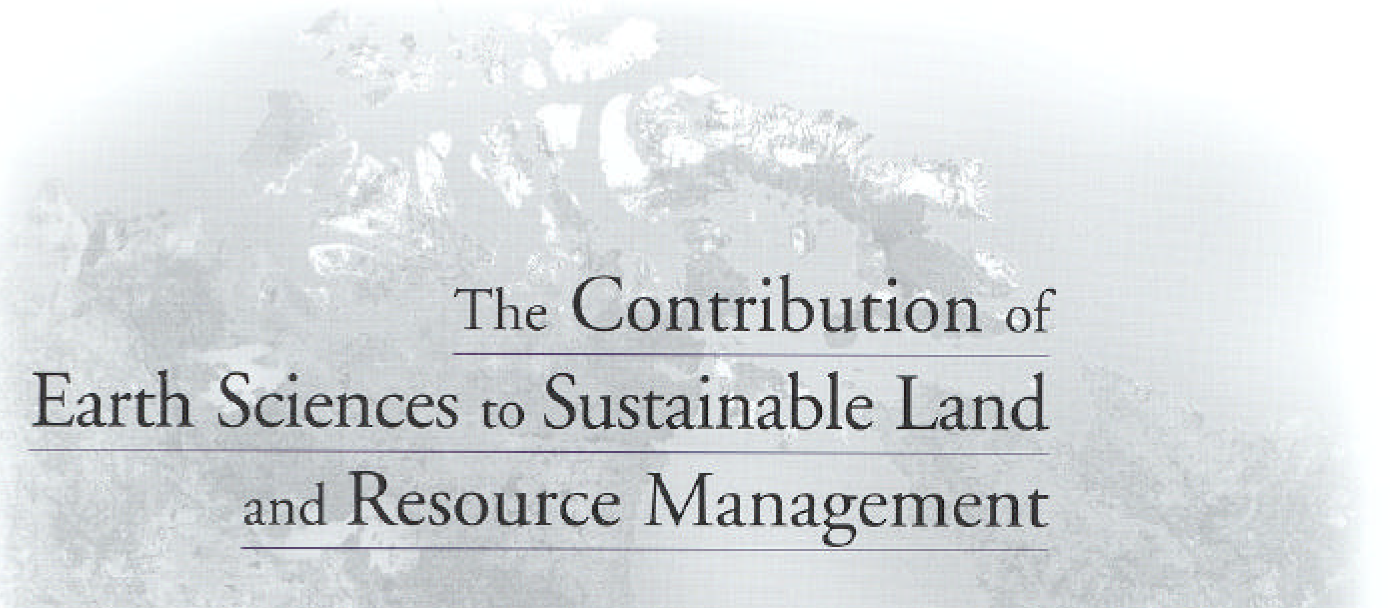
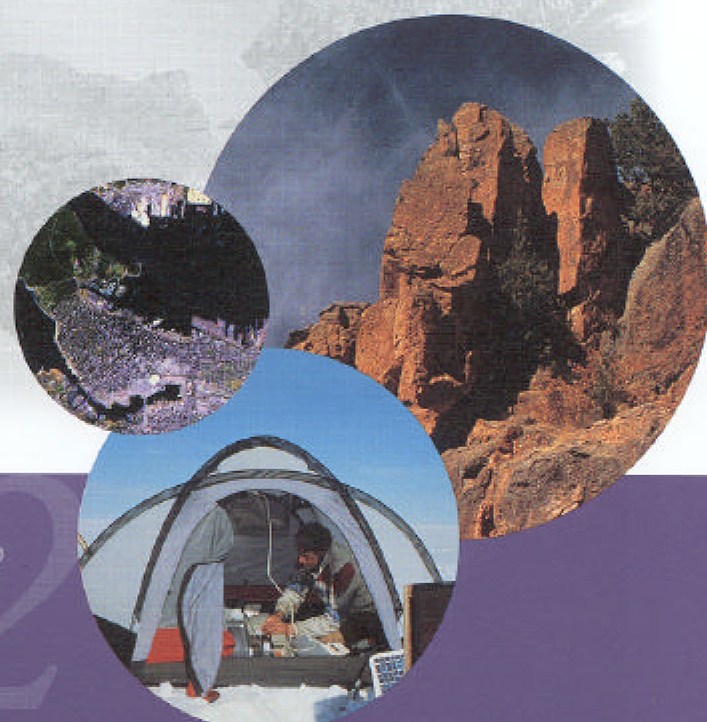


The Contribution of Earth Sciences to Sustainable Land and Resource Management



Monograph No. 12

Canada

The Contribution of Earth Sciences to Sustainable Land and Resource Management

A Canadian contribution to the land use dialogue at the Eighth Session of the United Nations Commission on Sustainable Development, April 24 to May 5, 2000

Ottawa, Canada

2000

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Cat. No. E2-136/13-2000
ISBN 0-662-64832-3

Printed on recycled paper.

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Preface

At its eighth session in the spring of 2000, the United Nations Commission on Sustainable Development (CSD) will be reviewing global progress made with respect to Chapter 10 of Agenda 21, "Integrated Approach to the Planning and Management of Land Resources". For Canada — the world's second largest country in land mass — the issues associated with the sustainable development of land resources are intimately entwined with Canadian history, in addition to being pivotal to its future well-being. As a contribution to the land use dialogue, Canada has prepared a series of six monographs describing its experience and the challenges that remain in the integration of sustainable development.

Agriculture and forests will be particular themes at CSD 8. Canada is world famous for its prairie wheat, and sustainable agricultural practices, both within Canada and internationally, have global implications. Canada presents its experiences in its first monograph on sustainable agriculture. As with the prairies, images of vast Canadian forests and the rugged Canadian Shield rich in minerals are familiar Canadian icons. For this session of the CSD, Canada has updated monographs on forests and on minerals and metals originally prepared for the five-year review of Agenda 21 in 1997.

Canada, along with its circumpolar neighbours, faces extraordinary challenges in the sustainable development of its Arctic regions and is working to this end directly with Indigenous peoples and territorial governments, including the newest territory, Nunavut, which came into being on April 1, 1999. Along with fellow members of the Arctic Council, Canada is looking for means to ensure that the world has a better understanding of the impact of southern activities on the vulnerable Arctic environment. In this regard, a monograph addressing sustainable development and Indigenous peoples in the Canadian Arctic has been prepared.

Key to successfully implementing sustainable development policy is a clear understanding of the issues to be addressed. The role of science cannot be underestimated in this search for understanding. In this regard, Canada has developed two additional monographs. One provides an overview of the applications of earth sciences to the gathering and interpretation of scientific information to contribute to policy development. Finally, Canada concludes its monograph series for CSD 8 with a review of its experiences of an ecosystem approach to the development of sustainable development principles.

This monograph explores how earth sciences in Canada contribute to the sustainable and integrated management of land and resources by generating, analyzing, and disseminating information that is critical to land use decision making on local, regional, and global scales. The earth sciences are critically important to making balanced decisions regarding sustainable land and resource management for several key reasons. First, the unknown cannot be managed. Second, Canada faces growing and competing pressures on land use. Third, there are global issues (for example, climate change, water, transboundary pollution, and natural hazards) where scientific data are integral to good policies for either preventative or remedial action or resolution. Fourth, and finally, the creative application of modern earth science technologies is enriching as well as empowering Canadians in implementing sustainable development principles in land use decisions to their own benefit, as well as to the benefit of future generations of Canadians.

For Canada, sustainable development is best represented as a journey, not a destination. The monographs described above, as well as the other monographs in the Sustainable Development in Canada Monograph Series, are milestones on this journey, and we invite you to join us and share our experiences.

The Contribution of Earth Sciences to Sustainable Land and Resource Management

INTRODUCTION — THE REGIONS OF CANADA

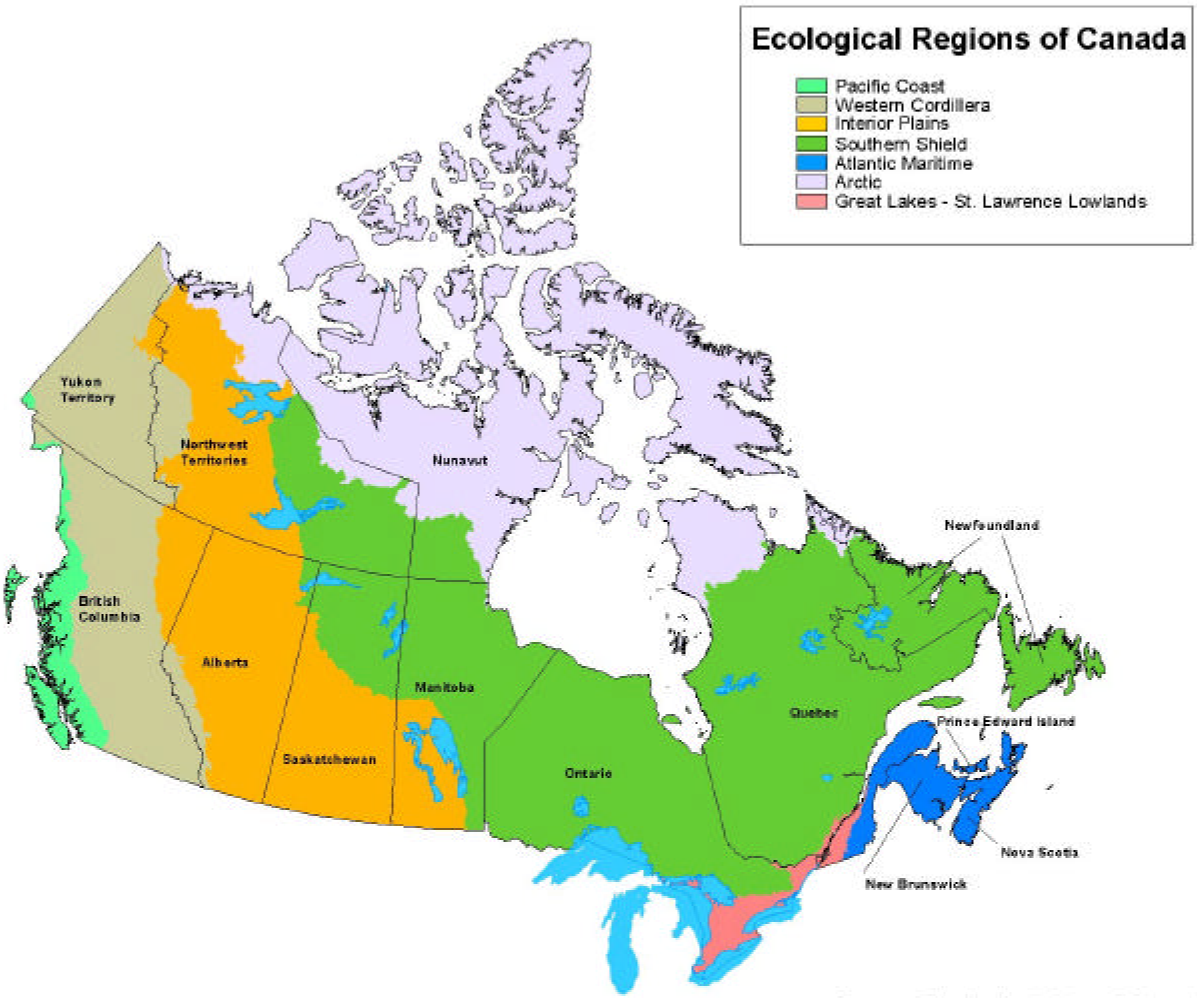
A comprehensive knowledge of the Canadian land mass and its offshore is fundamental to economic development, public safety, environmental protection, and national sovereignty. In part, this is the challenge for earth sciences. By bringing together expertise in surveying, mapping, remote sensing, geographic information systems, the Global Positioning System, and geoscience research, the earth sciences improve the understanding of natural processes, the magnitude of natural wealth, and the impact of human activities on the earth. For Canada, a country occupying the northern half of the North American continent, and, at 9 984 000 square kilometres, the second largest country in the world, this is a major task. It is made even more challenging by the diversity of physiography, geology, vegetation, and climate regions that are inevitably found in a country of this size.

Canada's most distinctive feature is in being a northern country — its land area extends from the midlatitudes (the southernmost point is at 42 degrees north) up to only 800 kilometres from the North Pole. As a result of climate and soil patterns, only the southern fringe of the country is continuously occupied. Almost all of the population lives within 300 kilometres of the southern boundary, with the settlement pattern being a more-or-less continuous band stretching from the Atlantic to the Pacific Oceans.

In dividing Canada into regions, it should be noted that its political division into provinces and territories already furnishes a major set of regions in its own right. Canada is a federal nation, which means the 10 provinces (and, to a lesser extent, the three territories) have substantial roles in running their own affairs, including managing their natural resources.

Ecologically Based Regions of Canada

There are a smaller number of distinct regions that cut across political boundaries. The following description of ecologically based regions points out their location, unique features, and economy, with



Source: The National Atlas of Canada

particular reference to natural resource-based activities. In several of these regions, the economy also makes substantial use of resources in the adjacent offshore areas.

The **Pacific Coast** region corresponds to the Pacific Maritime ecozone. Physically, this area is almost entirely mountainous and could be considered as part of the Western Cordillera, but as the Pacific Coast is so distinctive in climate, it is usually considered as a separate region. It has the mildest climate in Canada as a result of warming due to offshore currents. The area is also the wettest region of Canada. Both aspects help to give it Canada's most productive forest area. Most of the forested area is a temperate rainforest noted for its huge coniferous trees, notably Douglas fir. There are small areas of farmland, but the economy has always been based on forestry and related industries and on trade within the Pacific rim.

The **Western Cordillera** region consists of three ecozones: the Montane Cordillera, the Boreal Cordillera, and the Taiga Cordillera. The region covers almost all of British Columbia and Yukon, and overlaps slightly into Alberta. The distinctive feature of this area is its north–south mountain ranges. To the west, the Coast Mountains run without a break for nearly 1500 kilometres, while along the eastern edge of the region there are the nearly continuous ranges of the Rocky Mountains and the Mackenzie Mountains.

Human activities are diverse in this region, with most being closely based on natural resources. Most of the area is forested, with the result that a very large forestry industry is found extending over most of British Columbia. (British Columbia as a whole produces about 40 percent of Canada's wood production by volume.) The Western Cordillera region also has rich energy and mineral resources; along the eastern edge, these are more likely to be energy resources, such as coal or hydrocarbons, whereas in the rest of the area, they are mainly metals.

The **Interior Plains** region also consists of three ecozones (from south to north): the Prairie Plains, the Boreal Plains, and the Taiga Plains. This region spreads over four provinces and two territories, but is concentrated in the Prairie provinces — Alberta, Saskatchewan, and Manitoba.

Settlement and economic patterns in the region vary markedly from south to north. The southern part contains most of Canada's farmland; Alberta, Saskatchewan, and Manitoba together have 286 000 square kilometres of cropland, 82 percent of Canada's overall total cropland area of 349 000 square kilometres. These lands are mainly a dryland area, with the best soils (chernozem, or black earth) being a band that runs north in Alberta up to Edmonton, then southeast to Winnipeg, Manitoba. The Prairies are world-famous for their production of wheat and other grains, and nearly as well known for their beef and other livestock activities.

The Prairie provinces are also well known as Canada's main location of energy resources. Alberta, in particular, has large oil and gas reserves, and also large areas underlain by oil sands. Saskatchewan and British Columbia also have a substantial oil and gas production industry. All three provinces have large coal resources from which come coal for export and for local electricity generation. The northern part of the Interior Plains is relatively remote and thinly populated, however, that part that falls in the Northwest Territories contains the bulk of the population of this territory.

Canada's most distinctive geological feature is the Canadian Shield, which wraps around Hudson Bay and underlies almost half the country. The part that is largely forested is the **Southern Shield** region. The northern half of the Shield is treeless and is considered as part of the Arctic region. The Southern Shield consists of three ecozones: the Boreal Shield, the Taiga Shield, and the Hudson Plains.

The Southern Shield has very little farmland, but is otherwise a very resource-rich area, with its extensive forest areas and mineral resources each giving rise to a large number of extraction and processing towns. The total area of timber-productive forest land in this region is 1 178 000 square kilometres — 48 percent of Canada's total forest land of 2 446 000 square kilometres. The southern rim of the region (the Boreal Shield) is almost continuously forested and includes almost all of the forest lands of the region. In 1998, this region also produced more than 75 percent of Canada's metal output, with production being almost entirely composed of a small, diverse range of minerals: gold, copper, iron ore, nickel, and uranium. The Southern Shield is also Canada's main source of another resource, hydroelectric power.

This region includes one area not technically part of the Shield, but very similar in overall appearance to it. This is the island of the province of Newfoundland. It has some forest resources, but is otherwise barren. Its offshore fishing banks, however, were the first known natural resource of Canada, and settlements to exploit these grew up along the coasts of the island. The exceptionally rich fishing banks are not as productive now as they have been due to a variety of factors, both human and natural. However, they are being carefully monitored by Canada so as to ensure a viable future fishery. In recent years, other natural resources have become important to Newfoundland, notably the offshore oil and gas resources.

The **Atlantic Maritime** region consists of a single ecozone: the Atlantic Maritime. Both consist of all areas in the three Maritime provinces (New Brunswick, Nova Scotia, and Prince Edward Island) and a substantial neighbouring area of Quebec. A common element of this region is the Appalachian Mountains, which underlie the entire area.

The terrain is a varied one, usually of low mountains, hills, and substantial valleys, except for Prince Edward Island, which is an entirely flat, agricultural area. Otherwise there are few agricultural areas in the region; instead, the economy is based on forestry, fishing, manufacturing, and government services. There are some mineral resources, with the newest one being natural gas from areas off Nova Scotia.

The **Great Lakes–St. Lawrence Lowlands** region, consisting of the southernmost part of Canada, is a tiny area but home to more than half of Canada's population. It contains nearly all of the population of Ontario and most of that of Quebec. This region corresponds to a single ecozone: the Mixedwood Plains.

The region has the best climate for agriculture in Canada and a substantial area of good farmland. Consequently, it vies with the Prairies as Canada's leading agricultural producer. The nature of the agriculture, however, is much different. Because of the large local population, most of the produce from the Great Lakes–St. Lawrence Lowlands is consumed locally, with the result that its agriculture is dominated by dairy and livestock rather than by grains. The Prairies mainly produce for export.

The main basis of the region's economy, however, is manufacturing and the service industries. Canada's two largest urban areas, Toronto and Montreal, are both found in this region, and there are many other large manufacturing centres, as well as other large cities, such as the national capital, Ottawa. The region has always produced the majority of Canada's manufacturing output, and this is likely to remain the case as it is located adjacent to the industrial heartland of the United States.

The **Arctic** region consists of three ecozones: the Southern Arctic, the Northern Arctic, and the Arctic Cordillera. The underlying geology is extremely varied, with more than half the area being underlain by the Canadian Shield. The common aspect of the region is that it is entirely north of the tree line.

This region lies mainly in Nunavut, but much of it is also in the Northwest Territories and parts are in the northernmost areas of Quebec and Newfoundland. The population is small (only about 50 000) and is unusual in that nearly all of it is Aboriginal, predominantly Inuit. These people have lived in the area for thousands of years, primarily exploiting sea resources. Much more recently, substantial new mineral and energy resources have become important and, in some cases, developed. Some of the most recent developments are for Canada's newest mineral product, diamonds.

A Vibrant Technology Sector

Canada has earned recognition as a world leader in the field of geomatics — one of the fastest growing technology sectors over the last decade. The Canadian geomatics community provides software, hardware, and value-added services to help clients resolve problems and seize opportunities in areas such as the earth sciences, infrastructure management, the environment, land management and reform, natural-resource monitoring and development, development planning, and coastal-zone management and mapping.

THE EARTH SCIENCES

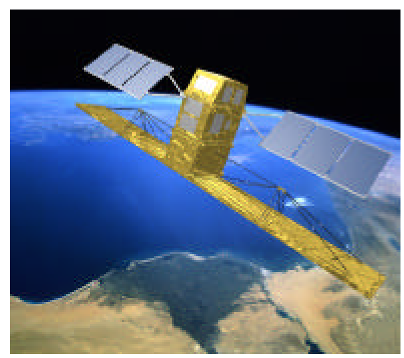
The earth sciences consist of two broad fields: geoscience and geomatics. Focused on the objective of characterizing the nature of the earth and understanding how the earth works, geoscience includes aspects of the scientific disciplines of chemistry, physics, and biology. It is the science of understanding the earth's crust, its components, and their relations and changes. Geomatics is the science and technology of collecting, analyzing, and applying geographic information. By bringing together expertise in surveying, mapping, remote sensing, geographic information systems (GIS), and the Global Positioning System (GPS), geomatics tools create detailed, yet understandable, pictures of the physical world and humankind's place in it.

Earth science information is used to support public sector activities, as well as investment decisions and operations by the private sector at home and overseas. In Canada, the earth sciences are characterized by partnerships, networks, and strategic alliances among governments, universities, and the private sector. The cooperative approach also extends to the international community. It is motivated by the increasingly complex nature of issues and the importance of synergy and collaboration in the national and international science and technology community, as well as by resource constraints.

The Government of Canada is responsible for maintaining a national coordinate system that serves as a reference for all mapping, charting, navigation, boundary demarcation, crustal information, and other georeferencing needs. Learn more at http://www.geocan.nrcan.gc.ca

SUSTAINABLE LAND AND RESOURCE MANAGEMENT

The earth sciences contribute to sustainable land and resource management by providing the basic knowledge and tools necessary to make wise land use decisions; by contributing to the sustainable development of Canada's agricultural, forestry, mining and energy, and groundwater resources; by providing insight into key environmental issues related to land resources, such as climate change, metals in the environment, and the conservation of biological diversity; and by improving the understanding of natural hazards as well as by mitigating the impact of natural hazards and emergencies. Efforts to enhance the capacity of Canada's Aboriginal and rural communities related to the earth sciences and related technologies also contribute to sustainable land management in Canada.



RADARSAT-2. Planned for a 2001 launch.

Applying Earth Sciences to Sustainable Development

Agriculture

Remote sensing has many useful applications in agriculture. It is used to assess crop type classification, crop condition assessment, and crop yield estimation and to map soil characteristics and soil management practices. Radar data collected by satellite are also useful to monitor drought or flooding events that can severely impact crop productivity. This information is valuable to decision makers and analysts within government agencies, grain marketing bodies, agricultural retailers, and insurance companies.

Remote sensing is the science of acquiring information about the earth's surface without actually being in contact with it. Learn more at http://www.ccrs.nrcan.gc.ca

Remote Sensing Technology

RADARSAT is an advanced earth-observation satellite program developed by Canada to monitor environmental change and to support resource sustainability.

The launch of RADARSAT-1 in 1995 gave Canada and the world access to the first radar satellite system capable of large-scale production and timely delivery of data that meet the needs of commercial, government, and scientific programs. RADARSAT-1 provides a new source of reliable and cost-effective data for environmental and resource professionals worldwide. With a planned lifetime of five years, it is equipped with synthetic aperture radar that can transmit and receive signals to "see" through all weather at any time and obtain high-quality images of the earth. These images have proven to be effective tools in the management and monitoring of the global environment in areas of ice navigation, cartography, geological exploration, maritime surveillance, disaster-relief operations, agriculture, and forestry surveillance.

RADARSAT-2, due for launch in 2001, will build on the successes of RADARSAT-1 and offer improved quality of data images to meet the growing world demand for earth-observation information.

Canada has two state-of-the-art satellite-receiving stations, in Quebec and Saskatchewan, with a range that covers Canada and the continental United States. Both stations handle the reception, processing, and archiving of earth-observation data. A centralized facility coordinates the scheduling of the stations, reconciling client data requirements, and scheduling the various satellite sensors with the respective earth-observation satellite-operating agencies. Together, they handle more than 12 000 satellite passes per year with a success rate greater than 99.7 percent.

The Government of Canada provides information on the state of its domestic grain crops through the Crop Information System. For the grain-growing regions of western Canada, data are acquired daily throughout the April to October crop-growing season. This information is customized within a GIS interface, and weekly updates can be viewed by subscribers via an interactive Internet site in the form of image and map products and statistical data. Historical data are provided so that subscribers can evaluate current crop conditions with those from previous years.

A geographic information system (GIS) can integrate and store accurate information on property size, shape, ownership, taxes, and usage. Learn more at http://www.geocan.nrcan.gc.ca/geomatics

Surficial geology mapping, soil geochemistry, and characterization of aquifers are examples of other earth science contributions to agriculture and related management. They provide information on the distribution of metals in soils, are critical to addressing water resource issues for agriculture, and help to assess the impact of climate change on agriculture and other human activities.

Precision farming

The availability of spatially georeferenced data enables a site-specific approach to farming. Such an approach can increase farming profitability and enable farmers to take better account of environmental considerations. Data supplied by a number of sources, ranging from measurements taken in the field to data collected from space, are used to assess the current condition of soils and crops. Changes in the state of these conditions can be monitored over time, providing the information required for near real time mitigation or for prescribing soil and crop treatments for subsequent years. Once fertilizing or harvesting needs have been identified using images from remote sensing satellites, in some instances, GPS technology can be used to guide the application of fertilizer or harvesting equipment.

Forests

The earth sciences help promote the sustainable management of Canada's forests. Governments and forest companies use remotely sensed data to collect information on forest type and health, as well as the extent of harvests and burns, among other things. GIS technology is being used in Canada to monitor forestry programs, assess site access routes, and manage reforestation efforts. The Government of Canada is developing thematic layers of data that are significant in the development and monitoring of criteria and indicators of sustainable forest management. GPS is used by forestry companies in Canada to record the location of trees within forests and to make decisions about which trees to cultivate. Satellites are also used to track forest fires and to identify forest fire hot spots.

The Global Positioning System (GPS) is an important geomatics tool. GPS is a constellation of satellites that beams signals to earth where they are picked up by receiving devices that range from hand-held units to more sophisticated vehicle-mounted and stationary equipment. Learn more at http://www.geocan.nrcan.gc.ca/geomatics

Minerals and Energy

Geoscience knowledge makes a fundamental contribution to the sustainable development of Canada's mineral and energy resources. In particular, geoscientific mapping and research are used to find new mineral and energy resources, to increase extraction and processing efficiency and transform raw material into value-added products, and to monitor and remediate deposit sites throughout their life cycle. Geoscience mapping and resource studies are of particular importance in rural and northern areas that have mineral and energy potential of economic significance — the creation of jobs, the stimulation of economic development, and the support of healthy, sustainable communities. Geoscience knowledge is also essential to land use decision making where land is restricted or excluded from resource exploration and development. For example, assessments of mineral, energy, and hydrogeological resources are used in defining or delineating national parks and marine protected areas.

Geoscience knowledge is the foundation upon which the mineral and energy industries plan and conduct their exploration activities. The knowledge base has been developed over many years through partnerships among governments, industry, and academia. Federal government and provincial geological surveys provide objective geoscience information in the form of data, maps, and reports, which aid the development and maintenance of essential expertise on the geology and resources of Canada.

Resource exploration is a complex, multistage process that proceeds from strategic decisions about what commodities will be sought in what countries and what deposit types will best deliver those commodities, through the selection of target areas and geoscience technologies to apply, to regional reconnaissance and detailed exploration. The regional geoscience knowledge provided by federal and provincial governments as a public good reduces the need for costly duplication of regional surveys at the early, high-risk stages of exploration programs. In the context of mineral exploration, this is particularly important in Canada, where junior companies and individual prospectors account for a large percentage of exploration activity and a significant number of discoveries.

Groundwater

Land use decisions affect the supply of groundwater, a renewable natural resource that is essential to the well-being of Canadians and ecosystems, as well as to the Canadian economy. It is currently the source of potable water for 25 percent of Canadians. Hydrogeological information, including three-dimensional characterization of aquifers and the geology that contains them, is critical to the sustainable use of Canada's freshwater resources. An example is the inventory of the nation's groundwater resources and the geology that contains them that is being developed by the Government of Canada and partners. Remote sensing information, collected through RADARSAT data, contributes to the mapping and monitoring of surface water resources.

Earth sciences information is used to define Canada's provincial, territorial, federal, and international boundaries. For example, the Global Positioning System is used in a collaborative effort between Canada and the United States to maintain an effective boundary between the two nations, as set out in international treaties.

Environmental Challenges

Environmental Research and Monitoring

Canadian geoscientists are studying the mechanisms through which metals are released and transported in the environment. They are also working to establish baselines and monitor levels of potentially hazardous metals and other toxic substances in the environment,

Developments in Near-Surface Geophysics

Over the past decades, the Government of Canada has been involved in the development of instrumentation and techniques directed toward the application of geophysics to near-surface problems. Such problems include

- prospecting and evaluating groundwater resources in glacial deposits
- detecting natural and anthropogenic contaminants within rocks and sediments in both permafrost and nonpermafrost environments
- selecting radioactive waste disposal sites in granite rock
- characterizing permafrost and ground-ice for arctic pipeline routing and for construction both on land and beneath the seafloor
- mapping unstable ground associated with landslides in soils
- estimating earthquake-induced ground motion amplification and susceptibility to ground failure of thick soil sites in urban environments.

World leadership in some areas of near-surface geophysics research by the Government of Canada includes ground-probing radar design, high resolution seismic profiling techniques, and borehole geophysics equipment designs and techniques.

These and other techniques and equipment have been specifically designed to provide an accurate three-dimensional framework for applied near-surface environmental, engineering, and groundwater geoscientific studies mentioned above, and most are available through technology transfer to the Canadian geophysical instrumentation and service industry.

The Government of Canada maintains close links with universities as well as companies in order to continue developing leading-edge geophysical technologies and to provide state-of-the-art advice, baseline standards, and testing services.

thereby providing valuable information for decisions relating to land and resource management. The Metals in the Environment Research Network, a network of Canadian universities, governments, and industry, was recently established to further foster and coordinate research on how metals move and transform within the environment and how they can affect ecosystems and human health.

By providing information about natural and anthropogenic contributions of metals and toxic substances to the environment, the earth sciences contribute to the assessment of the environmental impacts of current and future developments, including mineral and energy exploration and development projects. An example of the application of this knowledge is the assessment of the potential for storage of nuclear and other wastes in geological containers.

The earth sciences contribute to the tracking of the short- and long-range transport of pollutants in the atmosphere. For example, it is possible to differentiate natural and human sources of air pollutants by studying material emitted downwind from coal-fired power stations. This information helps determine compliance with environmental guidelines.

Geological information is also used to assess the potential for acid rain damage in different regions of the country. In the early 1980s, Canadian geoscientists initiated a pilot project, based on the interpretation of geological maps, to identify areas that lack the natural ability to absorb and neutralize acid precipitation. The result is a series of acid rain sensitivity maps that characterize broad areas with respect to their sensitivity to acid precipitation.

Climate Change

It is anticipated that climate change will impact the availability and quality of land resources. Land use patterns may be affected by slope stability, which is climate-dependent. The potential for sea level rise caused by higher temperatures raises concerns about increased flooding, coastal erosion, and sediment movement along Canada's extensive coastlines. Warmer temperatures may lead to permafrost thaw, which could jeopardize roadways, utilities, pipelines, and railroads in Canada's northern regions. Increases in frost heave and thaw settlement, also due to warmer temperatures, threaten the structural integrity of buildings.

The earth sciences are contributing to the improvement of the understanding and monitoring of the relationships between the climate, earth systems, and human activity. This knowledge is critical in assessing the potential impacts of climate change and adaptation options.

With a view to analyzing climate system history and dynamics, Canadian geoscientists have been monitoring the High Arctic ice caps for more than 30 years, producing the world's longest polar glacier records (see *http://sts.gsc.nrcan.gc.ca/page1/clim/new/e-uic-es.htm*). As part of an international project, ice cores are now being studied to evaluate the scale of climate change on a circumpolar basis. Geoscientists are also using data collected from the examination of tree rings to reconstruct moisture regime and temperature variations during the past centuries and to evaluate the response of ecosystems to natural disturbances. The capabilities of Canadian satellite technology (RADARSAT-1) are being harnessed to estimate the velocity of glacier ice motion in the Antarctic. This is linked to the study of changes in the area and volume of ice sheets in the Antarctic and Greenland, which could result in sea level increases.

Impacts and Adaptation

Adaptation involves making socioeconomic adjustments to deal with the impacts of current climate variability and with those expected as a result of future climate change. To be effective, adaptation strategies must be based on accurate assessments of the sensitivity and vulnerability of Canada's various regions and economic sectors to climate-induced impacts. Changing climate conditions must be considered when planning infrastructure and long-term natural resource use.

Part of the Government of Canada's Climate Change Action Fund is allocated to research on climate change impacts and adaptation. More information is available at *http://s-601-tsdweb.gsc.nrcan.gc.ca:80/adaptation/main.htm.*

Examples of research in support of adaptation include the following.

Slope stability. Geomorphic processes, including slope processes, are climate dependent. Indeed, some forms of slope movement, ranging from soil creep to slope failure, are climate driven. Effective adaptation strategies to avoid potential climate change impacts linked to slope stability must be based on an understanding of spatial variability, dynamics, and relation to climate.

Storms, sea-level rise, and coastal erosion. Canada is studying rapidly changing coastal systems in Atlantic Canada, where rising sea levels contribute to widespread shoreline erosion and landward coastal retreat. Seabed mapping has revealed former lakes and rivers in the Northumberland Strait, drowned shorelines off Newfoundland, and submerged estuaries off Nova Scotia. Recent studies provide clear evidence of episodic sea-level rise and coastal change.

As part of Canada's efforts to assess the potential of various environments to capture and sequester carbon dioxide, geoscientists are developing a model for estimating the amount of carbon stored in Canadian peatlands and forests.

Canada is also conducting research in support of adaptation to climate change, including decisions about land use. For example, geoscientists are studying slope stability in order to delineate high hazard areas so that they can be avoided or so that structures (e.g., pipelines and railways) can be designed to address the hazard. Severe storm impacts are being documented along the Nova Scotia coast to improve hazard assessment and mapping. Scientists are working with local governments and industry to assess the potential sensitivity of buildings in the town of Norman Wells, Northwest Territories, to permafrost thaw due to future climate change. With this information, municipal planners will be better able to plan changes to their infrastructure replacement and building guidelines in order to adapt to climate change.

Biodiversity

The earth sciences contribute to the conservation and sustainable use of biological resources by providing knowledge and technologies that support stewardship practices aimed at reducing environmental impacts and increasing the efficiency of natural resource development and use. In addition, GPS and GIS assist wildlife management, including the protection of species at risk. GPS can track the movement of wildlife, from individual animals to entire herds. GIS technology is used to map wildlife movements, as well as changes in wildlife habitat (e.g., wetlands and forests). This information is usefully applied in land use decision making to avoid land use practices that destroy or degrade wildlife habitat.

Natural Hazards and Emergencies

Natural disasters occur regularly in Canada, sometimes with devastating effects. They include earthquakes, floods, landslides, shifts in permafrost distribution, tornadoes, wildfires, and avalanches. Natural hazards constrain land use and economic development and jeopardize public safety. The earth sciences play a role in natural hazard monitoring, assessment, and research. They also contribute to mitigation policies, information services, and emergency response mapping.

In conjunction with partners across the country, the Government of Canada maintains and operates national networks, observatories, and surveillance programs on natural hazards and emergencies. These mechanisms provide risk assessments and information for policy, risk management, and mitigation advice. They are also used to alert appropriate provincial, national, and international agencies and the Canadian public to imminent dangers and assist in the response to disasters and emergencies by providing near real-time assessments of situations as they develop.

Knowledge of basic geological processes and conditions is essential to managing aquifers in a sustainable manner; assessing and addressing natural hazards, such as landslides and earthquakes; evaluating changes in environmental quality, such as those related to the release of metals in the environment; and studying the climate system, which is important for addressing climate change. Learn more at http//www.nrcan.gc.ca/gsc/index_e.html

Earth science organizations in Canada provide vital information for land use decision makers, including work related to slope stability, flooding, and permafrost. Geoscientists are studying landslides to determine their cause and effect with a view to identifying hazard areas and thereby contributing to safe land management practices in sensitive areas. For example, a major inventory of landslides has been compiled for most of Yukon. Because regions where a significant number of landslides have occurred are also the most susceptible to future landsliding, this compilation will help identify hazardous areas. It will be of benefit in the planning of transportation and pipeline routes and coastal facilities, and in the assessment of environmental risk.

The long-term flooding history of the Red River in southern Manitoba and the geological controls relevant to the flooding are being investigated as part of an effort to upgrade flood protection in this area. This research will provide a basis for assessing risks and will support decision making on appropriate long-term remediation measures and land use.

Geoscientists are also studying the permafrost that underlies more than half of Canada and its impact on Canadian development. As part of this work, models are being developed to quantify the risk to oil and gas infrastructure associated with permafrost degradation and slope movement and to analyze the mechanisms that transport contaminants from industrial waste sites in permafrost.

Red River flood, southern Manitoba, 1997. *Photo credit: Geological Survey of Canada.*

Partnerships

Each of the federal, provincial, and territorial governments requires capacity in geoscience and geomatics to fulfil its legal mandates. These governments discuss matters of mutual concern and formulate joint action plans related to the geosciences through the National Geological Surveys Committee. An Intergovernmental Geoscience Accord (IGA) was established in 1996 to define the complementary roles and responsibilities of the federal, provincial, and territorial levels of government. The accord defines the principles of cooperation to optimize the use of resources and established mechanisms to maximize collaboration in the area of geoscience. A renewed IGA is expected to be finalized by September 2001. The formalization of this accord confirms the need for collaboration on national and regional priorities. The Canadian Council on Geomatics is the senior federal, provincial, and territorial consultative body for geographic information management. GeoConnections is an example of an initiative where national consultation resulted in governments taking a participatory role in developing a geospatial information system. A GeoConnections National Accord, which is under development, will provide shared responsibility on national geospatial initiatives.

GeoConnections

The Internet is proving to be useful in providing Canadians with the information they need to participate in decision making. Efforts are under way to improve access to earth sciences and other geographic information via the Internet. Learn more at http://www.geoconnections.org

The governments in Canada work closely with the private sector and universities in the areas of geomatics and geoscience. GeoInnovations is a component of the federal government's GeoConnections program that promotes government–private sector partnerships. Geomatics for Informed Decision Making (GEOIDE) is a network aimed at linking all sectors involved in geomatics that was recently launched by Canada's Natural Science and Engineering Research Council's Networks of Centres of Excellence program. It brings together 90 researchers from universities, private sector companies, government agencies, and other organizations, and is expected to facilitate the efficient transfer of research results into marketable knowledge and technology products in Canada.

Aboriginal Peoples

On April 1, 1999, a newly created territory called Nunavut dramatically changed the map of Canada. Nunavut, "our land" in Inuktitut, is the traditional land of the Inuit in Canada's eastern Arctic and encompasses one fifth of Canada's land mass.

The Government of Canada is responsible for operating and maintaining a legal land survey system on Canada Lands (Indian reserves, national parks and historic sites, and the northern territories) and Canada's offshore. These lands, which encompass more than half of Canada, are inhabited mostly by Aboriginal people. A sound property rights infrastructure is fundamental to orderly sustainable development.

A key priority of the federal, territorial, and community governments is to empower rural, remote, and Aboriginal communities in order to increase their capacity and their ability to participate directly in shaping their own future. This goal can be achieved, in part, by providing communities with the skills, information, and tools to strengthen decision making in sustainable development, including integrating the management and planning of land resources.

As part of its responsibilities for the Canada Lands Survey System, the Government of Canada is working to establish a legal survey framework within the context of a property rights infrastructure that supports sustainable resource development and provides opportunities for the transfer of land-management skills and appropriate technologies to Aboriginal peoples.

Through the Sustainable Communities Initiative and other initiatives, the federal government is further working to build the capacity of rural, remote, and Aboriginal communities to use geoscientific and geospatial information for decision making with regard to land use, resource management, and sustainable development. The Sustainable Communities Initiative, together with its partners, is assisting Canadian communities to build their capacity to plan and make decisions by providing access to information on natural resources and socioeconomic issues via the Internet. A pilot project is under way with the Montreal Lake Cree Nation in Saskatchewan to monitor the movement and habitat needs of elk and to incorporate this knowledge into forest management plans. The aim is to reintroduce elk into the Montreal Lake area. Elk hunting is an important part of local Cree culture and provides additional economic benefits through tourism. Training in the use of decision-making tools and the preparation of research reports will assist with the ongoing self-sufficiency of these activities once the pilot project ends.

As an example of another Sustainable Communities Initiative pilot project, the Walpole Island First Nation in Ontario plans to use GIS in various aspects of its management, including governance, land use planning, identification and preservation of heritage archaeological sites, inventory planning for its sustainable forestry cooperative, and public health issues stemming from the community's water supply. This First Nation is already using GIS to record the memories of elders in relation to the geography of the reserve land.

INTERNATIONAL COOPERATION

Canada is a recognized leader in the earth sciences, and Canadian expertise is in high demand around the world. Canada is increasingly being called on to participate in international monitoring and research on issues of global importance such as climate change. For example, remote sensing scientists are contributing to the work of the International Steering Committee on Global Mapping, whose objective is to provide a consistent set of geospatial databases in support of national and international studies of climate change. Canada is also participating in the development of a World Minerals Database Project aimed at constructing and maintaining digital databases of global geology and mineral deposits.

Canada works with other countries on geoscientific research of mutual benefit, such as with Japan and the United States on the analysis of earthquake hazards and gas hydrates. In conjunction with the United States and Mexico, Canada has developed a North American hazard map.

Canada undertakes a wide range of initiatives aimed at building the earth sciences capacity of other nations. As an example, Canada is involved in a project aimed at providing the knowledge base for mineral exploration in a remote part of the Andes and has contributed to technology sharing and capacity building in several South American countries. Through GlobeSAR 1 and GlobeSAR 2 programs, Canada recently launched several initiatives to expand the application of radar data (a form of remote sensing), increasing the utility of this information for users and transferring technology, in particular to developing countries. Dozens of different projects have been undertaken through these GlobeSAR initiatives, many of them in agriculture. Under the GlobeSAR 1 program, airborne radar data have provided useful crop management information about rice type, growth stages, and acreages for an area in the south of China.

International Remote-Sensing Activities

With a focus on training and technology transfer, Canada has a program that builds radar remote-sensing capacity in participating countries. This program provides the opportunity for participants to develop an understanding and use of RADARSAT data in areas such as planning and resource management. It also supports the establishment of linkages between Canadian public and private sector organizations and their counterparts in the host countries. Several countries in Latin America and South America have already profited from the program.

Since 1972, Canada has participated in almost all major international remote-sensing satellite programs through the reception, processing, and archiving of North American data at the Canadian ground stations. In some cases, Canada has developed the technology to support these programs internationally. As well, in cooperation with international agencies, Canada continues to develop exciting and important new applications with global impact using remote sensing data and technology.

THE PATH FORWARD

There is growing recognition of the contribution that the earth sciences can make to public and private sector decision making. As

Canada addresses the challenge of sustainable development in the face of expanding local and global demand for land resources and increasingly complex environmental issues, there will be greater need for earth science information.

Canada is experiencing a rapid evolution and convergence of information and communication technologies. This, coupled with the expanding capability of satellites to transform how humans view and measure the earth and locate themselves, is having a major impact on how earth sciences information is acquired and delivered. The number of individuals and organizations requiring information generated by earth sciences is expected to increase in the future. This is due, in part, to better access to information via the Internet and a shift toward governance where citizens and communities play a stronger role.

Using a multidisciplinary partnership approach, Canada is working to improve the understanding of Canada's land mass required for sustainable development, to enhance the access to integrated earth sciences and other geospatial information, and to facilitate land use decision making through the provision of technologies. A major challenge is to ensure that the scientific and technical capacity in governments, universities, and the private sector expands to keep pace with the growing demand.

SELECTED READINGS

Energy, Mines and Resources Canada. 1991. The Science of Change: Environmental Geoscience at the Geological Survey of Canada. Energy, Mines and Resources Canada, Ottawa.

Government of Canada. [1999.] Canada's Perspective on Climate Change: Science, Impacts and Adaptation. Available on the Internet at *http://www.ec.gc.ca//cc/CoP5 sia/index_e.htm*

McNairn, H., and R.J. Brown. 1999. Remote Sensing in Support of Crop Management. Paper presented at the United Nations/China/European Space Agency (ESA) Conference on Space Application for Promoting Sustainable Agriculture, Beijing, China, 14–17 September 1999. Natural Resources Canada, Canada Centre for Remote Sensing, Ottawa. Available on the Internet at *http://www.ccrs.nrcan.gc.ca/ccrs/eduref/ref/bibpdf/4708.pdf*

Natural Resources Canada. 1996. The Minerals and Metals Policy of the Government of Canada: Partnerships for Sustainable Development. Natural Resources Canada, Ottawa. Available on the Internet at *http://www.nrcan.gc.ca/mms/sdev/mmp-e.pdf*

———. 1998. Background Paper on Land Access, Protected Areas and Sustainable Development. Natural Resources Canada, Ottawa. Available on the Internet at *http://www.nrcan.gc.ca/mms/pubs/land-e.pdf*

———.1999. Geological Survey of Canada: 1998-1999. Natural Resources Canada, Ottawa.

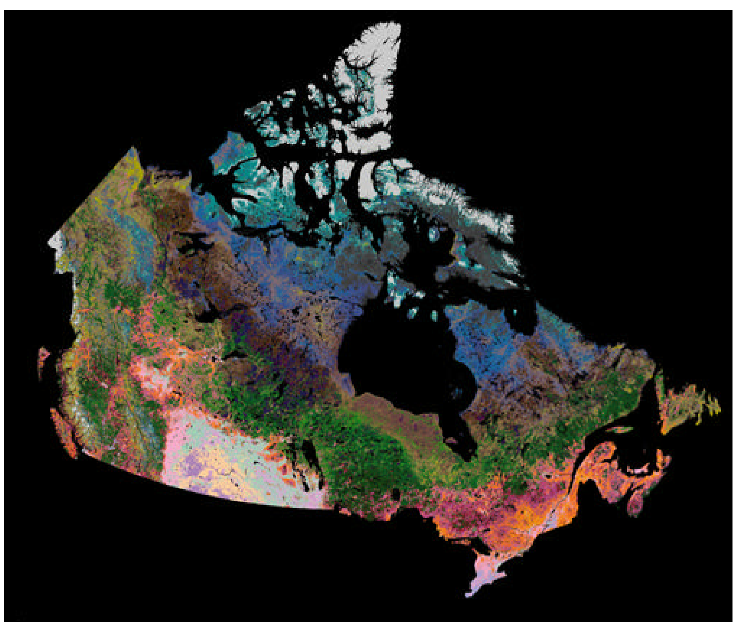
———. 1999. A Tradition in Innovation: Geomatics Canada 1998-1999. Natural Resources Canada, Ottawa.

Whitehorse Mining Initiative Leadership Council. 1994. The Whitehorse Mining Initiative Leadership Council Accord, Final Report. The Mining Association of Canada, Ottawa. Available on the Internet at *http://www.nrcan.gc.ca/mms/sdev/accord.pdf*

WEB SITES

Agriculture and Agri-Food Canada:
http://www.agr.ca
Arctic Council:
http://www.arctic-council.usgs.gov
Atlantic Coastal Action Program:
http://www.ns.ec.gc.ca/community/acap/index_e.html
Canada Mortgage and Housing Corporation:
http://www.cmhc-schl.gc.ca
Canadian Biodiversity Information Network:
http://www.cbin.ec.gc.ca/Biodiversity
Canadian Council of Ministers of the Environment:
http://www.ccme.ca
Canadian Council on Ecological Areas:
http://www.cprc.uregina.ca/ccea
Canadian Environmental Network:
http://www.cen.web.net
Canadian Museum of Nature:
http://www.nature.ca
The Canadian Pollution Prevention Information Clearinghouse:
http://www.ec.gc.ca/cppic
Canadian Wildlife Federation:
http://www.cwf-fcf.org
Canadian Wildlife Service:
http://www.ec.gc.ca/cws-scf/cwshom_e.html
CEONet:
http://ceonet.ccrs.nrcan.gc.ca
Commission for Environmental Cooperation:
http://www.cec.org
Department of Foreign Affairs and International Trade:
http://www.dfait-maeci.gc.ca
Earth Sciences Sector — Natural Resources Canada:
http://www.nrcan.gc.ca/ess
Ecological Monitoring and Assessment Network (EMAN):
http://www.cciw.ca/eman/intro.html
Environment Canada:
http://www.ec.gc.ca
The Evergreen Foundation:
http://www.evergreen.ca
Federation of Canadian Municipalities:
http://www.fcm.ca
Fisheries and Oceans:
http://www.ncr.dfo.ca
Fraser River Action Plan:
http://www.pyr.ec.gc.ca/ec/frap/index.html
GeoConnections:
http://www.geoconnections.org
Geological Survey of Canada — Natural Resources Canada:
http://www.nrcan./gc.ca/gsc
Geomatics Canada — Natural Resources Canada:
http://www.geocan.nrcan.gc.ca
Georgia Basin Ecosystem Initiative:
http://www.pyr.ec.gc.ca/GeorgiaBasin/gbi_eIndex.htm
Global Climate Change:
http://www.climatechange.gc.ca
Government of Alberta:
http://www.gov.ab.ca
Government of British Columbia:
http://www.gov.bc.ca
Government of Canada:
http://www.gc.ca
Government of Manitoba:
http://www.gov.mb.ca
Government of New Brunswick:
http://www.gov.nb.ca
Government of Newfoundland and Labrador:
http://www.gov.nf.ca
Government of the Northwest Territories:
http://www.gov.nt.ca
Government of Nova Scotia:
http://www.gov.ns.ca
Government of Nunavut:
http://www.gov.nu.ca
Government of Ontario:
http://www.gov.on.ca
Government of Prince Edward Island:
http://www.gov.pe.ca
Government of Quebec:
http://www.gouv.qc.ca/XmlDev/Site/Dhtml/Anglais/IndexA.html
Government of Saskatchewan:
http://www.gov.sk.ca
Government of Yukon:
http://www.gov.yk.ca
Health Canada:
http://www.hc-sc.gc.ca
Indian and Northern Affairs Canada:
http://www.inac.gc.ca
Industry Canada:
http://www.ic.gc.ca
International Development Research Centre:
http://www.idrc.ca/en
International Institute for Sustainable Development:
http://iisd1.iisd.ca
International Joint Commission:
http://www.ijc.org
Man and the Biosphere Canada/MAB Program:
http://www.cciw.ca/mab/intro.html
Metals in the Environment Research Network:
http://www.uoguelph.ca/cntc/mite
The Mining Association of Canada:
http://www.mining.ca

Ministère de l'Environnement du Québec:
http://www.menv.gouv.qc.ca/index-en.htm
National Atlas of Canada Online:
http://www.atlas.gc.ca
National Round Table on the Environment and the Economy:
http://www.nrtee-trnee.ca
National Water Research Institute:
http://www.cciw.ca/nwri-e/intro.html
Natural Resources Canada:
http://www.nrcan.gc.ca
The North American Waterfowl Management Plan (NAWMP):
http://www.wetlands.ca/nawcc/nawmp
North American Wetlands Conservation Council (Canada):
http://www.wetlands.ca/nawcc
Northern River Basins Study:
http://www.gov.ab.ca/ENGLISH/WATER/SCIENCE/nrbs95.html
Ontario's Niagara Escarpment:
http://www.escarpment.org
Our Great Lakes:
http://www.cciw.ca/glimr/intro-e.html
Polar Continental Shelf Project:
http://polar.nrcan.gc.ca
Ramsar Convention on Wetlands:
http://iucn.org/themes/ramsar
SDinfo:
http://www.sdinfo.gc.ca
St. Lawrence Vision 2000 Action Plan:
http://www.slv2000.qc.ec.gc.ca/slv2000/english/indexeng.htm
The State of Canada's Environment Infobase:
http://www1.ec.gc.ca/~soer
Statistics Canada:
http://www.statcan.ca
Survey on the Importance of Nature to Canadians:
http://www.ec.gc.ca/nature
Transport Canada:
http://www.tc.gc.ca
The Wetlands Network:
http://www.wetlands.ca



Land cover map of Canada showing the distribution of land cover types based on 1995 satellite data. More information is available at *http://otter.ccrs.nrcan.gc.ca:80/ccrs/comvnts/rsic/2701/2701rs4e.html*. *©Government of Canada*