Strengthening Environmental Research in Canada: A Discussion Paper

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Strengthening Environmental Research in Canada

Discussion Paper

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THE IMPACT GROUP

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1.0 The Environmental Science and Research Challenge

This report was commissioned by Environment Canada in support of the work of the Department's Science and Technology Advisory Board. Its purpose is to outline options and recommendations concerning new research models that could help to strengthen the national system of environmental research. The study is based on a literature review and interviews with selected individuals, listed in Appendix 2.

Canada's environmental science and research[1] system is currently at a crossroads. After more than two decades of steady growth, from the 1970s to the mid-1990s, investment in environmental science and research has levelled off and even declined in recent years. Concern is mounting that, as currently funded and organized, Canada's environmental science and research system will not be able to meet expanding demands to provide the knowledge needed to support decision making, public policies, environmental management, services Canadians depend upon, and new technologies in support of sustainable development. If this concern is valid, a new vision for Canada's environmental science and technology (S&T) system is needed. Such a vision will need to include two complementary objectives.

The first objective will be to raise the profile of, and rebuild "investor confidence" in, the Canadian environmental science and research system. There is a need to clearly articulate the demand for, and the value of, environmental science and research, as well as make a sound case for increasing the public resources dedicated to such research. The environmental science and research community cannot count on a substantial infusion of money in the near term. This situation calls for redefining roles and mandates, reorganizing existing resources, focusing on core competencies, and placing greater emphasis on establishing alliances, partnerships and networks. The aim is to improve research efficiency, effectiveness and impact.

The second objective will be to increase the mobilization and collective direction of existing resources within the Canadian environmental science and technology system. The Canadian environmental science and technology system currently comprises many discrete institutions operating within different government departments, at different levels of government, in universities and colleges, in the private sector, and within non-governmental organizations (NGOs). No common framework exists to organize the Canadian environmental science and technology system, or to develop common objectives or science priorities for this system. Research networks within the system are often extremely effective, but are not organized and portrayed as being part of a clear national agenda for environmental science in Canada.

A new vision and framework for Canadian environmental science and research can accomplish both objectives. It can demonstrate that the environmental science and research community is a high-profile and extremely productive scientific sector within

[1] Science refers to related science activities (e.g. data collection), whereas research refers to scientific research.

Canada. This will go far toward restoring investor confidence, and could lead to a new round of investment in the sector. In the 1999 Speech from the Throne the federal government stated:

> *Our ability to adopt innovative environmental practices and technologies will increasingly be part of Canada's strength in the 21st century.*

The government pledged to:

> *... continue to build partnerships at home and abroad to focus on sustainable development and improve the quality of the environment in our communities [and] ... strengthen the government's capacity for environmental research and place greater emphasis on sustainable development in government decision making.*

To accomplish these ambitious aims the Canadian environmental science community must consider options for a new vision and framework. This study explores the current situation of Canadian environmental science and research and some options for the future.

1.1 Background to the Challenge

Since it was formed more than 25 years ago, Environment Canada has been the country's foremost performer of public good–oriented environmental research and development (R&D). In that time environmental concerns have multiplied and become more global in scope. Each decade has brought new environmental challenges and added to the demand for accurate and timely scientific and technological information, knowledge and policy. For much of the period Environment Canada's S&T resources and capacity grew to meet the challenges. So, too, did environmental science and research capacity outside the federal government; in provincial governments, institutions of higher education, industry and the non-governmental sector. As the capacity of other organizations increased, Environment Canada's role evolved from that of being the largest single source of the nation's environmental science and research capacity to being the leading organization within an expanded network of environmental S&T institutions, each with its own resources and expertise.

The demand for environmental knowledge to support policy making, services, new management practices and technologies, and decision making by ordinary Canadians will continue to expand. Moreover, the long-term nature of most environmental issues and the policy responses to them tend to have a cumulative effect on the need for scientific knowledge and information. As a result, the more we learn about the character and interconnectedness of the natural and anthropogenic worlds, the greater the need to acquire even more environmental knowledge. Unfortunately, the need for this new knowledge is growing faster than the financial resources society is presently willing or able to devote to it. In the mid-1990s, the requirement to put the nation's fiscal house in order heavily impacted on federal S&T; it launched an era of static or declining investments across all sectors, including environment.

A general tendency of organizations, in response to shrinking resources and growing demand, is to try to stretch their available resources over a broader range of requirements. If this is carried too far, however, the organization begins to lose critical mass and its innovative edge slowly erodes. It is forced to direct a relatively greater proportion of its efforts to short-term external circumstances (i.e. "firefighting") and loses its capacity for foresight and leadership. Many believe that the federal government's science-based departments and agencies now find themselves in this situation. With respect to Environment Canada, members of the Department's Science and Technology Advisory Board have expressed this concern.

Increasingly, the challenge for such organizations is to find ways of increasing the mobilization of external resources to address common problems. Partnerships and networking are key mechanisms through which scientific organizations can access and integrate the capacity of many institutions in a given scientific community, so that the whole is larger than the sum of its parts. Older models of independent centres of S&T excellence are giving way to "networks of centres of excellence" and "virtual institutes." The emerging challenge is to network resources "horizontally," for example, across the environmental science and research system. This approach allows each institution to reinforce its inherent strengths and contribute its capabilities to those of the sectoral science and technology system.

Requests for investment of public money to re-establish lost science capacity is a difficult case to make, even if knowledge gaps and clear deliverables for the future can be demonstrated. If new financial and human resources are needed, and few would disagree that addressing society's environmental S&T challenges will ultimately require additional investment, then the following types of issues also will need to be addressed:

- Where in the environmental S&T system should investments be made?
- Who is best placed to do different kinds of science and research?
- How can the effectiveness of the overall system be improved?
- What common problems and issues need to be addressed?
- What is the current capacity of the environmental science and technology system?
- Can new models or frameworks be envisioned to increase the collective mobilization and direction of existing resources within the environmental science and technology system?

What this suggests is the need for a re-examination, and possibly a reorganization, of the roles of various institutions that currently comprise the Canadian environmental science and technology system. Arguably, new investment in environmental science and technology is being held back because governments and their advisors are not assured that new investments will yield significant new benefits. Unless existing structures, relationships and ways of doing business in this sector are modernized, and the profile of the sector is raised, it is unlikely that substantial new public resources will be directed toward environmental science in Canada. However, if a new and compelling

vision and model for Canadian environmental S&T can be forged and articulated, there is every reason to believe it can attract support and additional resources.

A new vision and new model (or models) are both required to raise the profile of environmental science and technology and attract the right level of investment needed to address key issues. What many observers have noted is that government departments need to better define and articulate their scientific roles within broader sectoral science and technology systems. The federal government's Council of Science and Technology Advisors explicitly made this point in their recent report *Building Excellence in Science and Technology: The Role of the Federal Government in Science and Technology*. The exciting opportunity here is to develop a compelling and widely shared vision for environmental S&T in Canada that will attract broad support inside and outside of government, and give investors and partners a new sense of enthusiasm for, confidence in, and understanding of, Canadian efforts in environmental science.

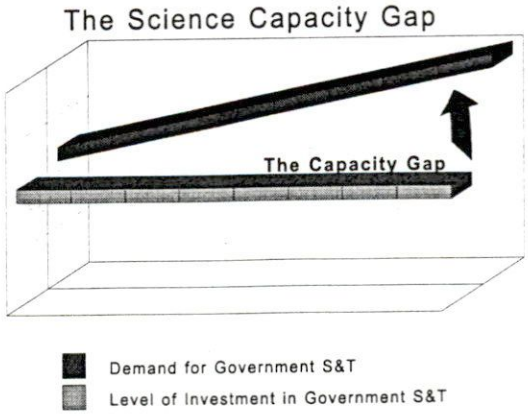
1.2 A Research Capacity Gap

As the demand for science-based advice in government continues to rise, science and technology are playing an increasingly important role in society and in government. Human, animal and plant pathogens that we thought had been conquered continue to evolve, sometimes more quickly than we can develop new drugs to combat them. Climate change is affecting the sustainability of ocean resources and is beginning to influence social and economic policy in many parts of the country. And with the increasing number of environmental issues, policies, agreements and other related information needs, the Canadian environmental research community is having to keep pace with demands for new knowledge while continuing to grapple with long-established environmental issues such as acid rain and the impacts of toxic substances on wildlife, water and air resources.

Along with each advance in science and technology, moreover, come new challenges and opportunities for the economy, society and government. Environment Canada's challenge in recent years has been to continue to provide excellent scientific information and a high level of scientific service for clients and partners in an era of flat resources. This challenge is best expressed as a growing "capacity gap" — the gap between the demand for science-based information and advice, and the resources that have been available to meet demands.

> *Although the mandate of the department has remained the same over the years, many of the environmental issues it faces have changed. Environmental concerns in Canada have shifted from local issues (air and water pollution) when the department was established, to regional issues (acid rain, Great Lakes pollution) in the seventies, to global problems (ozone depletion, climate change) in the eighties. In the nineties, as issues have increasingly been interconnected and more intractable (loss of biodiversity, climate change, toxic substances, stratospheric ozone), it has become clear that global environmental threats can best be managed in the context of a more integrated and equitable approach to economic and social development.*

Environment Canada's Science and Technology: Leading to Solutions. March 1996.



2.0 Responding to the Challenge

2.1 Environmental Science and Technology Expenditures

Science and technology activities account for a high proportion — up to 90% — of Environment Canada's annual budgetary expenditures. In 1998-99, for example, the Department was projected to spend a total of $424 million on S&T (Table 1). Of this, $375 million — or about 89% — was directed to intramural S&T expenditures. About $30 million (7%) was allocated to S&T activities performed by Canadian business. And around $6 million (1.4%) was to be spent in support of S&T conducted in the higher education sector.

R&D expenditures at Environment Canada were projected at $118 million in 1999-2000, which represented about 28% of all departmental S&T activity. Over 80% of departmental R&D is conducted in-house, with around 9% being contracted to business and 9% transferred to the higher education sector in the form of grants, contracts and fellowships (Table 1). Environment Canada's R&D expenditures in the higher education sector rose dramatically from the beginning of the decade, peaking at around $30 million in 1994-95. Transfers fell significantly in subsequent years. In 1998-99 the Natural Sciences and Engineering Research Council (NSERC) devoted about $36.7 million to environmental research at Canadian universities (Table 2).

Table 1. Environment Canada Science and Research Expenditures
($ millions)

Type of Expenditure	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99	1999-00*
Total S&T	**582**	**582**	**631**	**663**	**549**	**529**	**456**	**453**	**444**	**424**
Intramural	532	538	585	615	484	464	399	404	398	381
Business	19	16	18	19	27	29	32	26	27	25
Higher Education	2	2	5	9	16	15	8	6	6	6
R&D	**91**	**97**	**119**	**135**	**174**	**163**	**135**	**127**	**124**	**118**
Intramural	80	88	107	120	146	131	113	112	105	101
Business	7	5	5	4	9	13	10	10	9	8
Higher Education	4	4	9	18	30	28	14	10	9	9
Related Scientific Activities	**491**	**486**	**512**	**528**	**375**	**366**	**321**	**326**	**320**	**306**
Intramural	453	450	478	496	338	333	286	294	270	260
Business	12	12	13	14	18	16	22	23	21	20
Higher Education	—	—	—	—	—	—	—	—	—	—

* Estimated.

Source: Statistics Canada. *Federal Government Expenditures and Personnel on Activities in the Natural and Social Sciences, 1989-90 to 1998-99.* 88F0006XPB No. 9, and Impact Group estimates.

Table 2. NSERC Grants and Scholarships for Environmental Research, 1998-99

Program Type	Number of Awards	Total Amount	Average Award
Research Grants Programs	851	$25,571,125	$30,048
Research Partnerships Programs	113	$11,095,941	$98,194
Total	**964**	**$36,667,065**	—

Source: NSERC.

Provincial governments are another key performer and supporter (through universities) of environmental S&T. Provincial governments spent a total of nearly $100 million on S&T activities in support of environmental issues (air, land, water, other) in 1994-95, although it is likely that this amount has fallen since that time. Unfortunately, an official breakdown of provincial environmental S&T, R&D and related scientific activities (RSA) is not available in Statistics Canada records. However, it is estimated that provincial governments devote approximately 7-10% of their environmental S&T budgets to R&D. This would add around $7-10 million of R&D to the national total, but does not include

the investments provincial governments make in university infrastructure and researcher salaries at universities that conduct environmental research.

In 1999-2000, Environment Canada's S&T expenditures were about 36% lower than their highest levels during the previous decade; R&D spending fell by 29%, and RSA fell by 43%. Staffing for S&T fell by about 1,100, which mirrored the spending cuts. Environment Canada has not been alone in facing budget reductions for S&T. Most federal science-based departments and agencies confronted similar cuts.

2.2 Environment Canada's Science and Technology Roles

Science and technology at Environment Canada is not a set of activities done simply to produce knowledge for knowledge's sake or to satisfy curiosity. Environment Canada's S&T efforts are undertaken for specific reasons, and are carefully managed to achieve specific results related to Environment Canada's mandate. This S&T supports EC's ability to develop and implement policy; deliver important services to Canadians; and develop new technologies that support improved environmental prediction, ecoefficiency and pollution prevention.

Why do governments fund and conduct research? It could be argued that the core business of government is not science per se, but rather policy — setting the rules and directions that govern society, with the objective of maximizing citizens' quality of life, standard of living and so forth. As John de la Mothe has written,[2] one of the principal roles of government science is to:

> *support policy in the science-based departments and agencies as well as in industry, heritage, foreign affairs, international trade, defence, and transportation. To farm all these responsibilities out to academic or private sector concerns would not only create a government contract monitoring and management nightmare but could also lead to breaches of security, a de-coupling of government science from government policy, and a lost assurance that government and the public interest were in sync.*

However, federal S&T serves other essential roles such as provision of national services (e.g. weather forecasting), access to expensive facilities or equipment, technology development in strategic areas, etc. We call on our elected officials to make complex decisions that affect our private and public lives. Therefore, we want to equip them with the best information available — social, economic, political, scientific and technological — with which to render their decisions.

Scientific and technological research supplies an important component of the knowledge needed to make informed public policy decisions and contribute to other public good objectives such as the provision of services, technology development, etc.[3]

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[2] John de la Mothe. *Government Science and the Public Interest.* Ottawa. 1999.

[3] Government science also fulfils other roles, including providing technical assistance, developing new technology, establishing and negotiating standards, testing and approval, environmental monitoring,

This is reflected in the high proportion of Environment Canada's budget devoted to S&T activities. On average, Canada annually supplies about 4% of the world's knowledge.[4] Some branches of Canadian S&T supply more and some less. Environment Canada is particularly productive within the environmental research domain, and parts of the Department lead in the production of particular kinds of knowledge (e.g. climate science).

In 1995, Canada produced 25,882 scientific research publications, or 4.2% of the world's total. Of these, 368 (or 1.4% of Canada's total) can be attributed wholly or in part (through joint authorship) to Environment Canada. Whereas the majority of world knowledge — 96% — is produced by researchers in other countries, it can be argued that the 4% produced in Canada — for example, ecosystem science or regional climate change modelling — is more relevant to our unique circumstances and therefore carries more weight here. Nonetheless, the bulk of knowledge relevant to a particular issue is as likely to be found in the world literature as in publications authored by Canadians.

This reinforces the need for a robust system of science assessment. Science assessment comprises a capacity to interpret the findings of scientific research — wherever it is conducted — and formulate its implications for policy. This is a role that is often unique to science-based government departments such as Environment Canada. Scientific research usually provides only fragments of information relevant to a particular issue. Often, the results of scientific research are not definitive, and scientists are reluctant to interpret incomplete information for policy purposes. The task of science assessment is to assemble the fragments of information relevant to a particular topic and interpret their implications for policy, often in the face of incomplete or conflicting information. A robust science assessment capacity is a prerequisite for sound policy making. As the Council of Science and Technology Advisors said in its recent report:[5]

An effective advisory process brings sound science and the best science advice to bear on policy issues and ensures that:

- *Ministers are confident that a rigorous and objective assessment of all available information was made in providing the advice;*
- *the public and parliamentarians are confident that government is using science in the best interests of Canadians, and that science advice provided to decision makers is credible; and,*
- *Canada has an enhanced ability to influence international solutions to global problems ...*

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survey work and stock assessments, emergency preparedness, regulatory monitoring and compliance activities.

[4] Philip Enros and Abdelkérim Ousman. Science Policy Branch. Environment Canada. *Environment Canada's Scientific Research Publications in 1995.* Ottawa. June 1998.

[5] Council of Science and Technology Advisors. *Science Advice for Government Effectiveness.* Ottawa. May 1995.

Departments need a sufficient and adaptable internal capacity to identify science issues and to assess, translate and communicate science for policy.

Science assessment is a techno-social activity. It combines knowledge of the physical world (biology, atmospheric physics, botany, etc.) with knowledge of the social world (economics, law, politics, etc.). Once the exclusive preserve of "experts," society now demands greater transparency and openness in science assessment.

It could be argued that increasing the volume of scientific research undertaken in Canada (or in federal labs) will do little in itself to improve policy making unless assessment processes are also strengthened. Thus, a domestic research capacity is certainly a necessary condition for governance in the modern era, but science assessment capacity is equally important.

The reasons that governments invest public resources in S&T — that is, the reasons they fund knowledge production — are well known. They do it because of the need for knowledge that is specific to their own country; to have knowledge to exchange with other countries and thereby be full participants in the world of S&T; to be early adopters of international knowledge advances; to keep pace with developments abroad; to put the talents of their own citizens to work; to produce useful discoveries and devices; and so forth.

Governments also perform research in support of their public policy mandates. Again, the reasons are well understood. Sometimes there is a need for scientific independence, for confidentiality or for timeliness of information delivery. In some instances the high cost of facilities and equipment makes it more efficient for the infrastructure to be owned and operated by the public sector. In addition, government research organizations can assign large teams of full-time researchers to study particular issues that cross provincial or institutional boundaries. Furthermore, government officials working on science-related issues need to have hands-on experience with S&T so they can assess the relevance of research undertaken outside of government.

Another role of science in government is what the Organization for Economic Cooperation and Development terms "innovation-related networking." Innovation-related networking is the role that public sector labs play in bringing together different parts of the innovation system, and coordinating their activities to achieve public ends. To be credible innovation networking organizations, federal labs and scientists need to be seen as the peers (actively involved in the generation and advancement of knowledge) of other science institutions and researchers.

A convergence of circumstances is inviting a re-examination of the roles of the federal government (and Environment Canada, in particular) in the overall environmental research system. The most obvious development has been the downsizing of government (federal and provincial) size. Despite this downsizing, government scientists are still called upon to provide needed research and science assessment services. A second factor is the increased attention that governments (especially the

federal government) have given to strengthening the research capacity of the higher education sector through such initiatives as the Canada Foundation for Innovation (research infrastructure), increases to the budgets of the granting councils (operating funds), and research Chairs (personnel). This has created (or will soon create) new capacity in higher education which, if it is properly integrated, can help offset some of the loss of capacity in the government sector.

A third recent circumstance is the emergence (or in some cases re-emergence) of new models for research funding and performance, as evidenced by the federal Networks of Centres of Excellence (NCEs) and the soon-to-be-established Canadian Institutes of Health Research (CIHR). Existing research models, including Environment Canada's Climate Research Network (CRN) and Atlantic Cooperative Wildlife Ecology Research Network (ACWERN), are gaining attention as worthwhile options for funding and performing certain kinds of research.

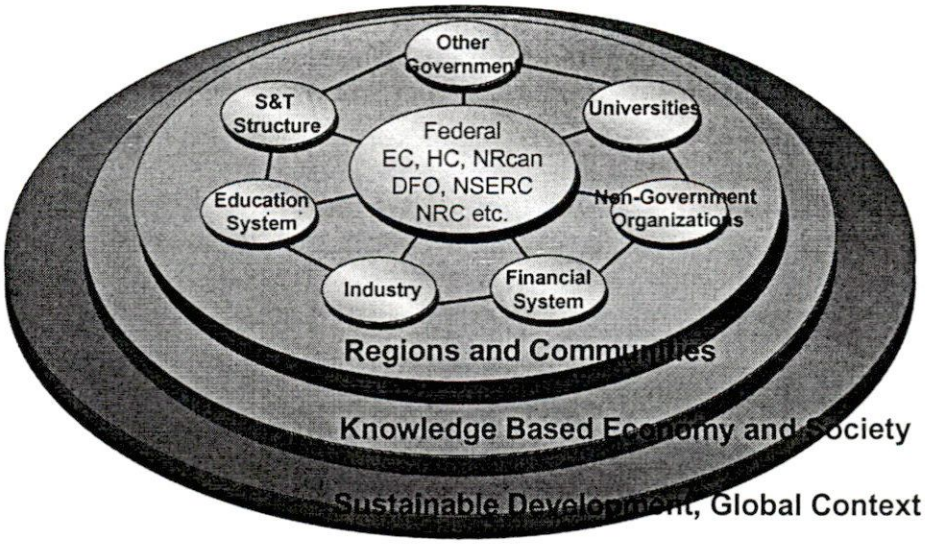
Finally, the concept of national systems of innovation (science and technology) is beginning to take hold. The science policy community is thinking about the implication of national systems of discrete, yet interlinked, institutions and the implications of this concept for different research sectors. Thus, in the environmental context we can think about a "national system of environmental research."

2.3 Toward a National System of Environmental Research

The "national systems" approach views a nation's research capacity as encompassing all the resources and capabilities of communities of researchers — federal, provincial, higher education, NGO, industrial, municipal, community, and so forth. There is no single model of a national system of science and technology (innovation). Some may choose to place the federal government at the centre of the national system model; others may choose different configurations. The federal government, however, is the single largest funder and performer of research in the Canadian environmental science and technology system; it manages national facilities on behalf of all stakeholders; it is responsible for negotiating and implementing domestic and international environmental accords; it has a major coordination role with other sectors; and, to the extent that environmental concerns do not respect geographic boundaries, federal agencies play a predominant role in environmental matters in most countries. In addition, environmental research has a large element of public good, and there is no appropriate market mechanism to govern its activities.

The national systems approach changes the emphasis of federal science and technology activities from a predominant focus on performance of research and science activities toward a greater emphasis on research networking, research planning, management and results achievement, as well as funding and performance of research and related science activities.

The Canadian Environmental Science and Technology (Innovation) System



Old Model: Federal laboratories *perform the research* needed to support (environmental) policy.

Emerging Model: Federal laboratories *ensure performance of and timely access to, as well as assessment of,* needed scientific and technological information to support (environmental) policy making, provision of services, technology development, etc.

In the emerging model, the role of federal labs is to ensure that the national system of environmental research organizations is generating the needed information for policy makers to drawn on. Federal laboratories and scientists continue to perform specific research unique to federal mandates and information needs, as well as maintain and manage national facilities. However, an additional function is required to focus attention on the capacity and integrated performance of the overall environmental science and technology system, rather than simply the capacity and performance of federal science units.

The national systems approach does not imply a diminution in the role of federal laboratories and scientists. The national systems approach recognizes value in the diversity and potential complementarities of various institutions. Table 3 describes the complementary roles of research organizations in three different sectors. It is intended to show that all have a unique contribution to make within a national innovation system, and that strong capacity is needed in each sector. However, the national systems approach does suggest a shift in emphasis within government science from in-house performer to system planner, networker, coordinator, research manager and information integrator. Public sector scientists and facilities are still needed to perform certain kinds of research within the system — for instance, where there is a substantial requirement for independence, timeliness, confidentiality, government-to-government

contact or public good, or where there is a requirement to address market failure, the use or management of national facilities, etc. Indeed, additional federal science capacity is necessary to provide the system facilitation and participation functions, as well as to continue delivering on mandate-driven scientific information needs. As this report will show, federal science departments are already moving in this direction by adopting novel ways of organizing, funding, managing and performing needed research.

Once the federal environmental research effort is viewed as being a critical component of a broader national environmental research system, certain possibilities present themselves. The national systems approach raises the possibility for government departments to take the lead, in partnership with others, to:

- Set national research priorities;
- Identify critical knowledge gaps and see they are filled;
- Coordinate and integrate fragmented research efforts;
- Reduce duplication of effort;
- Maximize resource and facility utilization;
- Reinforce excellence and utilize the skills, abilities and resources of each group in the most appropriate way;
- Enhance the transfer and application of knowledge and technology;
- Integrate the contribution of the social sciences; and
- Maximize the overall performance of the system.

Table 3. Complementary Roles of National Innovation System Partners			
Characteristic	**Government**	**University**	**Industry**
Wealth Creation Objectives	• Principal value: explicit and direct wealth creation • Seeks public benefits	• Principal value: basic research as an enabling condition for wealth creation • Seeks mixed private, public benefit	• Principal value: wealth creation for private ends • Seeks private benefits
Quality of Life Objectives	• Principal value: explicit and direct improvement of quality of life for all citizens • Seeks public benefits	• Principal value: basic research as an enabling condition for quality of life • Seeks mixed private, public benefits	• Principal value: quality of life as an outcome of private effort and good corporate citizenship • Seeks private benefits
Advancement of Knowledge Objectives	• Principal value: advancement of knowledge in support of missions	• Principal value: advancement of knowledge as an end in itself (basic research) • Advancement of knowledge in support of missions (targeted research)	• Principal value: advancement of knowledge in support of private gain • Main emphasis on application of knowledge rather than original creation
Purpose of S&T Activities	• Mission-oriented • Targeted basic and applied research and technology development • To achieve public benefits • Conforms to government and public policies and priorities (public goods)	• Majority: non-oriented, curiosity-driven • Minority: strategic, industrially oriented • Advancement of knowledge • Conforms to individual professor/student priorities	• Market-oriented • Achievement of private benefits • Conforms to company priorities (private goods)
Project Selection	• Projects selected by team, departmental and interdepartmental managers, with input from external advisory committees • Projects funded based on impact on public good	• Projects selected by individual researchers • Projects funded on recommendation of peers based on research quality	• Projects selected by research and product managers and approved by senior management • Projects funded based on impact on company
Level of Effort	• Full-time research effort • 5+ personnel	• Part-time research effort • 2-5 personnel (typical)	• Full-time research effort • Personnel level varies
Management	• Research plan with milestones, deliverables, key performance indicators	• Research plan optional	• Research plan with milestones, deliverables
Clients	• Elected officials • Public at large	• Self • Peers • Granting councils	• Company management • External clients
Time Frame for Research	• 6 months to 5 years	• 36 months to 7 years	• 6 to 18 months
Evaluation	• Semi-annual internal reviews • Regular external reviews • Oversight by Treasury Board, Auditor General • Political oversight	• No direct evaluation; indirect evaluation through peer review of publications • No oversight	• Market acceptance, sales, cost savings • Senior management, shareholder oversight
Accountability	• Direct accountability; moderate-high level • Accountable to Ministers, Parliament, Auditor General, senior government officials, senior scientists	• Indirect accountability; low-moderate level • Accountable to granting councils, peers	• Direct accountability; moderate-high level • Accountable to senior management, shareholders

So long as individual research enterprises see themselves as largely independent operators within an ambiguous national system, there is little hope of making progress on these objectives.

The real challenge for Environment Canada is to take a leadership position in forging an effective national system of environmental research. What the U.S. Committee on Environment and Natural Resources said in 1995, in respect of improving the effectiveness of federal government environmental S&T, applies equally as well to national environmental S&T:

> *To meet the challenge for sound and cost-effective management of the environment and natural resources in the United States, the Administration has undertaken significant changes in how we plan and fund federal research. The traditional single agency and single discipline approach to problem solving is being replaced by a coordinated, multiagency interdisciplinary approach. Intractable multidimensional problems, such as those posed by many environmental issues, can be addressed only by bringing together natural and social scientists, economists, engineers and policymakers. Science has often been decoupled from informed policy decisions; strengthening this connection is one of our highest priorities ... The NTSC, through the CENR, is coordinating decentralized agency programs to address environmental issues in an integrated manner.*[6]

The vision of creating a national science, technology and research framework is daunting at first glance but not at all impractical. Clearly, the United States began to move in this direction five years ago, with regard to environmental and natural resource research. But there are other examples, closer to home, that are worth examining.

2.4 New Research Models

Appendix 1 of this report presents a number of innovative research network and S&T system models that are currently in use or have recently been proposed. Two of these models come from the agri-food and forestry sectors, which have begun to develop national research strategies. In agriculture, strategy development was undertaken by a non-governmental organization (Canadian Agri-Food Research Council)[7] with support from a wide group of stakeholders, including Agriculture and Agri-Food Canada. In forestry, development of the national strategy was led by a working group of the Canadian Council of Forest Ministers,[8] also with input from many other organizations, such as the Canadian Forest Service.

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[6] National Science and Technology Council. Committee on Environment and Natural Resources. *Preparing for the Future Through Science and Technology. An Agenda for Environmental and Natural Resource Research.* Washington. March 1995.

[7] Canadian Agri-Food Research Council. *Canada's National Strategy for Agri-Food Research and Technology Transfer 1997-2002.*

[8] Canadian Council of Forest Ministers. *National Forest Science and Technology Course of Action — Science and Technology Priorities for the Forest Sector 1998-2003.* Canadian Forest Service. Ottawa.

Environment Canada itself has had excellent success in national research coordination on a smaller (disciplinary) scale, through its Climate Research Network (CRN), the Atlantic Cooperative Wildlife Ecology Research Network (ACWERN), the Ecological Monitoring and Assessment Network (EMAN), the Environmental Sciences and Technology Alliance of Canada (ESTAC) and the Toxic Substances Research Initiative (TSRI). CRN, ACWERN, EMAN, ESTAC and TSRI are successful examples of research coordination, funding and performance that could well serve as models for other environmental science activities in the future.

The Canadian Institutes of Health Research (CIHR) is an ambitious plan to organize university research under "virtual institutes" with distinct research themes (e.g. asthma, heart disease). An objective of CIHR is to improve research planning and the implementation of research results. CIHR has been very successful at attracting political and financial support.

The federal granting councils have also developed novel models for strategic research in distinct research sectors. The national Networks of Centres of Excellence (NCE) program supports targeted research that collectively mobilizes geographically distinct research groups working on common themes. The Natural Sciences and Engineering Research Council (NSERC) has also developed research partnership agreements with a number of federal science-based departments and agencies. These programs are used to leverage university and industry resources to achieve targeted research objectives.

Two models presented in Appendix 1 come from the United States. First, the U.S. National Science and Technology Council (NSTC) model presents an interesting example of an attempt to integrate federal environmental research planning. Second, the U.S. Army FedLab model is a valuable illustration of how science-based organizations can adapt to fiscal restraint and a changing mandate.

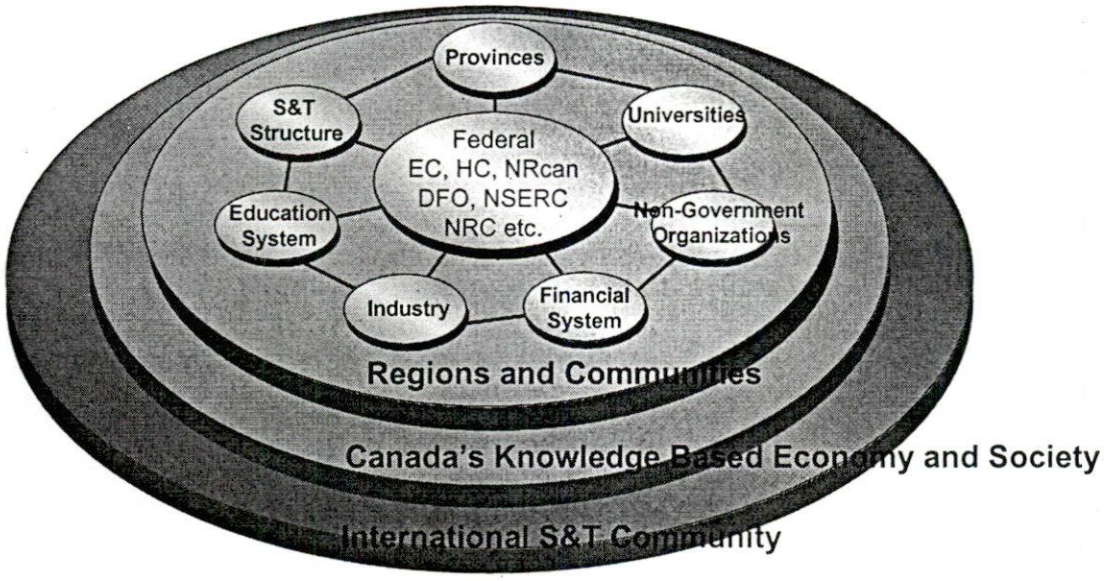
Action 1998-2003. Science and Technologies Priorities for the Forest Sector. Canadian Forest Service. Ottawa. 1998.

3.0 Discussion

> *The organization and delivery of research within national science and technology systems is currently undergoing a period of rapid evolution, both in Canada and abroad. The trend toward new dynamic research organization and funding models is undeniable and there is much to be gained from an examination and analysis of opportunities and options to guide the future of environmental research funding in Canada.*
>
> *Preamble to the Statement of Work*

In many countries — and certainly in Canada — the "environmental research gap" is growing. The demand for environmental knowledge is increasing, but the financial resources that governments are able or willing to spend to produce, assess and integrate the knowledge are not. As a result, all environmental research organizations in Canada are under pressure to do more with less and, in consequence, to adapt their ways of doing business. Even though financing has been a central issue, it would be a mistake to attribute changes in federal government environmental research to a shortage of money alone. Even if finances had been available, there would be compelling reasons to rethink how government research is funded and performed.

Canada's National System of Environmental S&T



A principal reason is a growing appreciation of the value of a national systems of innovation (or national systems of science and technology) model of research capacity. This model sees research organizations as centres of research specialization co-existing within the national S&T system. The strength of the system rests on its

ability to link together the specialized capacities of each organization, so that the capacity of the system is greater than the sum of its parts. This linking function is central to the mandate of federal science-based departments such as Environment Canada, given their national presence and reach. In many cases there simply is no existing mechanism or even an institution capable of undertaking this type of linking function.

A second reason is that the "old" model of federal government research, in which the government itself was the main performer of relevant S&T, is giving way to an appreciation that the critical roles of science in government are to provide decision makers with timely access to highly credible and relevant knowledge, wherever it is produced, and to properly assess and utilize scientific knowledge. Government departments still need a strong in-house R&D capacity in order to do this, but they need not view themselves as the only or even the predominant generators of scientific knowledge. Indeed, the bulk of relevant knowledge may be mostly produced outside the department; in other organizations or in other countries.

A third reason for change is that whereas in most countries federal government departments and laboratories still dominate the environmental research scene, the capabilities of other domestic and international institutions — universities, industry and non-governmental organizations — have been growing. Canadian university research capacity is undergoing a period of rejuvenation, thanks to new public sector investments. U.S. and European universities are strong environmental research performers. Industry spending on environmental research exceeds that of government (although its purposes are considerably different). And other organizations, such as provincial governments and community groups, are also important players in the national system. Thus, other sectors have much of value to bring to the table with respect to S&T.

Change in how governments meet their need for S&T knowledge is also taking place because there is a growing understanding and acceptance of the value of new research models that stress partnerships, alliances and networks that are focused on specific themes. Whether — as in the case of the Canadian Institutes of Health Research — those themes are human diseases such as heart disease or asthma, or whether they are "environmental diseases" such as toxic cleanup, habitat degradation or climate change, there is an emerging trend toward networking resources and focusing them in thematic ways.

Finally, demand is growing for two different kinds of knowledge. First is specialized (environmental) knowledge of all descriptions. The degree of specialization is such that all organizations have trouble staying at the forefront of scientific progress. Second is integrated knowledge of the kind that comes from the fusion of disciplines; for example, organic chemistry and biology. This calls for an ability to combine and assess knowledge from different fields; and, once again, traditional discipline-based

organizations may have difficulty, especially if they do not have a broad base of in-house S&T.

Thus, financial pressure is only one factor prompting a re-examination of the role and operations of federal science establishments. There are other good reasons for science-based organizations to evolve. Many scientific organizations in Canada and abroad — including Environment Canada — have begun to adopt new models for planning, performing, coordinating and assessing research, with the aim of improving policy development and implementation. In a national systems of environmental research model, it would be Environment Canada's role, in partnership with other stakeholders, to:

- Emphasize leadership rather than control;
- Establish national and regional priority research themes;
- Identify research gaps;
- Allocate available federal funds and coordinate external funding to address research needs and gaps;
- Perform an appropriate amount of research in federal labs;
- Create, fund and participate in research networks;
- Provide and manage national facilities;
- Assess research findings and provide quality control;
- Integrate research into policy;
- Maintain the health and vitality of Canada's environmental research system; and
- Manage environmental science and research "investor relations."

In our view, this is a more complex role than simply performing research. It demands more than bench research skills on the part of government labs; it requires that the scientific organization acquire networking skills, new research management skills, negotiation skills, effective communication skills and, most of all, leadership skills. Inevitably, it will mean that federal science organizations such as Environment Canada have to focus their in-house research activities more narrowly and provide resources for other organizations to undertake complementary research that is aligned with their competencies. Such an approach holds great potential for payoff in terms of the overall efficiency and effectiveness of the national environmental research system.

The following section outlines a series of options for Environment Canada to consider as possible mechanisms for strengthening the environmental S&T system within Canada. These options should not be seen as mutually exclusive; indeed, many could be pursued simultaneously. Moreover, the ability to take action along these lines will require investments of time and resources, significant planning, and many consultations and discussions both within the Department and with external partners and stakeholders.

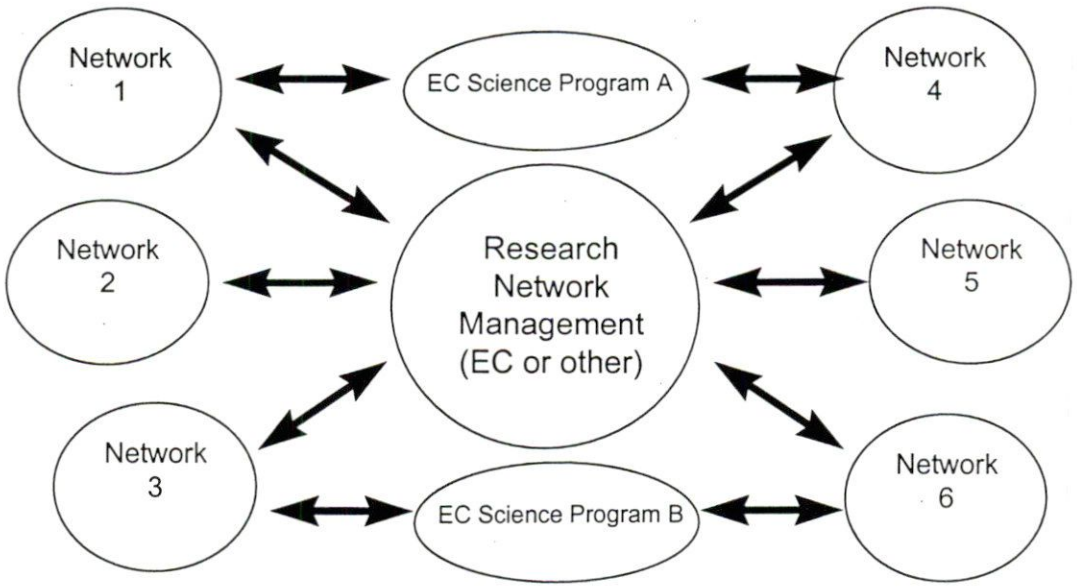
3.1 Network of Networks Model

In our view, the paradigm that a great deal of federal government research is evolving toward is what we term a "Network of Networks" model. In this model of funding and performing R&D a government department's role is analogous to that of a private "holding company" which has an interest in a portfolio of research "businesses." As such, the department would be responsible for establishing overall "corporate strategy" (a process to set research priorities). It would also be responsible for overseeing a process that would make strategic "investment" decisions (allocation of research funds) and would establish "profit expectations" (research performance targets or outcomes) for each "operating business" and for the holding company itself. While it might not be necessary (and possibly is not desirable) for Environment Canada to provide the entire management function for the Network of Networks, it would be responsible for ensuring the establishment and oversight of a well-functioning system, including responsibility for ensuring appropriate allocation of any public funding involved.

In the Network of Networks model, each operating business under the overall umbrella would be a research network (which would include federal scientists, research programs and national laboratories) that is focused on one or more specific research theme (e.g. wildlife, toxic substances, etc.). Other "investors," such as other federal government departments, universities, industry and NGOs, could also contribute equity to the individual networks. While the Department (or other special network administrative arrangement) would be responsible for the management and performance of the overall research portfolio, individual networks would be responsible for establishing and managing their own research programs.

In the Network of Networks model, Environment Canada scientists and research facilities would actively participate in the work of various research networks. Scientists wishing to participate in various networks would submit their proposals to the same peer review mechanisms as other network participants. In some instances, especially where they have unique expertise or facilities to contribute, federal laboratories could lead network research. In other cases, they would participate in networks under the leadership of an outside group (e.g. a university-based team). To facilitate knowledge creation and transfer, federal scientists and laboratories could expand mechanisms for personnel exchange to and from external research networks. In addition to participating in research networks, and where there is a sound public policy reason for doing so, Environment Canada would maintain its own independent research programs but try to maximize the involvement of in-house science programs in research network activities.

"Network of Networks" Model



In the Network of Networks model other stakeholders, such as other government departments, the federal granting councils, provincial governments, NGOs, industry partners and other research organizations, would be important members of the various research networks, contributing their expertise, facilities and financing. In some cases, these other types of research institutions might provide the administrative leadership for a specific network — and high-level science managers of different research institutions might be drawn on to provide an overall structure for the coordinated management of all the networks.

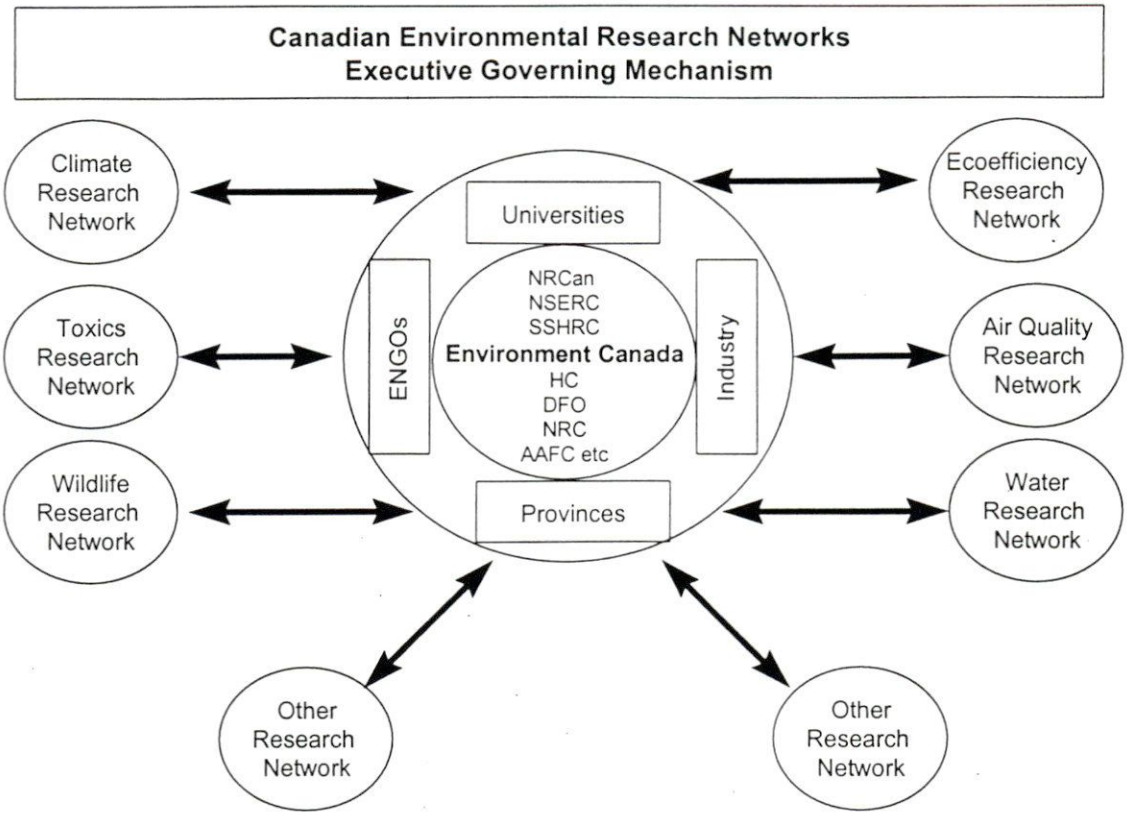
The Network of Networks model recognizes the science assessment and policy formulation roles of federal scientists and their parent departments. It reduces the need for federal scientists and laboratories to cover all the research bases and instead enables them to concentrate on specialized fields of knowledge. It shifts the emphasis of science in government toward assessment and policy, which, after all, are the core business of government. It also emphasizes the role of federal departments, in this case Environment Canada, in planning and coordinating the overall performance of the national environmental research system, integrating the management of knowledge, and ensuring the optimum use of knowledge to support public policy.

3.2 Canadian Environmental Research Networks (CERN)

The Network of Networks model is a generalized way of understanding the emerging role of federal science-based departments such as Environment Canada within national systems of innovation. The model can also be transposed onto the national system of

environmental research to create a new structure, the Canadian Environmental Research Networks (CERN).[9]

The development of the Canadian Environmental Research Networks would take a thematic, problem-solving approach to coordinating national environmental research resources, much as the Canadian Institutes for Health Research will.[10] The diagram below outlines one possible approach.



In the CERN model, Environment Canada would take a leadership role in helping to determine the important areas where new environmental knowledge is required. For example, the Department might initiate a consultative research priority-setting exercise to determine which networks are required; it could also work within specific theme areas to help set research priorities.

Once priority themes are established, calls for proposals could go out to the environmental research community, including scientists in Environment Canada, to solicit expressions of interest or intent. This process would provide researchers with an

[9] If pursued, the use of the name CERN may cause confusion within the domestic and international scientific communities, who recognize CERN as the European Organization for Nuclear Research, one of the world's largest scientific laboratories.

[10] The federal Networks of Centres of Excellence have recently taken a similar approach, by identifying themes for networks in advance.

opportunity to form alliances and begin thinking about operational details. Network proposals might be led by researchers from university, government, industry or NGO sectors, or even combinations of centres of excellence, depending on where the research capacity and interest lay.

Environment Canada could help establish an independent panel or overall governance structure to review network proposals, possibly in cooperation with one or more of the federal granting councils and representatives of other major environmental research institutions (including international representatives). Such a panel or governance structure would represent the highest quality scientific management; members could be eminent science advisors and research managers. The governance structure could review letters of intent, and, if necessary, narrow the list of proponents, recommend that some proposals be combined, and otherwise ensure that the strongest preliminary proposals are invited to submit full proposals to establish research networks.

Following a preliminary review, a number of proponents could be invited to submit full proposals to establish new environmental research networks or expand the scope of existing ones. These proposals would be judged on the basis of the detailed program criteria, such as the degree of networking proposed, the range of partnerships involved, the scientific strength of the proposed research plan, the adherence of the network to key research priorities established by the overall environmental science community, etc. Successful network proposals would be funded for a fixed period, perhaps up to five to seven years. Each network would operate under a semi-independent management structure, but with a reporting mechanism back to the overall governance structure established for CERN. Operating models for these types of networks are well established in the federal NCE program and elsewhere.

Funding for Canadian Environmental Research Networks could come from a variety of sources:

1. Redirecting internal Environment Canada S&T funds;
2. Partnering with the federal granting councils through research partnership agreements and similar mechanisms;
3. Partnering and using financial leverage with provincial governments, industry and NGOs; and
4. A new federal program to boost environmental research funding.

Obviously, there are many details that would need to be ironed out to launch an initiative such as CERN. However, there are an abundance of operating models upon which CERN could be patterned. In principle, CERN offers great potential to improve the efficiency and effectiveness of the environmental research system in Canada. But its greatest potential may lie in its ability to increase investor confidence, and investment, in a new and improved research system.

3.3 National Research Priorities

Arguably, the CERN model — and for that matter any research funding model — works best when there is an accompanying consensus on national research priorities to guide research selection and funding allocation. The "holy grail" of research planning in an innovation systems model would be a process for identifying and coordinating research priorities and organizational roles at a national level. Once national priorities are agreed on, rational decisions can be made about where and how to invest. However, the Network of Networks model can work well enough without a system for establishing national priorities; it simply takes as given available funding, research structures and (implicit) research priorities.

In recent years, specific research communities in Canada and the United States have made real progress in creating research priority and planning systems. In Canada, there is evidence of success in the agriculture and forestry research sectors. The Canadian Institutes of Health Research and the Networks of Centres of Excellence program represent another attempt to develop and implement a system for setting and acting on national research priorities. In the United States there has been substantial progress in setting federal priorities for environment and natural resources research, although it is less clear how much impact these priorities have had on the spending decisions taken by individual federal research agencies in that country.

The time may well have come for Environment Canada to consider sponsoring the development of a national environmental research priority-setting system. However, this is a complex and difficult undertaking, requiring significant input of time and resources by the Department, with a not insignificant risk of failure. Looking at similar efforts in other sectors, we see that several factors, alone or in combination, may be required for success:

1. A strong desire on the part of stakeholders within a given research sector to either (a) solve a major problem (e.g. budget cuts), or (b) seize a significant opportunity (e.g. gain access to new funds);
2. Political desire and bureaucratic support to engage in such an exercise;
3. A disinterested change agent;
4. Transition funds to facilitate change; and
5. The prospect of new permanent resources.

Whether or not the timing is right, and environmental research stakeholders are inclined to work together toward this objective, is a matter for Environment Canada and its Science and Technology Advisory Board to determine. Likewise, leadership and decision making is required to determine whether there is sufficient political desire and support among senior officials (especially in "sister" federal departments and the central agencies) to support such a vision.

As for a disinterested change agent, it is possible that an organization such as the National Round Table on the Environment and the Economy has sufficient credibility and the wherewithal to undertake such a task, provided it receives the necessary support from other stakeholders. Moreover, a national priority-setting system for environmental research might have a significant advantage apart from the obvious one of improving the efficiency and effectiveness of environmental research performed in Canada. It could boost the confidence of public sector "investors" — in particular elected officials and central agencies — that their investments are being well planned and managed. If confidence increased, the climate could be right for a new round of investment for transition costs, and possibly even for ongoing additional investment in the research system.

4.0 Options

This report has set out to examine the organization and delivery of research within national science and technology systems, and the trend toward new research and funding models. It has found no shortage of useful models that could serve to guide and strengthen Canadian environmental research in the future. Environment Canada itself has been in the forefront of developing and implementing new research approaches, and its Climate Research Network or Atlantic Cooperative Wildlife Ecology Research Network could well serve as the prototypes for other thematic environmental research networks, of the type proposed for the Canadian Environmental Research Networks.

There are two overriding issues that arise from this report. First is whether the time is right and there is sufficient reason for Environment Canada, in partnership with other stakeholders, to actively pursue the development of a national environmental research agenda. We believe there may be significant long-term benefits to moving in this direction, but it is not without risks and costs. Substantial thought would need to be put into the process by which to move forward, and major internal efforts would be required to provide policy and operational support. The experience of other jurisdictions, however, is that developing such an agenda and rethinking research networking arrangements is entirely feasible. But certain "winning conditions" may need to be in place first, such as:

- Consensus on a vision;
- Willingness to experiment;
- Political and administrative support;
- Participation of a neutral broker;
- Transition funds; and
- Potential for new investment in the system.

The second issue concerns the role of science and research within Environment Canada, and how to better link the Department's strengths with those of other

organizations in the national system of environmental research. With these points in mind, we propose the following (non-mutually exclusive) options for the consideration of the Science and Technology Advisory Board.

4.1 Option 1 — Status Quo

The first option is to retain the status quo; that is, make no significant change in how environmental science and research are prioritized, planned, financed and carried out. The main advantage of this option is that it requires the least amount of effort and causes the least disruption to existing roles or current operations. However, it is anticipated that sooner or later the status quo will produce a number of undesirable outcomes:

- A growing gap between the demand for environmental knowledge and the capacity of Environment Canada (and other environmental science and research organizations) to meet requirements;
- Ongoing dilution and weakening of environmental expertise and facilities within government, as current resources are spread too thinly;
- Fragmentation of national environmental science and research efforts and an inability to harmonize system strengths and activities; and
- A low level of confidence in environmental science and research by decision makers, resulting in a continued low level of investment.

The national system of environmental research is currently at a crossroads and, practically speaking, the status quo is not a viable long-term option.

4.2 Option 2 — Adopt the National System of Environmental Research Paradigm

A second option is for Environment Canada to explicitly embrace the national system of environmental research paradigm, perhaps by developing a policy statement on R&D roles. Under this option Environment Canada would see itself as a lead participant within a national environmental research system, in partnership with other government departments and the higher education and community sectors. As such, its mission would be to ensure that decision makers have timely access to and assessments of needed scientific and technological information to support policy making, provision of key environmental services, development of environmental technologies, and advancement of ecoefficiency. The Department's S&T role, therefore, would have to evolve from that of a major environmental S&T performer to a broader role that would include system integrator, leader of critical networks (which align with its core competencies), participant in external networks, and overseer of the health of the national science and research system. This option has several advantages. In particular, it would:

- Reduce the pressure on Environment Canada to fund and perform a majority of policy-relevant environmental science and research in-house;
- Better integrate the capacity of external research organizations into a national system;
- Lay the groundwork for national research priorities;
- Help to identify critical knowledge gaps and see they are filled;
- Reduce duplication of effort;
- Maximize resource and facility utilization;
- Reinforce excellence and utilize the skills, abilities and resources of each group in the most appropriate way;
- Enhance the transfer and application of knowledge and technology;
- Integrate the contribution of the social sciences; and
- Maximize the overall performance of the system.

Adopting a national system of environmental research networks model would not come without costs. It would require the Department to identify and place emphasis on its core competencies. It could also require federal laboratories to transfer certain responsibilities and resources — especially science and research that is not core to the Department's mission — to external organizations that have better capacity. In some cases the Department has already experimented in an ad hoc fashion with scientific staff and program outsourcing or placements in other institutions to enhance networking.

4.3 Option 3 — Establish the Canadian Environmental Research Networks

A third option for consideration is to begin organizing and financing a formal system of Canadian Environmental Research Networks (CERN). The CERN model would be inspired by a vision to expand the Climate Research Network and the Atlantic Cooperative Wildlife Ecology Research Network, which appear to be working well at present. CERN would be the principal mechanism for more formally implementing the Network of Networks paradigm developed earlier in this paper. CERN would be centres of excellence–type organizations focused on national and regional environmental research themes; for example, Arctic pollution, wildlife, persistent organic compounds, etc.

Internal and external research organizations would contend for leadership positions and research resources in a series of national competitions. Awards would be made based on the excellence and relevance of the researchers and research proposed, and proposals would be subject to a modified peer review. Inevitably, some networks would be headquartered outside the Department and others would be led by Environment Canada. Staff mobility would be enhanced, so that Environment Canada researchers could more freely participate in external networks.

Over time, CERN would lead to a transfer of more activity and resources to organizations outside Environment Canada. It would also require the Department to devote additional resources to integration, networking, coordination and assessment activities. The need for such resources could be substantial and should not be underestimated.[11] The chief advantage of CERN is that it harnesses the capacity of the entire national environmental research system. If it is well implemented, CERN will create a "whole that is larger than the sum of its parts." Adoption of the CERN model would require a detailed policy and business case to be developed. Significant planning efforts, including development of more focused discussion papers and policy processes, should be the next step in assessing the CERN option.

4.4 Option 4 — Develop Federal Research Priorities

Specific Canadian research sectors (e.g. agriculture, forestry) and groups in other countries (e.g. U.S. Committee on Environment and Natural Resources) have made progress in establishing multilateral priority-setting mechanisms for science and research in their respective fields. If such an effort is deemed worthwhile in the Canadian environmental research sector, one starting point would be to develop a joint planning and priority-setting mechanism for federal government science-based departments and agencies.

Because of the close working relationship established between Environment Canada and its "5NR" partners (Agriculture, Fisheries, Health, Natural Resources), the 5NR grouping would be a logical starting point for the development of such an accord. Other science-based departments and agencies, such as the National Research Council and federal granting councils, could also be invited to participate. In principle, a federal environmental research priorities system would help to improve the efficiency and effectiveness of current planning and implementation efforts within government. However, given the paradigm of ministerial responsibility and the natural reluctance of organizations to relinquish authority over planning, such a system would be difficult to implement without new financial resources and an accompanying vision for reorganizing the delivery of environmental research. An alternative approach would be to experiment with priority setting in a limited number of specific environmental research themes (perhaps where specific knowledge gaps are recognized) to iron out difficulties and build confidence in the overall approach.

4.5 Option 5 — Develop National Research Priorities

An approach aimed toward setting national research priorities would be more ambitious than the option to set federal research priorities. Environment Canada could adopt a strategy similar to Option 4 with respect to developing national research priorities (as distinct from federal priorities). If this option were pursued, it would be imperative to

[11] The Canadian Institutes of Health Research estimates that overhead costs will increase from around 4% of grants in the Medical Research Council model to 6% in the CIHR model.

involve an independent third party, such as the National Round Table on the Environment and the Economy, as a facilitator and partner.

4.6 Option 6 — Develop Research Partnership Agreements

The final option that is suggested is worth considering on its own merits: to immediately begin work with the Natural Sciences and Engineering Research Council and Social Sciences and Humanities Research Council to see if research partnership agreements can be forged. These agreements would help Environment Canada to leverage its current university research funding, and expand policy-oriented research in the higher education sector. Such agreements could be pursued in specific theme areas of interest to Environment Canada and university research partners. This option, moreover, could be undertaken in addition to any of the above options.

Appendix 1
Overview of Selected Sectoral Research System Models and Networks

1. National Strategy for Agri-food Research and Technology Transfer

This strategy was developed by the Canadian Agri-Food Research Council (CARC), in cooperation with provincial agriculture ministries, industry associations and Agriculture and Agri-Food Canada. It is the second five-year strategy (the first was developed in 1992). The plan was developed through in-depth consultation with federal, provincial, university and private sector representatives. Its premise is that:

> *...increasing pressures, both domestically and internationally, are demanding that the sector transform its methods of doing business ... While the focus of attention has been on fiscal constraints and downsizing, there have also been new research and development facilities coming online, and the introduction of programs to share the risk of undertaking research. Priority setting has been identified by many as a major role for CARC.*

The CARC report tries to balance short-term, industry-driven R&D with broad science knowledge (basic research) necessary to ensure the long-term health of the sector. The strategy has two main themes. First, because funding shortages are making it difficult for any one organization to deliver major research programs alone, the sector must develop more effective and synergistic partnerships. The second theme is improving communication among the various agri-food players and the public. Specific S&T objectives are:

1. Ensure sustainable use of resources;
2. Develop national and regional priorities;
3. Increase private sector involvement; and
4. Effectively manage human resources.

CARC had a number of things to say with respect to developing research priorities, many of which apply equally well to environmental research.

> *Restructuring within agri-food research organizations is expected to have long-term impacts on agri-food research ... unless the effects of the restructuring are properly managed and innovative solutions found, Canada's ability to do long-term research and to compete effectively in the global marketplace, will be in jeopardy.*
>
> *One of the realities of the increasing costs of research is that each country will have to be more selective about the science it conducts. Canada, like other countries, cannot afford to continue to try to be the best in all areas of research ... foreign partners are moving towards research specialization and are utilizing access*

agreements to acquire needed technologies developed in other countries ... To compete effectively the research community will need to support targeted research through the development of national and regional priorities. It is recommended that CARC develop research priorities in partnership with the federal government, provincial governments, universities and the private sector.

CARC has advocated a "Team Canada" approach to agricultural and agri-food research, and has proposed that *"All players in the agri-food research community augment research partnerships across the country and, where appropriate, internationally."* Additionally, it has addressed head-on the issue of duplication of effort. Some duplication is valuable, but too much can lead to the ineffective use of scarce financial and human resources; *"Input will need to be sought from all regions and a method will need to be found to ensure that the research information can be easily shared across the country."*

CARC has also discussed the need for effective technology transfer from public laboratories to industry. It observed that the present system of technology transfer required refinement, and that *"Efforts will need to be made to ensure that technology transfer becomes an integral part from the bench to the marketplace ... A co-ordinated national system of technology transfer would provide equitable access to technologies, including those sourced internationally."*

2. The National Forest Science and Technology Course of Action

The Canadian Council of Forest Ministers (CCFM) are the overall custodians of the Canadian forest sector research strategy, *National Forest Science and Technology Course of Action — Science and Technology Priorities for the Forest Sector 1998-2003.*[12] This research agenda, which is an outgrowth of the broader National Forest Strategy, was developed in 1997-98 as a collective effort involving all major research stakeholders in the forest sector — industry, government, non-government organizations and academia. The establishment of this national strategy for forestry science and technology has also resulted in FORCAST, a private, not-for-profit national coordination and communication mechanism that provides direction and infrastructure to ensure that forest science and technology is aligned with national priorities established in the National Forest S&T Course of Action.

As in agriculture, the national forest S&T strategy identified thematic areas under which activities would be organized, and where it was acknowledged that achieving agreement on a common course of action would be a good start:

- Forest S&T management to identify duplication, overlap and gaps in forest S&T;

[12] Canadian Council of Forest Ministers. Canadian Forest Service. Ottawa. 1998.

- Methodologies for developing sustainable forest management indicators;
- Public participation and integration of social and economic factors;
- Ecosystems-based research;
- Industrial competitiveness;
- Stewardship; and
- Aboriginal peoples.

FORCAST works to:

- Foster coordination;
- Facilitate communication;
- Champion investment in research; and
- Evaluate progress.

3. U.S. Agenda for Environmental and Natural Resource Research

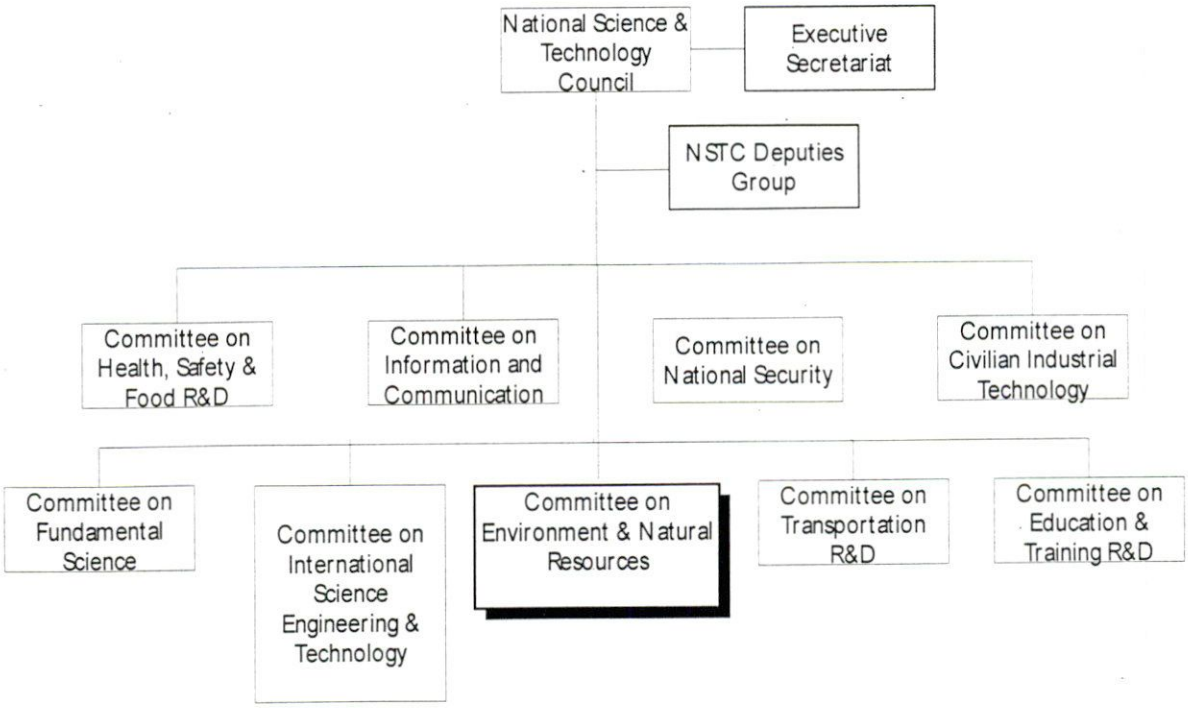
An example of a national environmental research agenda-setting process can be found in the United States, where the National Science and Technology Council's Committee on Environment and Natural Resources (CENR) has established a U.S. Agenda for Environmental and Natural Resource Research. The National Science and Technology Council (NSTC) is a standing, cabinet-level body chaired by the President and composed of the Vice President, the Assistant to the President for Science and Technology, the cabinet secretaries and agency heads with responsibilities for significant science and technology programs, and other White House officials.

NSTC's principal purposes are to (1) define clear national goals for federal science and technology investments; and (2) ensure that science, space and technology policies and programs contribute effectively to the national goals. NSTC's work encompasses the activities of 12 federal agencies spending roughly $5.5 billion (in 1996). NSTC was given the mission "to reinvent how R&D is conducted in the United States."[13] NTSC's Committee on Environment and Natural Resources took up the challenge to (emphasis added):

> *(make) significant changes in how the federal government plans and supports research on the environmenl and natural resources. ... This approach replaces the traditional* ***single issue***, ***single agency***, *and* ***single discipline*** *approach to solving environmental issues with an integrated, interagency research program".*

[13] National Science and Technology Council. Committee on Environment and Natural Resources. *Preparing for the Future Through Science and Technology. An Agenda for Environmental and Natural Resource Research.* Washington. March 1995

The National Science and Technology Council



CENR is strengthening the overall federal R&D program through:

- Increasing emphasis on competitive awards and on peer and merit review for federally funded R&D;
- Improving the links between research and policy, ensuring that research programs are anticipatory to prevent, not just mitigate environmental threats;
- Taking a leadership role in international scientific efforts by leveraging research through international agreements and programs; and
- Developing performance standards to evaluate research program effectiveness.

CENR provides leadership through its subcommittee structure for strategic planning, coordination and prioritization of research and assessment objectives across all federal agencies. CENR managed a process to evaluate the balance between intramural and extramural R&D in the overall mix of federal R&D.

> *Important roles exist for federal laboratories, national laboratories (government owned, contractor operated), universities, and private industry research activities. The process of strategic planning recognizes that each of these sectors has capabilities and resources that are integral to a balanced federal research program and will strive over the long term to take advantage of the diversity of strengths afforded by each.*

CENR has established seven issue subcommittees: Air Quality, Biodiversity and Ecosystem Dynamics, Global Change, Natural Disaster Reduction, Resource Use and Management, Toxic Substances and Hazardous and Solid Waste, and Water Resources and Coastal and Marine Environments. These subcommittees coordinate the federal agency programs within their particular environmental area.

Each subcommittee is charged with defining critical policy questions or issues relevant to its issue or methodological area (e.g. risk assessment, social and economic sciences). The scientific knowledge and corresponding research necessary to meet those policy challenges are then identified, and an interagency implementation plan is developed. Typically, large numbers of individuals (around 200) review subcommittee strategy documents at a national conference. Many hundreds of additional reviewers in subsequent review workshops and mail reviews do the same. Reviewers consist of non-federal scientists from academia, industry, environmental organizations, congressional staff, and state and local governments.

In addition to the seven issue subcommittees, CENR has three committees dealing with cross-cutting issues: Environmental Technology, Social and Economic Sciences, and Risk Assessment. There are also two working groups dealing with Observations and Data Management, and Ecosystem Research.

CENR encourages federal agencies to improve the quality and effectiveness of their R&D programs by increasing the use of external peer and merit review, increasing the use of open competition to award funds, and strengthening extramural academic research programs. It is encouraging federal agencies to actively seek international cooperation to leverage U.S. resources, provide access to research sites worldwide, and assist in developing international scientific consensus on environmental and resource issues.

With regard to science assessment, CENR is attempting to develop an infrastructure to involve experts from all stakeholder groups in conducting *"broad and credible national scientific and technical assessments of the state of knowledge."* The purpose of the national assessments is to complement international assessments (e.g. UNEP), so that consensus can be reached on knowledge and knowledge gaps.

CENR describes its strength as coming from the active participation of all relevant agencies and offices of the White House, including the Office of Science and Technology Policy (OSTP) and the Office of Management and Budget (OMB) during all phases of the budget process:

> *The CENR is working because there is buy-in at all levels of the agencies, from program managers to agency heads. R&D priorities must, and will, explicitly take into account Administration priorities, environmental statutes, and international conventions ... (individual) agencies responded (in the 1996 budget process) to the*

top priorities developed across the federal government and in concert with stakeholder guidance received through the national forum and external reviews.

CENR demonstrates that it is possible, in a complex multistakeholder environment, to fashion an effective system of national priority setting for environmental research.

4. The Climate Research Network

The Climate Research Network (CRN) was established in 1993, as one measure to fulfil commitments in the National Action Program on Climate Change adopted by the Canadian Committee of Energy and Environment Ministers. CRN was thus created *"...as a mechanism to enable the federal government to engage the energies, ideas and talents of the university and private sector communities in providing the critical scientific knowledge required for policy-making related to climate change and climate variability."* In establishing the CRN, the National Action Program on Climate Change sought answers to a number of policy questions especially relevant to Canada's environment, including:

- What is the current state of global climate — how does it respond to human-generated greenhouse gas (GHG) emissions and how is the future climate likely to respond to the effects of continued human interference?
- What effect will the rate of climate change have on the frequency, severity and consequences of extreme climate and weather events?
- What role do the earth's clouds and oceans play in climate change?
- How effective are carbon sinks in reducing GHG concentrations in the atmosphere?

In 1993-94, Environment Canada established a Scientific Advisory Panel to set out the research agenda for the CRN. The panel consisted of respected scientists from government and academic institutions. In 1995 the University of Victoria's Canadian Institute for Climate Studies (CICS) was given responsibility to coordinate the work of the CRN under contract. Currently, the main focus of work at CRN is:

1. Develop computer models of the climate system that can:
   - provide regional-scale (50 km) information;
   - take into account the dynamic interaction between the ocean and the atmosphere;
   - incorporate chemical processes;
   - simulate the climates of previous epochs;
   - incorporate an exchange of carbon between the atmosphere and the land/ocean surface; and
   - resolve regional eddies in ocean circulation.

2. Understand a range of processes that need to be incorporated into climate models, including:

- how the atmosphere interacts with land surfaces; and
- the role of clouds, aerosols and radiation.

3. Assess the nature of climatic variability on a variety of time scales.

CICS manages 26 research agreements with principal investigators of nine major projects ("nodes") and 16 sub-projects at 14 Canadian universities and three government laboratories. The research agreements were valued at $2.14 million in 1998-99. A particularly novel aspect of CRN is that Environment Canada assigns some of its own scientists to work with the Network, on campus at the University of Victoria. Projects typically run for three to five years. CRN operates much in the mode of a network of centres of excellence, with CICS providing program management and coordination services. In most cases the universities involved with the Network are making substantial contributions in the form of:

- Salary and benefits for the time investigators devote to CRN projects (between 10-50%). The estimated value is $500,000 per year;
- Office and laboratory space and support, estimated to be worth $150,000; and
- Forgoing of overhead charges on the CRN grants, estimated to be worth $1 million if priced at commercial contract rates.

In addition, other federal research support (mostly NSERC) amounts to approximately $1.96 million. Thus, the total estimated value of leveraged resources is at least $3.4 million, compared with the Environment Canada contribution of $2.2 million. A 1998 evaluation of CRN described the Network as:

> *... an innovative concept that has little parallel either in climate research outside Canada or in other research fields in Canada ... It was also felt that CRN was a unique concept that could serve as a model for other large, multifaceted research programs.*
>
> *(CRN) ... is an attempt to optimize the Canadian climate research effort by satisfying a number of goals:*
>
> - *Spending Federal government research dollars efficiently and avoiding duplication.*
> - *Contracting certain activities traditionally performed by government to agencies outside the Federal government.*
> - *Fostering the development of Canadian expertise in climate science.*
> - *Ensuring that climate research conducted in Canada is supportive of the policy-making needs of the Federal government in the climate field.*
> - *Respecting the traditional goal of scientists to conduct research that is of interest to them without external interference.*

From all reports, CRN appears to be a highly successful example of a federal-university partnership that has benefited both communities. Productivity seems to be high; at the end of fiscal year 1997-98, a total of 112 publications by CRN scientists had been submitted to or accepted by scientific journals. CRN research has also led to concrete improvements in climate change models produced by the Atmospheric Environment Service of Environment Canada.

CRN successfully combines the managed-research feature of government R&D with the curiosity-oriented aspect of university research. Some Environment Canada scientists work on campus with CRN university researchers, while others manage research nodes situated within Environment Canada or other federal facilities (e.g. Bedford Institute of Oceanography). There is a seamless approach to research and research administration.

That is not to say that the CRN model does not have problems of its own (e.g. continuity of project funding). However, it does demonstrate how the best of a nation's capabilities inside and outside of government can be brought together to achieve medium-term objectives. For example, one of CRN's accomplishments is that it has developed de facto national research priorities for climate change research, and funded the researchers best able to address those priorities, whether they are inside or outside of government.

5. Atlantic Cooperative Wildlife Ecology Research network (ACWERN)

In 1994, a group of scientists from academic and government research institutions in Atlantic Canada began combining their efforts to investigate the cause and effects of changing patterns of energy flow, and wildlife population dynamics, in terrestrial and marine ecosystems in Atlantic Canada. The organization was named the Atlantic Cooperative Wildlife Ecology Research Network (ACWERN).

According to the initial proposal developed by the partner universities and the Canadian Wildlife Service (CWS), ACWERN was designed as a regional research network focused on wildlife ecology in the marine, coastal and terrestrial ecosystems of Atlantic Canada. It brings multidisciplinary scientific approaches to bear on fundamental and applied problems in wildlife ecology and habitat relationships. The ACWERN research program was designed to improve understanding of ecosystem dynamics in Atlantic Canada and complement and enhance the ability of government agencies to conserve wildlife populations and habitats.

In 1996, the ACWERN chairs and management board agreed that ACWERN's *central mission* was to enhance understanding of the ecology of wildlife in Atlantic Region ecosystems through scientific research, with a *scientific focus* on the relationship between changing ecological patterns and processes and human activities, and with the

aim of enhancing the application of ecological research to problems in biodiversity conservation. A three-page ACWERN mission statement also addresses the research focus, management focus and educational focus.

The Canadian Wildlife Service worked closely with Acadia University, Memorial University and the University of New Brunswick in designing ACWERN, in hiring three research chairs to provide the focus for university involvement in ACWERN, and in setting overall direction through participation on the Network's management board. In addition, Environment Canada committed to providing substantial core funding for ACWERN's first five years, and has renewed that commitment for a second five-year period. It has provided additional funds to support specific projects and youth through its operating budget and the Science Horizons program.

Environment Canada provides a senior research manager who serves as Chair for the ACWERN management board, as well as a research manager who serves as ACWERN coordinator. CWS researchers in the Atlantic Region of Environment Canada are actively involved in ACWERN projects, and the direction of many parts of the ACWERN program has been influenced by Environment Canada.

The Natural Sciences and Engineering Research Council (NSERC) has long supported the effort to set up Canadian wildlife research chairs and has matched core funding from Environment Canada for the first five years of ACWERN. NSERC has expressed its satisfaction with ACWERN, and a sister wildlife research chair program based at Simon Fraser University, and has agreed to renew financial support for the second five years after having received responses to recent questions posed by the NSERC review committee. These questions related to the involvement of CWS, the research focus, the chairs' supervisory load, publications and other results of ACWERN research, and sources of internal and outside funding, and have been addressed by the chairs and management board.

Universities and non-governmental organizations view their involvement in ACWERN as generally having been very positive and strongly support renewal of the Network. Common themes identified among the major benefits of ACWERN include:

- an opportunity to accomplish important research that would not otherwise have been done, especially those projects with management applications;
- new expertise and skills for Atlantic Canada (e.g. landscape ecology, conservation ecology, ecosystem approach);
- dynamic researchers encouraging innovation and scientific rigour in their research; and
- improved links among partners, universities and the CWS.

6. Canadian Network of Toxicology Centres (CNTC)

The Canadian Network of Toxicology Centres (CNTC) was formed in 1988 by the signing of a memorandum of understanding between three existing research centres: the Centre for Toxicology at the University of Guelph, the Toxicology Research Centre at the University of Saskatchewan, and the Centre interuniversitaire de recherche en toxicologie de l'Université de Montréal et de l'Université du Québec à Montréal. These centres became the "nodes" of the CNTC. In April 1992, the CNTC was allocated five-year startup funding from Canada's Green Plan to implement a National Toxicology Program. General objectives include the following:

- To address Canada's national and regional needs in the understanding of toxic substances in the most efficient and coordinated manner;
- To facilitate communication between toxicology centres in the areas of management, research and education;
- To encourage the establishment of joint, cooperative research and educational projects between network members, federal and provincial government research establishments and industry;
- To develop and maintain the highest standards of scientific research and education in toxicology; and
- To transfer information and achieve toxicological literacy among all Canadians.

Environment Canada has been a major supporter and sponsor of the CNTC since its inception. The CNTC has developed an agenda that outlines priorities for research attention, as well as a detailed scientific peer review process for evaluating scientific proposals submitted to the CNTC.

7. Ecological Monitoring and Assessment Network (EMAN)

The Ecological Monitoring and Assessment Network (EMAN) is a national network of monitoring and research sites characterized by long-term, multidisciplinary studies, which is supported by Environment Canada. Sites within a single ecozone are loosely linked in an ecological framework. The overall Network strives to facilitate cooperation and a holistic approach to ecological enquiry and ecosystem understanding.

Ecological Science Cooperatives in the Network promote connections among sites operating across the country. The Network is highly decentralized and acts as a coordinating body, facilitating communications among participants and providing strategic direction. EMAN is an inclusive network (i.e. those who wish to participate are welcomed). It embraces all facets of ecological enquiry (including monitoring and research) and facilitates communication among its participants and interaction with international networks. The Network promotes the use of environmental indicators and the production of issue- and area-based assessments.

In April 1994 the Ecological Monitoring Coordinating Office was established by Environment Canada at the Canada Centre for Inland Waters in Burlington, Ontario.

This office functions as the secretariat to EMAN: it coordinates the organization of the Ecological Science Cooperatives, fosters new initiatives, and facilitates communication within EMAN. Each Ecological Science Cooperative (ESC) within EMAN covers at least one of the 15 terrestrial and five marine ecozones of Canada. Each ESC provides a forum for participants at research and monitoring sites in a single ecozone to communicate, share information sources, review projects and advise others. The group participates in cooperative planning, integrating results from research and monitoring with other sites, disciplines and agencies. ESCs conduct studies related to:

- ecosystem composition, structure, function and process (including energy flux, material cycling, sources and sinks);
- ecosystem history (paleoecology) and current state;
- causes and ecological consequences of environmental change;
- species inventory, population dynamics and biodiversity change; and
- rates and magnitudes of changes and whether such changes are parts of cycles or trends.

ESCs contribute to EMAN by:

- mobilizing the scientific community to address major policy and assessment needs;
- providing a base for undertaking additional monitoring and research activities;
- assisting in, clarifying and validating the basis for the selection of ecological indicators;
- encouraging the participation of scientists, educators and their students, and the general public within each ecozone;
- giving notice of unexpected changes in rates and trends, and thus being an early warning system; and
- communicating findings in forms useful for local, regional, national or international audiences.

Over 100 individual agencies comprising extensive monitoring networks in hydrology, weather, forestry and agriculture are involved in EMAN. This is strengthened by the many volunteer networks (e.g. Breeding Bird Survey and Ecowatch). Unlike the Climate Research Network, however, EMAN sites are funded through their own sponsoring institutions. Environment Canada does not provide core funds for environmental monitoring at EMAN research or monitoring sites. Rather, each site is responsible for its own budget and sustainability. Environment Canada provides a small budget for seed activities to support EMAN network development. It sponsors things such as organizational meetings, startup projects to demonstrate benefits, and new techniques. A major EMAN activity is the coordination of an annual National Science Meeting.

8. Canadian Institutes of Health Research

In the February 1999 budget, the federal government announced its intention to create the Canadian Institutes of Health Research (CIHR), which will become the successor to the Medical Research Council (MRC). CIHR was developed through a lengthy stakeholder consultation process, which was managed by the Interim Governing Council, with significant input from Health Canada. CIHR's budget will rise from $271 million (MRC 1998) to $484 million (CIHR 2001), an increase of nearly 80%.

As an agency of the Crown (Crown corporation), CIHR will link health researchers from a broad spectrum of disciplines to work toward improving the health of Canadians. CIHR will do more than support existing research excellence in Canada. It is designed to foster new synergies among researchers to solve complex, difficult health challenges, based on integrated, collaborative and multidisciplinary approaches. It will build on the research base in Canadian universities, health and research centres, teaching hospitals, federal and provincial governments, and the voluntary and private sectors.

By integrating loosely linked health research into a network of "virtual institutes," important health issues can be more effectively addressed, using the resources from four cross-cutting approaches to health research (biomedical, applied clinical, health system/services, and society, culture and the health of populations).

CIHR is designed to significantly improve linkages with existing health research partners and foster collaboration with voluntary, community and private sectors. A more integrated and dynamic research environment, combined with greater financial resources, will create new knowledge that will generate better health and health care for Canadians and expedite discovery and treatment and a broader look for effective policy interventions.

CIHR is intended to help forge an integrated health research agenda to accelerate discovery and treatments where emerging health threats can be identified. CIHR will build on the rapidly growing body of evidence demonstrating that some of the most important determinants of health lie outside the scope of clinical, biomedical interventions.

CIHR will serve as a base to transfer knowledge to local communities and monitor and report on the quality of the social environment and health of Canadians. For a new generation of researchers, this new direction will mean made-in-Canada opportunities for training and innovation. In this way, CIHR will make health research conducted in Canada among the best anywhere in the world. CIHR's four health research perspectives or themes, in more detail, are:

- Basic biomedical research: Basic research conducted by scientists in, for example, the discovery of a new gene; building the knowledge base.
- Applied clinical research: Applying knowledge, possibly to find a cure for diseases and disabilities; testing and applications of basic research in a clinical setting such as labs, research centres, communities, etc.
- Research on health care systems and services: Advances related to the health care system and health services such as identifying the most effective delivery mechanism or system for rehabilitation services, etc.
- Society, culture and the health of populations: Dealing with factors outside the health care system that affect the health of communities and populations; research on social, cultural, environmental and behavioural determinants and dimensions of health; factors outside the health care system that directly impinge on health.

The objectives of CIHR are to excel, by international standards, in the creation of new knowledge, and its translation into improved health for Canadians, more effective health services and products, and a strengthened Canadian health care system, by:

- creating a robust health research environment in Canada;
- building the capacity of the Canadian health research community;
- forging an integrated health research agenda across disciplines, sectors and regions; and
- encouraging interdisciplinary, integrative health research through the creation of thematic institutes that pertain to all aspects of health.

CIHR envisages the full spectrum of health researchers being brought together within "virtual institutes" that will be established based on different thematic areas. For example, a disease-focused research effort on asthma could have the basic genetic research done at a hospital in Quebec, while the clinical trials and evaluations of asthma therapies would progress in Saskatchewan and Ontario. Research by social scientists and public health officials could be done in rural areas of Manitoba and Newfoundland and Labrador, and an evaluation of a pilot project to determine how best to deliver effective therapies could be performed in British Columbia and Prince Edward Island. Individual (university) investigators will elect which institute they wish to join, and will attach their (peer-reviewed) research funding to that institute.

The institutes will use CIHR programs, the mechanisms by which both investigator-initiated and targeted research will be funded, as the key tools to meet their strategic objectives. In the context where institutes support collaborative, multidisciplinary research approaches carried out by health professionals on a thematic area of research, each institute will be responsible for developing and supporting clinical research within its area.

CIHR aims to break new ground in striving to become an "inter" and "multi" disciplinary health research organization. This new structure will mean significant changes in the way researchers and decision makers conduct their work. The new knowledge-sharing environment will require a modification in organizational culture, which may translate into a change in the day-to-day tasks performed by individuals.

Each CIHR institute will be headed by a respected researcher, who will become the Institute Director. Directors will function more as ambassadors than as managers, since most of the funding relevant to the institute will be decided in national peer-reviewed competitions. Directors will oversee four different budget "pots," only one of which will be largely discretionary. The first budget pot is a small amount to cover the expenses of the Institute Governing Council. The second is a discretionary Institute Development Fund, to seed new initiatives. The third pot is the Investigator Fund, which is allocated based on individual investigator success in (formerly MRC) peer review. The Investigator Fund at each institute will be allocated a funding "floor" — a base funding amount. Finally, there is a Targeted/Strategic Fund, which will be allocated to each institute to finance oriented research projects. This fund will be equivalent to the current MRC fund for targeted/strategic research.

CIHR is an adaptation of a well-established university research funding system — the MRC — which has been in operation for over 25 years. Although it does envisage some participation of federal laboratories in its institutes (in particular Health Canada labs), it is intended mainly as a new way of funding and coordinating the activities of the relatively homogeneous university sector. CIHR is not a full-fledged national research coordination initiative, in that federal labs, industry, and others are not full partners in setting policies and programs. There is no attempt on the part of CIHR to determine national health research priorities, and the bulk of its research will still be investigator-driven.

CIHR (and MRC) work in part because there is no attempt to reconcile the different requirements of government science and university science. Similarly, there is no real or perceived competition between government labs and university scientists for CIHR funds. In any event, transposing CIHR onto a mixed government-university-industry-NGO system would require a very different governance structure. This is not to diminish the accomplishment that CIHR represents, but simply to recognize that the model is not readily transferable to a mixed government-university research system.

10. The Networks of Centres of Excellence Program

The Networks of Centres of Excellence (NCE) program is an innovative approach to R&D designed to develop Canada's economy and improve the quality of life of Canadians. Canada's three granting councils combine their efforts to support and oversee the NCE initiative. The funding for research and training in Canadian

universities through the Councils' peer-reviewed research programs is the foundation upon which the successful network approach is built.

The NCE program, which has been operating successfully for 10 years, was made permanent by the federal government in 1997, with an annual budget of $47.4 million. On February 16, 1999, the federal government announced that the NCE program budget would be increased by $90 million over the next three years, starting in 1999-2000. NCEs are unique partnerships among industry, universities and government designed to develop the economy and improve our quality of life. These nationwide networks connect excellent research with industrial know-how and practical investment. In 1997-98, a total of 463 companies, more than 100 provincial and federal government departments and agencies, 44 hospitals, 61 universities, and more than 200 other organizations from Canada and abroad were involved in the NCE program. There are currently 15 NCEs funded by the program. A new competition will establish four new NCEs in 2000-2001.

11. NSERC Research Partnership Agreements

NSERC has negotiated Research Partnership Agreements (RPAs) with six different federal government departments or branches (National Research Council, Department of National Defence, Agriculture and Agri-Food Canada, Canadian Forest Service, Canadian Space Agency, and NRCan Earth Sciences Sector). The objective of RPAs is to build strong linkages between the private sector and researchers in universities and federal institutes. A number of the agreements are similar to the National Research Council's RPA, which supports activities such as research projects, programs and workshops that:

- capitalize on the complementary R&D capacity existing in the universities and in NRC institutes to generate new knowledge in selected areas required to meet economic, industrial, social and environmental needs and opportunities;
- build strong three-way linkages and create synergy between the private sector and researchers in NRC institutes and universities;
- efficiently and effectively transfer research results and technology to receptors in the private and public sectors; and
- train and develop highly qualified personnel in priority areas consistent with the future human resource requirements in the public and private sectors.

Grants are awarded for a period of up to five years and are in the range of $100,000 to $400,000 per year, but may exceed this amount for very special opportunities. Funding is provided for research that involves collaboration with at least one NRC institute and at least one Canadian-based company that contributes in cash or in kind. The participation of small and medium-sized enterprises is encouraged. Proposals must address priority research areas.

In RPAs, NSERC matches departmental funding for research projects that involve university researchers. In exceptional cases, the industrial collaboration component may be waived. Clearly, a number of departments have found it in their interest to partner with NSERC to stretch their research dollars.

12. U.S. Army Research Laboratory - FedLab

The U.S. Army Research Laboratory (ARL) adopted a new concept of operations to deal with the challenge of responding to a new mission assignment at the same time as resources were being reduced.[14] The assignment required technical capabilities for which ARL did not have the necessary expertise. ARL recognized that the private sector possessed strong expertise that could be leveraged. As a result, ARL developed a new approach to partnering with the leaders of relevant private sector efforts. The approach, called Federated Laboratory (FedLab), allows ARL to jointly plan and execute technical programs, jointly evaluate, assess and report on the work accomplished, and redirect the work as necessary.

FedLab involves a collection of geographically distributed "virtual" laboratory divisions, augmenting the capabilities of ARL. Under ARL leadership, programs in the private sector are integrated with those already existing within ARL. Funding is provided by the government; it is not a cost-sharing arrangement.

Technology areas were defined and consortia were selected (involving at least one industry partner as consortium lead, one major research university partner and one historically Black college or university or minority institution) through a competitive peer-reviewed process. Consortia activities are directed by a Consortium Management Committee formed by senior representatives of all partners and chaired by a senior ARL technical manager.

To enhance technology transfer between ARL and the partners, there is a requirement for long-term technical staff rotations between ARL and the partners. The approach does more than bring together the best of the private and public sectors. It responds to other demands being placed on ARL: to increase outsourcing, to find dual-use solutions, and to use commercial standards and products.

FedLab has an important leveraging effect. ARL's science and engineering staff is enhanced through working relationships with the best of the private sector (including staff exchanges); FedLab takes advantage of the best existing state-of-the-art facilities and encourages the construction of new industry facilities; commercial technologies are adopted and adapted to the military environment; and ARL is building an in-depth knowledge base and technical competence despite resource reductions.

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[14] Auditor General of Canada. Report of the Auditor General of Canada, November 1999. *Attributes of Well-Managed Research Organizations.*

Appendix 2
List of Interviews

Dr. Bob Slater
Senior ADM
Environment Canada

Dr. Arthur Carty
President
National Research Council of Canada

Dr. Mark Bisby
Director of Programs
Medical Research Council of Canada
(CIHR)

Ms. Janet Walden
Director, Research Partnerships
Directorate
Natural Sciences and Engineering
Research Council

Ms. Elizabeth Atkinson
Senior Policy Advisor
National Round Table on the
Environment and the Economy

Mr. David Runnalls
President
International Institute for Sustainable
Development

Mr. Robert Davidson
Director of Research
Association of Universities and Colleges
of Canada

Dr. Howard Alper
Chair
Environmental Sciences and
Technology Alliance of Canada

Mr. Grant S. Trump
Executive Director & CEO
Canadian Council for Human Resources
in the Environment Industry

Dr. Gordon McBean
ADM
Atmospheric Environment Service
Environment Canada

Dr. Doug Whelpdale
Acting Director, Climate Research
Atmospheric Environment Service

Mr. David Oulton
Head
Climate Change Action Fund

Dr. Donald Strange
Manager
Climate Change Action Fund

Mr. Graham Campbell
Director
Office of Energy R&D

Mr. Bill Jarvis
Director General
Policy Research Branch
Environment Canada

Dr. Thomas Brzustowski
President
Natural Sciences and Engineering
Research Council

Dr. David Minns
Director General
NRC Institute for Chemical Process and
Environmental Technology

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10 *Measuring The Impacts Of Environment Canada's R&D: Notes On Methodology*

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12 *Environment Canada University Research Partnership Expansion Strategy: A Discussion Paper*

13 *Environment Canada's S&T: Expenditures & Human Resources, 1990-1999*