using Système International (SI) and other standard units.** **Include: SI conversions.** **GLO: C2** **(MATH: S2-AMA: H-2, CMA: D-1)** **S2-0-5c Record, organize, and display data using an appropriate format.** **Include: labeled diagrams, graphs, information technology.** **GLO: C2, C5 TFS: 1.3.1, 3.2.2** **(ELA: S2: 4.4.1; MATH: S2-AMA B-5, 6, D-1, 2, F-1, A-1)**	**S2-0-5d Evaluate, using pre-determined criteria, different STSE options leading to a possible decision.** **Include: scientific merit; technological feasibility; social, cultural, economic, and political factors; safety; cost; sustainability.** **GLO: B5, C1, C3, C4** **TFS: 1.3.2, 3.2.3** **(ELA: S2: 3.3.3)**

Analyzing and Interpreting	Scientific Inquiry	STSE Issues
	S2-0-6a Interpret patterns and trends in data, and infer and explain relationships. **GLO: C2, C5** **TFS: 1.3.1, 3.3.1** **(ELA: S2: 3.3.1; MATH: S2: AMA J-2, CMA D-5, F-2, H-4)** **S2-0-6b Identify and suggest explanations for discrepancies in data.** **Include: sources of error.** **GLO: C2** **(ELA: S2: 3.3.4)** **S2-0-6c Evaluate the original plan for an investigation and suggest improvements.** ***Examples: identify strengths and weaknesses of data collection methods used...*** **GLO: C2, C5**	**S2-0-6d Adjust STSE options as required once their potential effects become evident.** **GLO: C3, C4, C5, C8**

Concluding and Applying	Scientific Inquiry	STSE Issues
	S2-0-7a Draw a conclusion that explains the results of an investigation. **Include: cause and effect relationships, alternative explanations, supporting or rejecting the hypothesis or prediction.** **GLO: C2, C5, C8** **(ELA: S2: 3.3.4; MATH: S2: AMA J-3, CMA F-2, PCA H-4)** **S2-0-7b Identify further questions and problems arising from an investigation.** **GLO: C4, C8**	**S2-0-7c Select the best option and determine a course of action to implement an STSE decision.** **GLO: B5, C4** **(ELA: S2: 3.3.4)** **S2-0-7d Implement an STSE decision and evaluate its effects.** **GLO: B5, C4, C5, C8** **S2-0-7e Reflect on the process used to arrive at or to implement an STSE decision, and suggest improvements.** **GLO: C4, C5** **(ELA: S2: 5.2.4)**
	S2-0-7f Reflect on prior knowledge and experiences to develop new understanding. **GLO: C2, C3, C4** **(ELA: S2: 4.2.2)**	

Reflecting on Science and Technology	Scientific Inquiry	STSE Issues
	S2-0-8a Distinguish between science and technology. **Include: purpose, procedures, products.** **GLO: A3** **S2-0-8b Explain the importance of using precise language in science and technology.** **GLO: A2, A3, C2, C3** **(ELA: S2: 4.3.1)** **S2-0-8c Describe examples of how scientific knowledge has evolved in light of new evidence, and the role of technology in this evolution.** **GLO: A2, A5** **S2-0-8d Describe examples of how technologies have evolved in response to changing needs and scientific advances.** **GLO: A5** **S2-0-8e Discuss how peoples of various cultures have contributed to the development of science and technology.** **GLO: A4, A5** **S2-0-8f Relate personal activities and possible career choices to specific science disciplines.** **GLO: B4** **S2-0-8g Discuss social and environmental effects of past scientific and technological endeavours.** **Include: major shifts in scientific world views, unintended consequences.** **GLO: B1**	

	Scientific Inquiry	STSE Issues
Demonstrating Scientific and Technological Attitudes and Habits of Mind	S2-0-9a Appreciate and respect that science and technology have evolved from different views held by women and men from a variety of societies and cultural backgrounds. GLO: A4 S2-0-9b Express interest in a broad scope of science- and technology-related fields and issues. GLO: B4 S2-0-9c Demonstrate confidence in their ability to carry out investigations in science and to address STSE issues. GLO: C2, C4, C5 S2-0-9d Value skepticism, honesty, accuracy, precision, perseverance, and open-mindedness as scientific and technological habits of mind. GLO: C2, C3, C4, C5 S2-0-9e Be sensitive and responsible in maintaining a balance between the needs of humans and a sustainable environment. GLO: B5, C4 S2-0-9f Demonstrate personal involvement and be proactive with respect to STSE issues. GLO: B5, C4	

APPENDIX 2: ABORIGINAL TRADITIONAL KNOWLEDGE AND ENVIRONMENTAL MANAGEMENT*

Over centuries of living in harmony with their surroundings, Aboriginal peoples in Canada have gained a deep understanding of the complex way in which the components of our environment are interconnected. In recent years, a growing awareness among non-natives of the value of this traditional knowledge (TK) has increased efforts to link it with science, particularly in the area of environmental management.

A number of resource-management boards, commissions, projects, and legal agreements—including the *Convention on Biological Diversity* and the proposed *Species at Risk Act*—recognize this value, and encourage the participation of Aboriginal people and the use of traditional knowledge in decision making. Environment Canada is engaged in a variety of efforts to supplement its science with traditional knowledge, and build the capacity of Aboriginal communities to manage their resources.

Aboriginal traditional knowledge has been and continues to be accumulated through time spent living on the land. It encompasses all aspects of the environment—biophysical, economic, social, cultural and spiritual—and sees humans as an intimate part of it, rather than as external observers or controllers. TK is part of the collective memory of a community, and is passed on orally through songs and stories, as well as through actions and observation.

This holistic view of the environment is based on underlying values that support sustainability. They include taking only what is needed and leaving the rest undisturbed, and providing for the well-being of the community without jeopardizing the integrity of the environment. The belief that all living creatures deserve respect has enabled Aboriginal peoples to hunt, trap and fish, while at the same time conserving wildlife populations for future generations.

In addition to an understanding of environmental systems as a whole and knowledge of appropriate techniques for harvesting, TK includes qualitative information on animals, plants and other natural phenomena. While significantly more knowledge is available on species that are harvested (such as caribou, seals, whales and fish), Aboriginal hunters, trappers, fishers and gatherers are also aware of the presence and biology of other species in the local environment. Elders, who are the main knowledge-keepers, are astute at noticing subtle patterns and changes within ecosystems.

While TK was often dismissed in the past due to its anecdotal nature, it is an important piece of the puzzle. It has helped scientists recognize and evaluate species and spaces at risk by providing information on broad trends in species distribution, abundance and seasonal behaviour patterns, and saved time and money by guiding field work.

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* Reproduced, by permission, from *Science and the Environment Bulletin*, Issue No. 32 (September/October 2002): 1-3. Environment Canada <http://www.ec.gc.ca/science/>.

To help break down some of the barriers between TK and science, Environment Canada [EC] researchers and officials working under the Northern Contaminants Program have taken part in several Elder/scientist retreats. The two groups meet in northern camps to share their knowledge and thoughts about changes in the environment. Thanks to such efforts, scientists are now addressing more relevant research questions, and Aboriginal peoples are becoming more comfortable with the concept of sharing their TK.

Environment Canada scientists collect TK in both formal and informal ways. One formal method is by conducting interviews with knowledge-keepers—often with the assistance of staff or community members who speak both the interviewee's native language and either English or French. To avoid misinterpretation, questions are straightforward, and are often assisted by maps or photographs.

Such interviews have yielded valuable information on historic and present patterns in land use, wildlife and other aspects of local ecosystems. For example, an important component of the Northern River Basins Study was to determine how TK could complement physical-science studies of northern Alberta's aquatic ecosystem. Hundreds of maps were created from archival records and interviews with long-term residents. In another instance, EC scientists partnered with a local hunters and trappers association to interview Elders in Pangnirtung, Nunavut, about seals, polar bears and ice patterns. The baseline data they provided is being used to monitor the impacts of climate change and contaminants on the region.

Interviews are also useful for collecting TK on the status of species. For example, Gwich'in Elders and fishers helped biologists identify Dolly Varden char as "at risk," and provided details on the species' movements and habitat, including spawning areas. This method has proven particularly effective for assessing changes in the distribution and abundance of migratory birds and other species with northern ranges, because of the expense and logistics involved in conducting scientific studies in this part of the country.

In 2001, EC researchers asked Inuit hunters and Elders whether they had seen any changes in the number of Ivory Gulls on northwestern Baffin Island, in Nunavut. When half replied that they had observed fewer gulls in recent years, a survey was carried out, revealing that breeding colonies in the area had declined by some 90 per cent. Interviews about birds and mammals at risk in the region also provided the first evidence in 70 years that Harlequin Ducks were still breeding on the island.

Also in Nunavut, perceived declines in Common Eider populations reported by Inuit hunters near Sanikiluaq led to surveys that confirmed a 75 per cent decline over the previous survey period. The hunters provide detailed observations for the annual life cycle of the Hudson Bay subspecies, and have helped identify important relationships between eider distribution and ice movement, winter mortality and eider age, nesting success and fox occurrence, and physical condition and seasonal changes in diet.

EC scientists and researchers also involve Aboriginal people as guides and assistants in sampling and surveying efforts, with both parties learning from the informal discussions that take place. For example, while working closely with Aboriginal guides in the Northwest Territories to collect fish and water samples, National Water Research Institute scientists have learned much about observed changes in fish health, harvesting, and important features of the fish's environment.

Since TK loses much of its relevance when removed from the context of its source, many recent efforts to incorporate this kind of information in environmental management include Aboriginal people more actively in decision making. One example includes the numerous co-management boards established by Comprehensive Land Claim Agreements to manage renewable resources in a sustainable manner. Made up of an equal number of Aboriginal and government representatives (including Environment Canada), these boards share scientific and traditional knowledge on everything from wildlife and water to land-use planning. All of their decisions are made by consensus.

In British Columbia, Environment Canada has been working for several years to build partnerships with Aboriginal peoples to achieve important conservation objectives. A key element of this strategy has been the creation of conservation interns who work with the department to inventory populations and habitats on their territories. Such capacity building is aimed at better equipping Aboriginal communities to handle future resource-management responsibilities.

Aboriginal TK is also a key component of recovery programs for two highly threatened habitats out West: the South Okanagan's pocket desert and the Garry Oak ecosystems of southern Vancouver Island and the Gulf Islands. In the South Okanagan, the Osoyoos Band is helping to preserve some of the last undeveloped and unfragmented desert habitat—a significant part of which is located on their reserve—by developing a cultural centre with interpretive trails and guides. The strategy for Canada's endangered Garry Oak ecosystems incorporates aspects of historic Aboriginal management regimes, such as the use of prescribed fire, active cultivation techniques, and the harvesting of traditional foods on some of the few remaining tracts of these grassy parklands.

Best Practices for Traditional Knowledge

- Respect the ownership, source and origins of the knowledge and the needs and sensitivities of its holders, and obtain their approval and involvement.
- Take the time needed to establish a strong, trusting relationship based on honesty, openness and sharing.
- Work on projects of common interest and benefit.
- Continuously foster communication between partners.
- Provide value-added knowledge back to the community in the form of useful products (such as reports) and services, and share equitably with the holders any benefits arising from the use of TK.

On the other side of the country, the Ashkui Traditional Ecological Knowledge Initiative is using the knowledge of the Innu people to examine the landscape and ecology of northern Labrador. With large-scale development pressures in the region increasing, and a lack of scientific information available for environmental assessments, the Innu and Inuit are an important source of ecological knowledge. Environment Canada scientists worked closely with Aboriginal Elders to learn more about elements of the land that are critical to the Innu culture and way of life. Together, they decided to focus their collaboration on *ashkui*—the areas of rivers and lakes that are first to become free of ice each spring.

The first couple of years of the Ashkui Initiative were spent building relationships between Elders and scientists, conducting interviews, shaping the project, and finding study areas of common interest. Meetings were held in camps, with scientists spending several days at a time on the land. Traditional knowledge was compiled into a database, and a series of scientific questions were formulated as the basis for research at 13 ashkui sites. Added value is provided back to the community through such products as newsletters, posters, CD-ROMs, technical reports on water quality and potability, and spring ice-risk maps.

The Ashkui Initiative has spawned several offspring. For one, the project is expanding to study another site of great importance to the Innu—the intersections where caribou paths merge at certain times of year. Scientists are also creating an on-line mapping atlas for Labrador that will enable developers and others to see the value of the landscape to Aboriginal communities. Environment Canada is helping to build capacity within the Innu nation through the university-accredited Environmental Guardians Program, which trains and involves Innu students in planning, report-writing, wildlife monitoring, water chemistry, and other hands-on environmental work. The guardians, who will soon have a permanent office, serve as an important conduit for the flow of information to and from the community.

In the North, Aboriginal people play an active role on the steering committees of such major projects as the Northern Ecosystem Initiative. A variety of efforts under this initiative link traditional knowledge and science. Among them is the Arctic Borderlands Ecological Knowledge Cooperative—a community-based monitoring program that focuses on large-scale trends in climate change, contaminants and regional development in the Porcupine caribou range. Aboriginal assistants interview hunters, trappers and others in their own communities about observations made over the past year of caribou, fish, berries and other environmental indicators. In addition to being part of the department's ecological monitoring network, this information feeds into a number of other programs.

More science projects in the North are also being driven by traditional knowledge. For instance, the Vuntut Gwich'in people, who have traditionally hunted and trapped in the Old Crow Flats of the northern Yukon, told biologists that water levels in the more than 2000 shallow lakes and ponds in the flats have dropped over the past decade. A research team used satellite images and aerial photos to examine the situation, and confirmed that some lakes are draining catastrophically and a large number are drying up—another possible indicator of climate change.

In the South, where traditional knowledge has long been part of consultations with Aboriginal peoples, Environment Canada is taking steps to develop more formalized processes. In Ontario, the last two State of the Lakes Ecosystem Conferences featured special sessions on traditional knowledge, and invited Aboriginal people to provide direction on how science and TK can work together. The result is a co-existence model that recognizes the value of both types of knowledge, and uses relevant information from each to address issues of common interest, such as water quality and invasive species.

While documented TK is already being incorporated into species reports, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) is currently creating an Aboriginal traditional knowledge sub-committee to determine, among other things, how to involve Aboriginal communities more directly. Environment Canada is also in the process of developing a guide on the collection, documentation and use of TK that will establish protocols and high standards of ethics for partnerships and initiatives involving Aboriginal people.

In the meantime, the ongoing use of informal methods to incorporate TK in regional initiatives across the country will continue to reveal best practices for linking this age-old wisdom with scientific expertise. Each piece of the puzzle improves our understanding of the many and complex influences affecting our environment, and the steps we must take to ensure its sustainability for future generations.

APPENDIX 3: RESPONDING TO GLOBAL CLIMATE CHANGE IN CANADA'S ARCTIC (EXECUTIVE SUMMARY)

Executive Summary*

In the Arctic, the Mackenzie area has warmed by 1.5°C over the past 100 years (the warming being most pronounced in winter and spring). The Arctic tundra area has warmed by 0.5°C, but mainly prior to the 1970s. On the other hand, since about 1970, the Arctic mountains and fjords area has cooled slightly, mainly in winter and spring.

Global circulation models (GCMs) suggest increased global annual mean temperature relative to the present of 1 to 3.5°C by 2100 including the possible effects of future changes in atmospheric aerosol content. Pertinent to the circumarctic area are such features as: maximum warming in high northern latitudes in winter, little warming in summer, increased precipitation and soil moisture in high latitudes in winter.

For the Canadian Arctic, winter should see a 5 to 7°C warming over the mainland from west to east and over much of the Arctic Islands, and up to 10°C warming over central Hudson Bay and the Arctic Ocean northwest of the Islands; summer is likely to see up to 5°C warming on the mainland extending into the central Arctic Islands, and 1 to 2°C over northern Hudson Bay, Baffin Bay, and the northwestern High Arctic Islands. There is some suggestion that a modest cooling may occur over the extreme eastern Arctic in winter and spring. For precipitation, increases of up to 25% will be spread throughout the year over much of the region, but mainly in summer and autumn. Some early autumn or spring precipitation currently in the form of snow would become rain.

Potential Impacts on the Physical Environment

- At high latitudes such as in Arctic Canada, **glaciers and ice caps** seem likely to change little in overall size. Enhanced melting at lower altitudes in summer would likely be combined with increased accumulation in higher zones.
- A warmer atmosphere and longer thaw period will be conducive to increased **evaporation** in the Canadian Arctic. Over land, evaporative losses will be modified according to changes in vegetative cover. Recent work for the Mackenzie Basin suggests that evapotranspiration will increase for that area.
- **Northward flowing rivers** throughout the mainland are expected to have decreased flows and levels.

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* Source: *Responding to Global Climate Change in Canada's Arctic—Volume II of Canada Country Study: Climate Impacts and Adaptations*, pp. xiv to xvii, author Barrie Maxwell, Environmental Adaptation Research Group, Environment Canada, 1997. Reproduced with the permission of Public Works and Government Services, 2003.

- Over half the discontinuous **permafrost** zone would disappear eventually. The boundary between continuous and discontinuous permafrost will shift northward by hundreds of kilometers, although the ultimate position and timing are uncertain. The active layer will deepen slowly in the discontinuous zone to perhaps double its current depth. Pronounced thermokarst topography and increased erosional effects on coasts are likely. There will be an increased frequency of occurrence of shallow landslides.
- **Sea ice** occurrence will decline in northern and western areas. A decrease in Northwest Passage winter fast-ice thickness by about 0.5 m (although increased snow cover thickness could temper this) and an increase in the ice-free season of 1 to 3 months are expected. The open water season should lengthen from the current average of 60 days to about 150 days for Beaufort Sea. The maximum extent of open water in summer will increase from its present range of 150–200 km to 500–800 km; and the maximum thickness of first-year ice will decrease by 50–75%. Decreased first-year ice ridging thickness and old-ice incursion frequency (given no change in wind regime) are also anticipated. There will possibly be increased sea-ice extent in the eastern Arctic area in winter.
- **Iceberg** calving rates would likely change little. Concentrations of icebergs in eastern Arctic waters may therefore remain fairly stable.
- **Sea Level**—Overall, much of the Arctic has low sensitivity to such change, as its coastline is generally emergent, but the Beaufort Sea area will be highly sensitive, as will some glacial shores on Bylot, Devon, Baffin, and Ellesmere Islands.
- **Coastal Processes**—An increase in storm surge frequency will impact some areas significantly, such as the Beaufort Sea. In addition, some coastal areas currently protected virtually year-round from wave action by sea ice (such as the northwest Arctic Islands) will be at risk.
- **Freshwater Ice**—The river ice season will be reduced by up to a month by 2050, and up to 2 weeks for larger lakes.

Potential Impacts on Natural Ecosystems

- **Terrestrial Vegetation**—Current global Arctic biomes are expected to change in area as follows: ice-shrink by 12 to 24%, tundra-shrink by 31 to 58% (so that, in Canada, it is mainly confined to the Arctic Islands), taiga/tundra-expand by 16 to 35%. Ecosystem composition will change (more shrubs and moisture tolerant vegetation, less nonvascular plants) and species diversity will decrease. The speed at which forest species grow, reproduce, and re-establish themselves or that appropriate soils can be developed will be outstripped. Shrinking of the Arctic tundra biome will occur hand-in-hand with a northward shift of the treeline, by up to 750 km in eastern Keewatin. An increase in forest fires, along with more insects and a longer growing season, is expected to result in noticeable changes in vegetation in the Mackenzie Basin. Insects now common to southern Canada would move into the Mackenzie Basin area. Similarly the pests which are in the region today would move not only further north but also to higher elevations. Peatlands will be extremely vulnerable to climate change.

- **Terrestrial Wildlife**—In the Arctic, it is the indirect effects of global warming on feed and water availability that will be the more significant for wildlife. Changes in timing and abundance of forage availability and parasite infestations may accumulate to drive populations into decline, with serious consequences for people still depending on them. Bathurst caribou which live north of Great Slave Lake would probably lose weight in part due to heavier snow cover, and in part due to an increase in the number of insects harassing the herd. North of the mainland, High Arctic Peary caribou and muskoxen may become extinct. Predator-prey relations are a critical component of life cycles of Arctic species; such relations will shift where snow cover and snow type distributions change. The summer habitat of shorebirds in the Mackenzie Delta probably would not change much; on balance, projected future changes in climate and environmental conditions are more likely to be detrimental than beneficial to geese.
- **Freshwater and Marine**—Lake temperatures would rise but the effect on fish habitats in freshwater is uncertain. Cold water species might be at greater risks as their potential to adapt is not completely known. Arctic char, for example, is one species which could be affected as the northward expansion of southern fish species, such as brook trout, provides competition. Many species in lakes and streams are likely to shift poleward by about 150 km for every 1°C increase in air temperature. The distribution and characteristics of polynyas (ice-free areas, such as the North Water at the northern end of Baffin Island, Hell Gate between Devon and Ellesmere Islands, in Foxe Basin off the coast from Hall Beach, and in Penny Strait) and ice edges that are vital to Arctic marine ecosystems will change. Impacts on mammals such as polar bears, whales, and seals, or on seabirds may be both positive and negative, even on the same species. The range and numbers of some Arctic marine mammals, such as beluga and bowhead whales, may increase or at worst hold steady. Ringed and bearded seals, sea lions, and walruses require expanses of ice cover for breeding, feeding, and other habitat functions and may suffer population decline through pack ice recession. On the other hand, some species (e.g., the sea otter) could benefit by moving into new territories with reduced sea ice. Consequences for polar bears may be especially of concern—prolonging the ice-free period will increase nutritional stress on the Hudson Bay population until they are no longer able to store enough fat to survive. Should the Arctic Ocean become seasonally ice-free for a long period, it is likely that polar bears would become extinct.

Potential Socio-Economic Impacts

- **Oil and Gas**—Even though climate change is generally viewed as easing the environmental conditions under which exploration and development will be carried out, an increased cost for operations in the Canadian Arctic is likely, due to the conservative nature of the industry.
- **Transportation**—Northward expansion of agricultural, forestry, and mining activities would result in the need for expanded air, marine, rail, and road coverage and related facilities.
  - **Air:** Float planes would benefit from a longer ice-free season, but there would be a correspondingly shorter season for winter ice strips.

  - **Marine:** The impacts in Arctic areas would likely be significant. Benefits would take the form of longer shipping seasons in all Canadian Arctic areas, with the likelihood of easy transit through the Northwest Passage for at least part of the year, deeper drafts in harbours and channels, and the potential for reduced ice strengthening of hulls and/or reduced need for icebreaker support. On the other hand, increased costs would result from design needs to address greater wave heights, possible flooding of coastal facilities in the Beaufort Sea and Hudson Bay, and the generally increased need for navigational aids owing to increased precipitation and storm frequencies and requirements for search and rescue activities.
  - **Freshwater:** The Mackenzie River barge season would increase, perhaps by as much as 40%, but lower water levels would make navigation more difficult.
  - **Land:** Increased permafrost instability will likely lead to increased maintenance costs for existing all-weather roads and rail beds, at least in the short term.

- **Building and Construction**—Increased air temperature will have a number of effects, including: reduced power demand for heating, reduced insulation needs, and increased length of the season for construction activities that occur in summer (heavy construction, which may be confined to winter due to the movement of equipment only being possible on frozen, snow-covered ground, would face a shorter season). Affected in various ways will be: northern pipeline design (negative); pile foundations in permafrost (negative, although depends on depth of pile); tailings disposal facilities (positive or negative); bridges, pipeline river crossings, dikes, and erosion protection structures (negative); open pit mine wall stability (negative).
- **Recreation and Tourism**—Warmer temperatures would be expected to be beneficial for recreation and tourism in the Arctic (with, for example, the likelihood of extended summer activities into September, at least in the southwestern mainland areas). Yet their impact may be counteracted by stronger wind and/or reduced visibility in some areas. For the Mackenzie Basin, sport hunting could be hurt. In Nahanni National Park only minor changes for river recreation such as canoeing and rafting due to changes in the hydrological regime of the area are anticipated. On the other hand, forest fire and ecological changes traceable to climate change could have significant negative impacts there.
- **Settlements, Country Food, and Human Health**—Climate change may affect the distribution of animals and other resources on which the northern economy is based. In addition, traditional knowledge and local adaptations may no longer be applicable enough to rely on. The health of northerners may be affected through dietary dislocations and epidemiological changes.
- **Agriculture**—Opportunities would be presented in the central and upper Mackenzie Valley areas. For example, wheat production could improve although expanded irrigation services would be needed.
- **Forestry**—In the Mackenzie area, average age of trees will decline and the yields from all stands of commercial timber—both softwood and hardwood—will fall by 50%.

- **Fisheries**
  - **Arctic Marine**—There will be increases in sustainable harvests for most fish populations due to increased ecosystem productivity, as shrinkage of ice cover permits greater nutrient recycling. There is potential for establishing a self-sustaining salmon population in the western Arctic.
  - **Northern Freshwater**—There will be increases in sustainable harvests for most fish species, due to longer warmer growing seasons and relatively small changes in water levels. A potential increase in the diversity of fish species that can be harvested sustainably is likely, due to increases in the diversity of thermal habitats available to support new species expanding their ranges from the south.
- **Defence**—Canada's position that all waters within the Archipelago are under its sovereign control could be more seriously tested due to more easy access. Increased surveillance and other activities such as a greater search and rescue capability will be required. A lower probability of extremely cold weather would result in Arctic weather and climate being looked upon by strategists as less of a natural defence in its own right. Military sites such as Alert will face altered costs due to changes in space heating requirement and infrastructure maintenance. Overall, an increased DND [Department of National Defence] role and attendant costs are envisaged.

Adaptation

Human beings, vegetation, and wildlife have shown great ingenuity and resourcefulness in adapting to the environmental conditions which characterize the Arctic, but a rapidly changing climate is almost certain to make some existing adaptation strategies obsolete while creating situations that will require new adaptive responses. Adaptation to the impacts of climate change will also have to occur at the same time as northern communities adjust to numerous other social, institutional, and economic changes related to land claims settlements and the creation of new territorial structures such as Nunavut. Climate change could alter many aspects of life, both subsistence and wage-related, in Arctic communities, and in the coming years efforts will have to be intensified to understand how these changes will come about and what effects they will have. Insights from traditional ecological knowledge as well as from modern scientific inquiry will play a key part in this process.

Future Directions

Much work is still needed to understand more fully not only the relationship of climate to all aspects of the biophysical environment as well as socio-economic activities, but also the impacts of climate change on them. In addition to these specific research needs which are well-document in the literature, there are several general concerns which are pertinent to all such sensitivity- and impact-related research for the Arctic.

- **Environmental Monitoring**—Commitment to continued monitoring of atmospheric and oceanographic variables throughout the Arctic is needed.
- **Climate Scenarios**—There is a need for more credible and detailed regional scenarios than currently available from the GCMs [global climate change models].

- **Geographic Emphasis**—The eastern Arctic is much less well-studied than the other regions of the Arctic.
- **Socio-Economic Sectors**—Existing and potential relationships between climate and socio-economic sectors in the Arctic are even less well-understood than those between climate and the biophysical environment.
- **Traditional Ecological Knowledge**—TEK should be more effectively utilized, particularly in respect to quantifying terrestrial and aquatic environmental sensitivity to climate.
- **Stakeholder Involvement**—Real partnerships between researchers and users that involve both communities actively in the planning, developing, and carrying out of impact-related research for the Arctic are essential.