Environment Canada's Research Laboratories: Institutional Change and Emerging

Working Paper No. 21
Science Policy Branch
Environment Canada

Document de travail n° 21
Direction de la politique scientifique
Environnement Canada

Environment Canada's Research Laboratories: Institutional Change and Emerging Challenges

Three Case Studies

Jeffrey S. Kinder and G. Bruce Doern

Carleton Research Unit on Innovation,
Science and Environment (CRUISE)

A Report Prepared for Environment Canada

March 2003

ACKNOWLEDGEMENTS

We wish to thank all of the 32 Environment Canada staff members (listed in Appendix A) who assisted us in this project by agreeing to be interviewed or helping in other ways. Special thanks are due to Philip Enros and the heads of the three laboratories studied, namely, Michel Béland, Dan Bondy, and Dave Thornton, without whose help this project would not have been possible.

Jeff Kinder and Bruce Doern
March 2003

CONTENTS

CHAPTER 1

INTRODUCTION

The purpose of this report is to provide a summary commentary and individual case studies of three science and technology (S&T) institutions within Environment Canada. It is the result of a study by the Carleton Research Unit on Innovation, Science an Environment (CRUISE) commissioned by Environment Canada. The study's two-fold purpose was:

1) To review and analyze the nature and variety of institutional change in federal government S&T laboratories, through case studies of three Environment Canada labs:

- the Environmental Technology Centre (ETC);
- the National Wildlife Research Centre (NWRC); and
- the Atmospheric and Climate Science Directorate (ACSD).

2) To discuss the nature of future challenges facing federal S&T labs, taking into account their considerable variety and differing mandates.

The report is organized into four chapters. This first chapter provides a summary overview of the project's findings and is followed by three chapters that present the individual case studies. This chapter is organized into three sections. First, we define key terms and describe the core framework and methodological approach used to produce the three case studies. Second, we comment on the findings across the three labs using this framework which examines the labs as a changing mix of "hierarchies, networks, and markets." The third section then highlights key issues and challenges which emerge from the three case studies and from other sources, including the discussion and comments offered at a CRUISE workshop held in April 2002. The issues are of both strategic and day-to-day concern to the S&T managers and personnel of the labs and to federal S&T policy makers as a whole. They are not, it must be stressed, fully examined because they were not the initial focal point of the study. Rather we present some discussion of the nature of these issues, and highlight some of the linkages among them.

Concepts, Analytical Framework and Methodology

Table 1 provides a quick "at a glance" profile of each lab's mandate and some other basic details about location, size and budget. It is immediately important to point out that while the word "laboratory" or "lab" is often the short-hand term we employ in fact it is always necessary to think of each of these entities more broadly as S&T institutions. This is because, for many, the word "lab" may only evoke the image of a specific facility with fixed S&T assets where research and development (R&D) are conducted. However, in reality the case study institutions are also providers of funding, brokers of funding and expertise, and suppliers of science-based services, policy advice and technical information. Clearly, the term laboratory is inadequate but we have adopted it given its common usage in both the academic literature on S&T institutions and within the federal S&T community.

TABLE 1: THE THREE LABS "AT A GLANCE"

Lab / Core Feature	Environmental Technology Centre (ETC)	National Wildlife Research Centre (NWRC)	Atmospheric and Climate Science Directorate (ACSD)
EC Parent Service	Environmental Protection Service	Environmental Conservation Service	Meteorological Service of Canada
Location (primary)	Gloucester, ON	Gatineau, QC	Downsview, ON & Dorval, QC
Budget (approx.)	$11.5 million	$5.5 million	$40 million
Staff (FTEs)	96	53	316
Mandate/Mission	To support the Departmental national and international mandate for environmental protection by: a) developing and transferring pollution measurement, prevention, control and remediation knowledge, and new technology in areas related to air pollution and unplanned releases of oil and hazardous materials; and b) providing relevant specialized sampling and analytical expertise and services of the highest standards.	To be the principal source of knowledge and expertise in the federal government on the impact of toxic substances on wildlife and the use of wildlife as indicators of environmental quality, to conduct national surveys and research on migratory birds, and to produce scientific publications on wildlife.	To conduct research in climate, meteorology, air quality, and environmental impacts and adaptation, and to produce science assessments on pressing environmental issues (such as climate change, acid rain, and the depletion of the ozone layer, etc.) for Canadians and government policy makers.

Similarly, although "research" or "science" are often the terms used throughout the report these too must be understood broadly as potentially encompassing all "science and technology" or "S&T" activities. By definition, S&T consists of research and development (R&D) and related scientific activities (RSA). R&D is defined as creative work undertaken on a systematic basis in order to increase the stock of scientific and technical knowledge or to discover new applications for existing knowledge. RSA includes those activities that complement and extend R&D by contributing to the generation, dissemination and application of scientific and technological knowledge. Examples include scientific data collection, assessments, monitoring, testing, scientific and technical information services and museum services. Importantly, RSAs include many activities not normally performed by university or private sector researchers such as long-term monitoring or disease surveillance. As with many government laboratories, S&T activities at the three labs studied extend beyond traditional research to include various related scientific activities.

The CRUISE research study of labs employs a common "hierarchies-networks-markets" typology as an organizing framework to understand S&T institutions. This framework is drawn from literature on the nature of changing institutions (Thompson, Frances, Levacic and Mitchell, 1991; Lane, 1995). It also builds on recent work on other federal S&T institutions such as Atomic Energy of Canada Ltd. (Doern, Dorman and Morrison, 2001) and the National Research Council (Doern and Levesque, 2002).

The research decision to focus on institutions and on institutional change (as opposed to a direct look at policy change) was also the product of an earlier CRUISE study of federal reports and policy analyses of government laboratories (Doern and Kinder, 2001). This study documented a persistent limited understanding on the part of government policy makers and advisors of the institutional diversity of the federal government's laboratories. Rather, labs are often viewed unidimensionally and merely as "black boxes" which can, will, and even should respond uniformly and "on cue" to the latest policy dictates. The study concluded that in order for Canada to formulate and implement informed science, technology and innovation policies it is necessary to have a more complete understanding of the dynamics between those policies, the institutional design of government laboratories and the roles they play. In particular, the study suggested that S&T policy towards the labs would not fully succeed if such institutional diversity was not better understood and considered.

The case studies examine how each laboratory has evolved and changed as an institution, basically in the last decade but also in some instances dating back to the mid-1980s. There are many ways in which S&T institutions and public bureaucracies have been examined in the published academic literature (Guston, 2000; Crow and Bozeman, 1998; de la Mothe, 2000) but we are using a basic "hierarchies, networks and markets" approach to designate and track key elements of institutional change.

Table 2 captures some of the key institutional framework elements. Specifically, in the case studies we look at how the laboratories have changed as *hierarchies*, namely both as hierarchical structures themselves and as a hierarchy located inside, and interacting with, other hierarchies such as their parent department and the larger Government of Canada. Such hierarchies involve vertical superior-subordinate relationships and levels of reporting and control in traditional forms. But even "flatter" hierarchies, the norm in recent years, are also still profoundly bureaucratic in the ways in which they impose rules and procedural requirements, including requirements for demonstrating performance.

TABLE 2: ASPECTS OF HIERARCHY, NETWORK AND MARKET IN GOVERNMENT LABS

Hierarchy	Network	Market
- Vertical layers of reporting and superior-subordinate relations in lab as a public bureaucracy - The lab as a unit lodged within "hierarchy of hierarchies" (departmental and the federal government) - Traditional public sector management strategies and styles; emphasis on written modes of communication; nature and timeframes of macro-planning, budgeting, etc. - Evolution in systems of budgetary and allocative control (Program Review, budget cuts, revenue raising, Vote-netting etc.) - Prescribed policies and rules linked to S&T funds and programs with varying eligibility features - Procedural bureaucracy to ensure accountability on inputs, outputs, and results-based performance to multiple stakeholders - Support for core Public Service values and traditions of lab but also potential for inertia - Consistency sought in managerial levels, span of control, concern for getting the org chart right - Human resource practices conditioned by traditional Public Service practices; emphasis on permanent positions; formal career system and merit-based performance; rigid occupational categories; low mobility - Government-wide policies on intellectual property	- Horizontal relationships of trust and exchange of information, knowledge and support - Links with universities, firms, NGOs, provincial/local governments, communities, and other federal departments, "networks of networks" - Internal networking and collaboration within and across the lab to integrate across former divisions or disciplines - Complementing predominantly informal discipline-based networks with more formal issue-based and even service delivery networks - Scientific peer review networks used in granting, refereed publication process and performance evaluation - Participation on domestic and international committees and working groups as sources of networked advice - Labs functioning as critical nodes within local/regional innovation networks - Increase in policy funds requiring levered and partnered funding intended to foster networks - Greater flexibility in organization structure; "inconsistencies" embraced; greater emphasis on interpersonal factors, tacit knowledge, and verbal or face-to-face forms of communication - Human resources focus on hiring internally shifts to accessing expertise externally - Participation in global networks in science and innovation.	- Extent of commercial orientation and links to markets; extent of lab's role in supporting and brokering within key industrial sectors - Extent of adoption of quasi-markets (e.g., cost recovery, user fees) and business-like methods - Shift from discipline-based divisions to technology groups - Use of external boards of directors or advisors and review mechanisms - Use of revenue generation, partnered funding, performance targets as proxies for market relevance - Greater presence of private sector personnel in labs or co-location of firms and lab (clustering) - More autonomy in human resources practices including special hiring authority outside the Public Service; greater use of on-site contractors - Greater attention to intellectual property rights, strategies and revenue streams - Privatization of functions or creation of "spin-off" companies - Greater policy emphasis on university-based "commercialization" effort with effects on the labs, both cooperative and competitive

Source: Table adapted from Bruce Doern and Richard Levesque, *The National Research Council in the Innovation Policy Era* (University of Toronto Press, 2002)

We also ask how these institutions have changed as *networks*, again internally and in relation to other institutions such as other government departments, private firms, universities and NGOs. Networks imply a variety of more horizontal relationships and partnerships at and among all levels of the organization and outside it. Such networks can be informal or formal but at their core are based on trust and exchange.

Finally, we also look at *markets* by which we mean the extent to which some S&T laboratories have become more market- or business-like in the way they function. We recognize from the outset that for some government labs this may not be an appropriate institutional design where overriding "public good" roles are dominant. We also recognize that S&T labs are not themselves firms functioning in markets. However, given policy pressures in recent years to operate in a more business-like manner, we seek some insight into how the labs have become more commercially-oriented or business-like, such as through cost-recovery and revenue generation, use of contracting, policies and practices regarding intellectual property or even, where appropriate, policies to encourage the creation of spin-off firms.

It is important to stress that the three categories in the framework must be considered as "ideal types". It would be rare to find an institution that was organized as a pure hierarchy, network or market. Rather, most institutions (including the labs in this study) exhibit a blend of features of all of these institutional orientations with the mix changing over time.

The three-part framework has analytical value in two basic senses. It helps classify certain institutional phenomena which helps tell the story of the labs in a somewhat different way and which may resonate well with some policy makers. Thus, the framework is useful as a classification and heuristic device. Such classifications can also perform a second analytical function by providing a way of seeing some relationships we may not otherwise see or appreciate through traditional approaches. A third strength of the framework becomes obvious when viewed against other approaches. For example, approaches based on the New Public Management movement with its emphasis on the transfer of private sector practices to the public sector or approaches drawing on innovation systems theory tend to be suspicious of hierarchy but enamoured of networks and markets. Our approach does not map laboratories based on any *a priori* assumptions about the superiority or weakness of public sector vs. private sector organizational modes. We recognize that these categories are not airtight or totally self-contained. For example, the greater use of special policy funds and programs is an imposition of hierarchical rules and eligibility requirements and thus rightly shows up as a feature of hierarchy. But such funds and policies are also often the result of a disenchantment with hierarchical "stovepipes" and represent an inducement to form networks and find partners, especially partners with money. Thus there are boundary problems in the framework but no more so than with other ways in which S&T labs have been assessed, employing other analytical frameworks.

This approach also provides a point of entry into some key institutional issues and challenges. Though our focus is primarily to trace and understand institutional change among the S&T labs this does not mean that other common challenges and policy-oriented issues do not arise in the case studies. These include: the changing requirements for revenue raising; the impact of

Program Review; the need for labs to support various policy initiatives; S&T staff capacity, retention and renewal; the recent emergence of specialized, including third-party, S&T funding sources (e.g., CFI, CIHR, and other interdepartmental pools of funding such as PERD, CCAF, etc.); and the combined ideas of, and policies regarding innovation policy and national and local systems of innovation, science as a public good, and horizontal policy challenges such as climate change and sustainable development. However, the limited time available for the research and the brevity of each case study paper means that we do not explore these issues in great analytical depth. Such issues and challenges are discussed in the third section of this chapter.

The strengths and limitations of the project and case studies are also a function of the research methods used. We have relied on published reports and business plans of the labs and related federal and other studies, although these documents are of a very uneven nature across the laboratories. The review of these documents was complemented by interviews with a number of S&T personnel and senior management at each laboratory. The interviews were conducted on a not-for-individual-attribution basis and were intended to complement the published sources and provide a better sense of some of the basic dynamics of change. These sources and approaches allow for a reasonable overview of change to be understood by the authors but inevitably, they are also selective. The case studies do not allow in-depth coverage of the substantive S&T activities of each lab and all of its sub-divisions or technology clusters. We only look at such sub-areas of activity in a selective and illustrative manner.

The Three Labs as Changing Institutions

Table 3 provides a profile of the three case study labs using the "hierarchies, networks and markets" framework. This section offers our summary comparison across the three case studies and also takes into account some of the comments and criticisms made by participants at the workshop.

TABLE 3: PROFILE OF LABS AS HIERARCHIES, NETWORKS AND MARKETS

S&T Laboratory

Design Features	Environmental Technology Centre (ETC)	National Wildlife Research Centre (NWRC)	Atmospheric and Climate Sciences Directorate (ACSD)
Hierarchy	- flatter structure; six divisions reduced to five via ASD approach - two divisions consist of <8 staff - vertical reporting to ADM of Environmental Protection Service - closely tied to regulatory role, including emergencies - Program Review cuts of 44% in A-base, but only 7% cut in staff (no involuntary departures) - A-base budget only 67% of total - increasing use of policy funds (PERD, CCAF, Ozone Annex) - public service HR policies seen as barrier to effective human resource management; increased use of terms and contractors	- small organization with flatter structure; a documents division recently reorganized away from lab - remaining two S&T divisions largely "two solitudes" - vertical reporting to ADM of Environmental Conservation Service - closely tied to regulatory role - some budget and staff cuts due to Program Review but bigger cuts occurred in mid-1980s - budget primarily from A-base - limited use of policy funds - public service HR policies seen as barrier to effective human resource management; mostly permanent staff	- large, dispersed organization; five divisions with one recently added and one almost "virtual" - two divisions consist of <14 staff - vertical reporting to ADM of Meteorological Service of Canada - closely tied to MSC Operations - major Program Review cuts in budget and staff (some involuntary departures) - budget is 78% A-base - increasing use of policy funds (PERD, CCAF, Ozone Annex) - public service HR policies seen as barrier to effective human resource management; increased use of terms
Network	- external advice from peer review, working committees, etc. - links to universities not central but growing - some staff are adjunct professors - graduate students on-site - communicates in scientific journals and technical reports - links to business are extensive through client work, joint research, and demonstration projects - basically no links with NGOs - wide variety of links with regional offices, provincial governments and other federal departments - international networks growing through OECD, CIDA-funded work; many MOUs in place particularly with U.S. agencies	- external advice from peer review, working committees, etc. - pervasive links to universities and individual academic faculty - staff serve as adjunct professors - some graduate students on-site - lab's new co-location at Carleton University likely to increase links to academic community - communicates mainly through scientific journals, technical reports - virtually no industry/business links - extensive and increasing links with NGOs and volunteer birders - links with regional offices, provincial governments and other federal departments (Parks Canada, Health Canada, INAC) - international research and peer-review links with U.S. and Europe	- external advice from peer review, working committees, etc. - pervasive links to universities and individual academic faculty - staff serve as adjunct professors - graduate students on-site - one division co-located at University of Victoria - communicates through scientific journals, assessment reports - some industry/business links - some links with links with NGOs and volunteer birders - links with regional offices, provincial governments and other federal departments (NRC, NRCan, Transport) - extensive international collaborations and peer-review links; strong ties with U.S. and U.K.
Market	- extensive business links and explicit mandate to foster environmental industry through technology transfer - has privatized one division - revenue targets not central but earns large external revenues - no board of directors/advisors	- virtually no commercial orientation or links to business - potential tension with industry since research often identifies environmental problems caused by industrial processes - very limited external revenues - no board of directors/advisors	- limited commercial orientation - some links to weather services and wind energy industries - limited external revenues - no board of directors/advisors - very limited use of contracting - modest IP activity and revenues

	- extensive use of contractors - high level of IP activity and revenues - no spin-off companies - aligned with Clean Environment business line - client-focussed - produces 3-year business plans and biennial reports - lab certification and quality assessment processes	- very limited use of contracting - low IP activity and revenues - no spin-off companies - aligned with Nature and Clean Environment business lines - low emphasis on clients, business plans, annual reports, etc. - lab certification and quality assessment processes	- no spin-off companies - aligned with Weather and Environmental Prediction and Clean Environment business lines - client-focussed - has produced retrospective "annual report" - lab certification and quality assessment processes

Labs as Hierarchies

The first way we examine the institutional design of the three laboratories is to explore the extent to which they are structured and operate along classic bureaucratic lines, as well as how they function within the hierarchies of their parent department and the broader federal government. Max Weber, the great German sociologist, was one of the most prominent early theorists on the nature of hierarchical bureaucracies. A Weberian bureaucracy is composed of a hierarchy of office holders and a division of labour based on functional specialization. Authority is exercised primarily through vertical and impersonal superior-subordinate relationships, often referred to as the chain-of-command (Weber, 1946; Starling, 1986). In such organizations officials hold permanent, salaried positions with selection and promotion based on qualifications and technical competence. A hierarchy features systems of rules and procedures and engages in primarily written modes of communication to ensure accountability (Hood, 1998; Pollit and Bouckaert, 2000). Organization by hierarchy is intended to produce reliably predictable behaviour, a highly valued capacity especially when linked with responsible government (Doern and Kinder, 2001), though it is not necessarily conducive to the creative environment desired for an organization concerned with advancing scientific frontiers.

As government establishments it is to be expected and not surprising that the laboratories exhibit many characteristics of hierarchy. What we find, however, is that during the period studied the labs' internal hierarchies have tended to become "flatter" with greater horizontal collaboration across the labs' units. This is in line with the general trend and ethos of "reinvented government" promoted across the federal government in an attempt to de-emphasize hierarchical levels. Flatter, leaner structures have been motivated by the need to focus on core competencies which led to a reduction in the number of units at most of the labs, resulting in fewer "silos" or "stove pipes" in the labs' internal structures.

As departmental organizations all of the labs continue to have their primary accountability channelled vertically through the departmental chain-of-command, consistent with traditional hierarchies and unlike the more arms-length arrangements of some other federal S&T institutions. The labs are all managed within Environment Canada's structure of four business lines which align the department's operations to the federal government's priorities and initiatives. The four business lines are 1) Nature, 2) Clean Environment, 3) Weather and Environmental Predictions, and 4) Management, Administration and Policy. Reporting on progress against the goals of the relevant business lines is achieved primarily through internal communications, although the ETC produces biennial reports and the ACSD has recently produced a retrospective report of accomplishments. The labs must also be responsive to various government-wide legislation and policies, international treaties and, in some cases, federal/provincial jurisdictional considerations.

The labs are situated within the Environment Canada hierarchy and most of the interaction with the department is funnelled through the labs' senior management. This facilitates management and accountability but may interfere with the creation of more horizontal connections and communications across the departmental science / policy interface. Indeed, at the NWRC scientists were concerned that the existing mechanisms for cooperation with the department's policy staff are inadequate. On the other hand, in the ACSD a unit dedicated to facilitating communication across the interface is considered to be working well.

There is considerable variation in the sources of funding across the labs. At the NWRC, as within a traditional government hierarchy, virtually all of the lab's budget comes through their annual A-base appropriation. This is in sharp contrast to the situation faced by, for example, the ETC where less than two-thirds of its total budget comes from A-base funding. Since the mid-1990s the ETC and to lesser extent the ACSD have become increasingly dependent on non-A-base funding. However, a key difference here is that the ACSD's external funding is primarily from other government sources, such as interdepartmental policy or program funds,[1] while ETC attracts significant revenues from sources external to government.

As part of the broader Government of Canada hierarchy, the labs were all subject to the Program Review of the mid-1990s. The Program Review cuts had major impacts on all of the labs although, interestingly, the different tradeoffs were made between cuts to staff and operating budgets. The ACSD experienced cuts of approximately 35% in its budget and some downsizing in staff, including some involuntary departures. At the ETC, the budget took a greater hit of 44% cuts to the A-base while staff declined by only 7% and there were no involuntary departures. The NWRC experienced some reductions following the demise of the Green Plan and during Program Review although bigger cuts had come in an earlier era of downsizing during the Mulroney Government.

Another aspect of the labs as hierarchies within the broader public service centres on human resources policies and processes. In order to continue to provide its clients with cutting edge science and science advice, a government laboratory must continuously renew the knowledge embodied in its human capital. All of the labs studied face an ageing workforce and view the renewal of human resources as a major concern. But whereas some government S&T establishments have been granted greater independence and flexibility with respect to recruitment and retention practices, all of the labs studied must comply with and operate within the public

---

[1] Such as the Program for Energy Research and Development (PERD), the Climate Change Action Fund (CCAF), etc.

service-wide human resources system, which is often seen as a barrier to effective human resources management. For example, research indicates that it takes an average of 230 days to complete a new permanent hire competition in the public service (CSTA, 2002). When in the late 1990s the NWRC was able to complete a recruitment, it was the lab's first hire in over a decade. In such an environment, what we find is that all of the labs make use, to varying degrees, of term and student employees. The ETC also makes extensive use of on-site contractors. While these approaches are an understandable "work-around" in the post-Program Review staffing environment, the reliance on non-permanent staff makes it difficult to ensure the long-term integrity of the workforce.

It is important to note that while this era of "reinventing government" has de-emphasized hierarchies it has not meant the end of bureaucracy. Although reforms were introduced in the federal government in an attempt to reduce certain pathologies common to hierarchies, they at the same time introduced new forms of bureaucratic requirements in the interest of greater public accountability, horizontality, or more business-like and performance-based management approaches. For example, funding comes increasingly from interdepartmental funds such as the Program on Energy Research and Development (PERD) and S&T managers must learn how to function within the various rules and procedures of such funding mechanisms. This is not to say that greater use of such horizontal funds is not appropriate, only that it does not come without transaction costs.

Labs as Network-based Organizations

In contrast to hierarchies, networks are a way of organizing that involve horizontal exchanges of information and expertise, degrees of shared accountability, and relations based to a larger extent on trust and collegiality rather than rules and authority (Rhodes, 1997; Thompson et al, 1991). Networks can be informal or formal but, to be successful, must have conventions about how the relationship of trust-based exchange is maintained and enhanced. Networked forms of organization are common among scientific/professional groups and federal laboratories, as scientific institutions, were heavily networked long before networks became managerial fashion.

Whether under the rubric of "partnerships", "alliances", "linkages", or "networks" the labs have been under pressure over the last decade to engage in more horizontal relationships and collaboration both internally and with external actors. Internally, the labs engage in informal networking based on discipline or project activity as personnel in different parts of the hierarchy learn to trust and interact with one another for mutual benefit. More formal internal networking occurs where laboratories operate with multi-disciplinary teams that vary over time depending on the needs of a project, or as advances in science and technology both enable and require greater coupling of expertise across the institution.

But the more important notion of networks in the current era centres on what kinds of partnerships and other horizontal relationships are fostered with key external stakeholders and

S&T institutions in the broader Environment Canada matrix, other government departments, provincial and municipal governments, universities, business and industry, non-governmental organizations, local communities, as well as internationally. While all the labs studied have extensive informal networks with their respective members of the broader scientific community, what we are also seeing is the greater use of more formal network arrangements. The labs participate in these networks, and in fact often serve as the lead coordinator and catalyst, in order to access expertise, leverage additional funding, and, increasingly, to deliver on core program mandates.

Networking with Academe

Universities are seen by some in the federal S&T community as competitors for federal S&T funding, given the recent funding initiatives that have increased resources to the academic sector.[2] Typically, government laboratories are not directly eligible to compete for this funding. At the same time, while the universities are rarely a source of funding for the labs, they remain an important source of expertise and the most important source of highly qualified personnel.

In general, relationships between the three labs and academe are important although we found that the degree of networking with universities varies considerably across the three labs. At the ETC, networks involving universities have not been central to their operations but are growing in importance. One example is the recently created Environmental Technology and Training Institute. On the other hand, academic connections are pervasive and increasing at the ACSD and NWRC. For example, the NWRC is involved in the Canadian Cooperative Wildlife Health Centre, a network of centres of wildlife health services and disease surveillance located at the four veterinary colleges in Canada. In addition, the NWRC has recently relocated to the campus of Carleton University and this move is expected to further increase its links with the academic community. It will be of interest to follow what impact the relocation has on the evolution of the organization's culture and on the communication of science for policy within the Environment Canada hierarchy. The ACSD has extensive ties with the university sector. In particular, one of its divisions is located on the University of Victoria campus.

Most of the labs have scientific staff serving as adjunct professors at a variety of Canadian and foreign universities. These relationships are beneficial in many ways. They facilitate intellectual and interpersonal connections with academic researchers and graduate students. Adjuncts are often eligible to compete for third-party and granting council funding. All of the labs host graduate students and post-doctoral researchers on-site which human resources research has shown increases the likelihood that they will consider government employment after graduation. There is varied emphasis across the labs on publishing scientific results in the academic literature, reflecting the labs' differing mandates and audiences for their knowledge products.

---

[2] Through, for example, the creation of the Canada Foundation for Innovation, increased funding to the granting councils, and a commitment to address the universities' indirect costs associated with federally-funded research.

Networking with Business and Industry

The nature and extent of linkages between the labs and the private sector vary considerably. In addition, the labs often have mixed motives for maintaining these relationships ranging from technology transfer to supporting regulation. The ETC has key industrial sectors (e.g., automotive, petrochemical, agri-food processors) as major clients and partners and it engages in joint research and industrial demonstration projects. This is not the case with the ACSD which has only limited links with certain weather-related services firms and a growing relationship with Canada's nascent wind energy sector. Given its regulatory science mandate and the lack of commercial interests in its areas of research, the NWRC has virtually no formal links with the private sector and interactions with industry scientists are rare though not entirely non-existent.

Networking with Non-Governmental Organizations (NGOs)

To an extent unique among the labs studied, linkages and partnerships between the NWRC and NGOs are prevalent. In the area of wildlife conservation NGOs represent increasingly important actors that bring expertise, profile, (limited) resources and alternative service delivery options to the table. In fact, NWRC's primary partners in its national and regional bird monitoring programs are the local naturalist and conservation groups and bird enthusiast clubs. Linkages between the other labs and NGOs are minimal.

Networking with the Regions, Other Federal Departments, and Other Domestic Governments

As a country of regions, government labs are under pressure to have segments of S&T activity located in Canada's regions. While this perhaps laudable goal is understandably politically attractive, it presents challenges to lab managers who must maintain a critical mass of S&T capacity in a given location to ensure viability of the work. Geographically, the ETC and NWRC are located primarily in the National Capital Region although they have facilities and operations in other regions. The ACSD is more dispersed as an organization with primary facilities near Toronto and Montreal and other key facilities and researchers at various locations throughout Canada. In addition, Environment Canada employs a matrix management approach with a large regional emphasis. All three labs work extensively with personnel in the department's regional offices.

All of the labs have exhibited growth in the degree of networking with other federal departments and agencies, particularly Agriculture and Agri-Food Canada, Natural Resources Canada and Health Canada, but also with Parks Canada, Indian and Northern Affairs Canada, the Canadian Space Agency, Transport Canada and others. Much of the interaction with other government departments is a result of the increasing use of interdepartmental policy- or program-based funding mechanisms that induce greater collaboration. However, it is also a reflection of the horizontal nature of the policy challenges facing government as well as the recognition that no laboratory can "know it all" or "do it all" (de la Mothe, 2000).

In addition, but to a lesser extent, the labs collaborate with provincial, territorial and municipal governments. For example, the ETC has cooperated with the City of Calgary to assess and quantify greenhouse gases emanating from the city's three active landfills. Across the three labs, collaboration occurs through the Canadian Council of Ministers of the Environment and through various federal-provincial committees working on a range of activities including setting Canada-wide environmental standards, wildlife conservation, implementing ecological toxicity testing, and development and delivery of air quality indexes to name just a few.

International Networking

International networking is also growing and is of two types. The first form of international networking is the informal collaboration that occurs naturally within the global scientific community. This networking results in the coordination of research priorities, joint publications in international journals and reports, presentations at international conferences and workshops, participation on foreign and international peer review panels, and the occasional foreign visiting scientist working in one of the labs or a Canadian scientist working for a time abroad.

The second form of international networking occurs at a more formal or strategic level due to treaty obligations, increasing trade relations, or simply the complexity of transboundary issues. A number of bilateral agreements and Memoranda of Understanding are in place that foster linkages between the labs and various foreign governments, research institutes, and international bodies. Much of the work of the NWRC dates back to the Migratory Birds Convention of 1916 and, as migratory patterns and exotic pests and diseases do not necessarily respect geopolitical boundaries, much of the research and monitoring is done collaboratively. The ETC is increasingly engaged in international networks and is currently involved in a CIDA-funded project to provide training and institutional capacity building in China. Similarly, many of the ACSD scientists serve as Canada's representatives to various international bodies such as the World Meteorological Organization and the Intergovernmental Panel on Climate Change.

The inherent transboundary nature of atmospheric and climate science, of environmental pollution, and of migratory patterns of wildlife increases the importance of international networking. However, unlike in some other federal labs, these labs do not have an international office so as to better foster and manage these links.

Labs as Market-like Organizations

The final institutional design consideration is to examine how the labs behave as markets. Clearly, the labs are government institutions not market-based firms so what we are really exploring is how the labs have evolved to become more "market-like." We use this term to examine two related concepts. First, we explore the extent to which the labs exhibit a commercial orientation in their mandates, funding, research priorities, and knowledge products.

Second, we examine the extent of their use of business-like practices such as boards of directors/advisors, intellectual property policies, the creation of spin-off companies, the use of contracting and other practices.

The labs vary considerably in their degree of market orientation and in the extent of their links with the private sector. The ETC, as a "technology centre," has an explicit mandate to support the relevant industries and it exhibits deep links with industrial clients. On the other hand, consistent with their "public good" and regulatory science mandates, the ACSD and NWRC have virtually no market orientation and links with the private sector are minimal.

In the past, some government labs have been charged with the criticism that they operated as "universities without students." Whether or not this was a fair characterization, government labs have had to change their cultures and discipline-based forms of organization to become more clearly client-focussed and project-based. Not surprisingly, there appears to be some correlation between the degree of market orientation and the extent a lab employs business-like practices.

The ETC brings in about a third of its overall budget from external sources and employs many business-like practices. The lab is experimenting with an alternative service delivery approach by privatizing its emergencies engineering unit. Under the arrangement the contractor firm, which has operations located on the lab's campus, undertakes research studies and provides technical services through work orders and at least matches the $600,000 per year it receives from the ETC.

As institutions within traditional line departments, none of the labs employ corporate-style boards of directors with decision-making authority, such as those that exist at more arms-length S&T institutions.[3] Nor do they have advisory boards as some other federal labs do to provide strategic advice on the lab's overall direction. The three labs employ various mechanisms including peer review panels, participation on working groups, and client surveys to obtain external feedback and advice on their programs and operations. Also, all of the labs fall under the potential purview of Environment Canada's departmental S&T advisory board.

Increased attention to policies and practices regarding intellectual property (IP) are another area of market-like change. Responsibility for IP management was assigned to science-based departments in the early 1990s and throughout the decade government labs were under general pressure to revise their IP policies to facilitate technology transfer to industry. In recent years the IP policy guiding all federal departments was clarified and IP issues and revenues are becoming increasingly important. The ETC has had considerable success in the commercialization of IP, bringing in an estimated $2 million in revenues to date. The ACSD has not been extensively active in the commercial licensing of intellectual property although it is the source of some

[3] i.e., at Crown Corporations such as Atomic Energy of Canada Ltd. and departmental corporations such as the National Research Council.

additional revenues for the lab. At the NWRC there is very little intellectual property activity in terms of technology transfer, product development, patenting, or licensing.

Another potential market-like behaviour is the creation of spin-off companies. Some federal S&T institutions such as the National Research Council are experimenting with human resources and intellectual property policies to encourage and enable employees to form spin-off firms in order to commercialize an idea or technology. None of the labs studied have created any spin-off firms, although the MAP Division at the ETC is being considered for spin-off in the near future.

Other business-like practices include the use of contracting. For example, approximately a third of the total ETC workforce are contract employees. This is consistent with the overall trend across the public service towards greater use of non-indeterminate positions (term, contract, casual, etc.) and the labs all make greater use of term positions. This approach to human resources has the advantage of greater flexibility in meeting specific needs but, as stated earlier, may be damaging to the long-term health of the organization.

Another part of the more business-like ethos at all of the labs is the move toward lab certification. The analytical laboratories seek accreditation through the ISO process and by the Standards Council of Canada and the Canadian Association for Environmental Analytical Laboratories. The ETC has the additional responsibility of promoting good laboratory practices and monitoring compliance in commercial labs involved in the generation of data used to assess new substances under the Canadian Environmental Protection Act.

Key Issues and Challenges

In this section we shift the discussion to issues and challenges facing the labs. Some of these issues did not inherently emerge out of the framework used in the case studies but they are to varying degrees present in the narratives of each case study and/or emerged in the workshop discussion. This discussion is brief and by no means an extensive analysis across the three labs. There is also unavoidably some overlap between points raised in this section and elements addressed in the section above on hierarchies, networks and markets.

Balancing "Public Good" versus "Commercial" Roles in the Context of a Knowledge-Based Economy, the Innovation Agenda, and the Sustainable Development Era

One of the longest term pressures on Canadian government laboratories generally has been that they should be more market-oriented and serve the government's innovation policy goals by enhancing the commercialization of research. This viewpoint remains prevalent today with the emergence over the last decade of an "innovation policy" paradigm in which government laboratories are now often cast as critical components of national and regional innovation systems. However, this perspective fails to recognize that emerging regulatory and risk management pressures may quite properly be pushing some government laboratories to act less as direct contributors to economic development and more as guardians of public confidence. Thus, it is critical for government S&T policy to understand the circumstances where the more market-oriented roles collide with risk regulation and public interest roles.

The fundamental roles of the case labs were often discussed within the context of this trade-off between public good versus commercial good mandates. As we have seen above, the ETC has an explicit role in industrial support while the NWRC and ACSD are more closely aligned with public good roles, in which more commercial roles are even deemed to be inappropriate. The three labs are concerned about the proper balance between their commercial and public good roles.

Discussion at the workshop on this trade-off issue also centred on whether there really was a trade-off. Commercially-relevant S&T developments are often needed to bring public goods to fruition. Thus, the S&T labs must not be overly stereotyped when it comes to these labels and categories of analysis. This need for caution against the blanket categorization of core functions may be all the more necessary because of the fact that the labs are increasingly being asked to contribute to the realization of two somewhat antithetical but ultimately entwined policy goals of fostering sustainable development and a dynamic knowledge-based economy in Canada.

Evolving Policy Mandates and Concerns

As S&T institutions it is understandable that to a large extent the labs' mandates and programmatic agendas are shaped by the evolution of their respective fields of science and technology. At the same time, the three labs are located in a government department. It is obvious, therefore, that the labs would be strongly influenced by evolving government and departmental policies with respect to the environment, climate change, wildlife, and sustainable development in an overall sense. These policies in turn are crucially influenced by industrial concerns and other policy communities and pressures. Thus, the labs' mandates and research agendas are both "science-driven" and "policy-driven." The entry point for the study as a whole is to examine the labs as *S&T* institutions, but of course they are also *policy* institutions as well, and are intricately tied to the nature of Environment Canada's statutory and policy-based clientele and business lines.

The ETC has served largely as an S&T support for Environment Canada's regulatory tasks in air pollution but it is also involved in other ways in encouraging the development of environmental industries, industries which can prosper in the development of technologies driven by or required by regulation. The NWRC has seen its policy context change as it moves from a historic wildlife mandate centred mainly on birds to new demands flowing from Canada's broader commitments regarding toxicology and endangered species. The ACSD's historic focus on the meteorological and weather prediction sciences has been complemented in recent decades by concerns for air quality issues and climate change science.

The S&T Spectrum and Lab Roles

Federal S&T policy as a whole is also a key influencing factor on the labs. Traditional concepts and statistical measures based on the spectrum of R&D activity (basic, applied, development, etc.) and linear models of innovation are still often employed in federal S&T policy. These simplistic heuristics have been challenged both conceptually and in practice by scholars and policy analysts but, despite their limitations, they remain important points of reference in situating the roles and functions of government labs.

The challenge, of course, for the study labs is that their key functions demonstrate the continuing importance of aspects of the continuum which are given short-shrift by excessively simple external definitions of the spectrum of R&D activity. In particular, the emphasis on R&D underplays the importance of Related Scientific Activities (RSA) where scientists and technologists are engaged in continuous monitoring and data-collection rather than pure research. This is an issue of particular importance within the context of Environment Canada, given its heavy emphasis on RSAs.

The Nature of Links with Universities

There was considerable recognition in the workshop discussion that links with universities had to be increased and reinvigorated. But it was also recognized that universities were often seen by staff in the labs as competitors in two senses: 1) universities have been more successful in the last several federal budgets in getting additional funding (such as via the CFI); and 2) universities are becoming more commercially-oriented, a situation which developed out of two causal forces. The first factor was the cuts in provincial funding of university budgets which meant that universities were forced to seek out more private sector funding. The second factor was that the federal government was itself urging the universities to focus more on commercialization of research in the interests of enhancing Canada's innovative capacity. These factors have led changing relationships between government laboratories and universities.

As mentioned there are university links in all case study labs in varied forms ranging from staff being adjunct faculty at universities, graduate students as summer and periodic researchers using the labs' facilities and equipment, and individual informal networks with faculty and some formal networked research activities. The NWRC has taken the most dramatic step to expand its academic links with its move to Carleton University.

The Nature of Links With NGOs and Communities

Over the past decade, the three labs have had varied experiences in conceptualizing and developing links with non-governmental organizations (NGOs) and with communities (local-regional governments; community groups and stakeholders). As the discussion of networks in the previous section has suggested, the labs' core instincts are centred primarily on networks with industry, academe, other federal departments and foreign or international players rather than NGO's and communities.

The key exception to this the NWRC. It has worked extensively with NGOs and with networks of birders, and indeed these networks are essential to its capacity to fulfill its mandate. This form of participatory "citizen science" is a unique form of alternative service delivery that is rarely recognized as such. For the other labs, there are less articulated relationships with NGOs and local communities. The ETC's role in environmental emergencies is of course intensely local-community focussed when it is engaged in fast moving crisis or accident situations.

Shifting Nature and Balance of Funding and Funding Sources

During the study, the issue which undoubtedly raised the most passionate discussion dealt with the shifting nature and balance of funding and funding sources. This issue is of direct concern to the labs but it is also ultimately tied to many of the other issues being surveyed. We have already noted how changes in the funding mix can be evidence of both new forms of hierarchy and the need for and inducements to network. The money question is also linked to the previous discussion of the appropriate balance between public good and commercial roles.

The three case studies highlight the labs' key funding sources and how they have changed in the past decade or more. The broad tendencies have been: a) the shrinking of the A-Base though to varying degrees across the three labs; b) the growth of commercial revenue and some increase in intellectual property revenues (again varied among the labs, with the ETC showing the greatest growth in this area and NWRC being the exception); and c) the growth of policy funds, third-party funds, and flow-through funds some of which the labs can access directly but many of which require partnerships with other players, usually universities. These trends have produced a complex arena of incentives and requirements (and new bureaucracy), and have yielded new forms of entrepreneurship by lab S&T staff and managers as they seek new forms of funding to support their mandates. The new context has also led to more explicit transaction costs as S&T managers are forced to continuously "read" the proverbial "tea leaves" of the evolving federal S&T system.

There was general agreement of the need for some form of reinvestment in government S&T. In particular, there is a concern that if the balance of funding tilts too far toward a strictly commercial support function (important as that is) the labs will be less and less capable of replenishing their own intellectual capital on medium- to long-term S&T issues and, hence, will have less and less to offer both future industrial clientele and the federal government in the fulfilment of public policy roles and mandates.

S&T Lab Performance Measurement Criteria and Indicators

The federal government's shift to a more results-based system of management and accountability means that federal S&T labs have had to develop more specific targets and indicators of performance. The three case studies do not focus in any great detail on the criteria employed to assess results since these are often quite lab-specific. Rather they show the more general trend toward the need for business plans, annual reports, and the development and use of "business lines" as management concepts. They also suggest that different policy funds also impose quite strict performance requirements and the need to report not only to departmental masters but also to multi-departmental arenas and to network partners and clients.

While all of the labs employ traditional measures of scientific productivity such as the quality and quantity of referreed journal publications, some variety in other performance indicators is to be expected across the three labs and is not hard to find. Another point raised at the workshop was the suggestion that the government has become so output, outcome and results oriented in its systems of accountability and management information that it has forgotten the input side of management, including that of S&T and lab governance and management. The issue of the labs' inherent capacity (in terms of staff, knowledge, equipment inputs) is too often a "second order" concern or, worse still, a long delayed afterthought.

Investing in S&T Staff and Lab Facilities

The crucial input issues of S&T personnel and up-to-date laboratory equipment often arose as items of concern in both the lab case studies and in the workshop discussion. These issues are linked to broader concerns about ongoing institutional renewal.The renewal question is not just one of attracting younger scientists whose university education has exposed them to the latest S&T approaches and theories. It is also a question of keeping and attracting experienced S&T staff who are expert in substantive S&T fields but also familiar with the science, art and craft of regulatory science and in the communication of science advice to support policy goals. There are difficult choices in what mix of competencies are needed to meet emerging challenges and how to acquire S&T and policy staff who are skilled at brokering funding and managing networks. Traditionally, a lab's required competencies were co-terminus with S&T disciplines but increasingly they are not.

There are additional common human capital challenges revealed in the case studies and which mirror other recent federal studies. One is the age profile of S&T staff. Like many institutions across the public service, the labs face a large retirement cohort in the coming few years. This represents both a loss and an opportunity. The NWRC and ACSD see few problems in locating new recruits largely due to their efforts to build up the capacities of Canada's universities within their respective spheres. The problem, however, is being able to attract and retain these personnel. In addition, the ETC sees itself in competition with key industrial sectors for highly qualified personnel, especially technicians.

Having said that, the study brought out for each of the labs the strong degree to which S&T staff are attracted to government laboratories by the challenges of helping to meet public interest objectives. There seemed to be considerable agreement that, while federal S&T can never compete with the private sector on salary levels, it can attract persons on other bases.

Nonetheless, the labs must remain keenly aware of their relevant labour markets. Universities are facing similar demographic trends. And, universities have received considerable new funding, including capital and equipment funding, in recent years and are able to attract and retain the best and the brightest through the Research Chairs program. Thus, at the same time that government labs will be interested in hiring and retaining its S&T staff, the universities are able to provide relatively attractive incentives while government labs have not received comparable support. In addition, the public service human resources system is seen as creating many barriers to the government's ability to compete for these highly qualified personnel.

In addition, to attract and keep high-quality S&T staff as well as to deliver on their mandates, the labs need up-to-date research, testing, and monitoring facilities and equipment. The three labs have each faced their own versions of physical "rust-out" in their research infrastructures and have explored different mechanisms to address these concerns (the most dramatic being the NWRC's move to new facilities on the Carleton campus). Some limited replenishment has been possible in recent years but there is the sense that all of the labs are relying too heavily on capital investments made earlier in the decade. Complicating the issue is not only the need for different equipment as research needs and priorities evolve but also the general trend that new equipment is often more expensive, often by orders of magnitude. An even larger macro governmental reality is that the federal government's financial and budgetary system has no real capital budget, i.e. no system which provides for the depreciation of equipment and the gradual build-up of funds for ongoing capital replacement.

Conclusion

While issues regarding federal S&T labs can be categorized and discussed in many different ways, the three case studies and the workshop discussion showed in a convincing fashion that the labs are complex entities and that there is great variety among even the small subset examined. Federal policy towards the labs has too often been based upon a unidimensional view that assumes that all government labs are alike, when they plainly are not. There is also enough evidence to suggest that federal policy as a whole has underplayed and been unclear about the crucial roles which federal labs are playing and will have to play as an ever more challenging set of policy and regulatory needs are faced by Canadians.

CHAPTER 2

THE ENVIRONMENTAL TECHNOLOGY CENTRE (ETC)

The purpose of this chapter is to examine how the Environmental Technology Centre (ETC) has changed in the last ten to fifteen years as a federal S&T institution and to highlight some of the key challenges it faces in going forward. The information on the ETC was collected during the latter part of 2001 and early 2002 through interviews with ETC managers and staff members and a review of Centre publications and other key documents. These are listed in the Bibliography.

The ETC richly illustrates how the concept of a "government laboratory" must be viewed broadly to encompass more than the narrow image of a place with fixed assets where science and technology (S&T) research and development is conducted. In addition to traditional "bench" science, the ETC engages in what could be called "distributed" S&T, for example through the National Air Pollution Surveillance Network, through field work to demonstrate and validate soil remediation technologies, and through on-site contamination measurements at complex spill sites of federal responsibility or national concern. As with the other labs examined in this study, the ETC is a complex S&T institution fulfilling diverse roles and functions.

Origins, Mandate and General Features

The ETC has evolved out of what was first established in 1975 as the 'River Road Labs.' It is located on a six hectare campus in Gloucester, Ontario, just south of the nation's capital. Broadly speaking, the ETC provides specialized scientific support and undertakes research and development in support of Environment Canada's environmental protection programs. Although its S&T mandate and activities are quite broad, the ETC is concerned primarily with technologies to monitor and control air pollution and spills of oil, chemicals and other hazardous materials.

The origins of the ETC reflect those of its parent department. When the Department of Environment was formed in the early 1970s, directorates were established along environmental "business lines" such as air, water, etc., by combining various programs and units from what are now Natural Resources Canada and Health Canada. The 'River Road Labs' were similarly assembled by pulling together the various R&D efforts related to air pollution from throughout the relatively new Department of Environment and from other departments.

At its birth, the 'River Road Labs' moniker represented an umbrella under which was found a collection of groups focussed on the science and technology of air pollution. It housed a vehicle emissions testing facility, an analytical chemical laboratory for air pollution, an engineering capacity to support the nation-wide network of air pollution monitoring stations and instrumentation, and a small program for testing small source samples of pollution for referencing purposes. These various functions reported to different chiefs at the department's headquarters, and thus, in this early period, the ETC was actually more just a collection of co-located labs dealing with air pollution.

In the early 1980s the situation was rationalized by designating an on-site director of the renamed River Road Environmental Technology Centre[4] who was brought in to manage the ETC as an institution. The ETC Director reports to the Director General of the Environmental Technology Advancement Directorate of the Environmental Protection Service. In addition, at that time an emergencies science group was shifted to the RRETC from a different directorate adding a second major research emphasis to the Centre's traditional focus on air pollution.

Today, the mission of the ETC is "to support the Departmental national and international mandate for environmental protection by:

- developing and transferring pollution measurement, prevention, control and remediation knowledge, and new technology in areas related to air pollution and unplanned releases of oil and hazardous materials; and

- providing relevant specialized sampling and analytical expertise and services of the highest standards." (ETC, 2000)

In seeking to fulfill its mission the ETC plays the following roles:

- to support the regulatory role of Environment Canada by undertaking and promoting research and development (R&D), and technology advancement and transfer in measurement and control of air pollutant emissions, and in response to unplanned releases of oil and hazardous materials;

- to support pollution assessment and assist in solving environmental problems associated with specific sources of air pollution or spill/waste sites that have international, national, or regional implications by undertaking R&D based on in-house and external expertise and resources and co-operation with stakeholders;

- to manage or support Environment Canada's programs related to measurement and control of air pollution and releases of oil and hazardous materials by providing relevant sampling, analytical, and quality assurance expertise and services;

- to promote the better integration of economic and environmental issues and to foster a healthy and creative environmental protection industry in Canada through information and technology transfer, and by supporting the development of national and international technology standards and policies;

---

4 Later shortened to the Environmental Technology Centre (ETC).

- to provide advice on environmental protection technology and emerging technical issues relating to air pollution and response to spills of oil and hazardous materials to the Department and other clients including the industry, provinces and territories, other R&D organizations, and the public; and

- to represent the Department and Canada in federal-provincial, national, and international environmental protection technology organizations and programs and act as full partners in the international community involved with the development and application of leading-edge technology and technical standards for environmental protection relating to air pollution and control of hazardous materials. (ETC, 2000)

This statement of mission and roles first appeared in the 1992-94 Biennial Report and has not changed substantively since.

The ETC consists of six divisions (see footnote 3). The characteristics and major functions of these divisions are briefly described to provide a flavour of the diversity of S&T activities at the ETC. However, it is not possible here to describe each unit in full.

Analysis and Air Quality Division

The Analysis and Air Quality Division (AAQD) was created following Program Review by reorganizing parts of the former Chemistry and Pollution Management Divisions. The AAQD consists of approximately 37 staff, primarily chemists, engineers, scientists and technicians/ technologists. Its base budget is approximately $2.7 million and it will now receive an additional $5.3 million per year as part of new money targeting ozone-related research[5]. The AAQD is responsible for coordinating the operation of the federal-provincial National Air Pollution Surveillance (NAPS) Network, as well as the two monitoring stations located in Ottawa. This network provides the air quality data that enables governments to monitor and assess the quality of ambient air in Canada and is described further under *Profile 1*.

The Division also develops and evaluates new measurement technologies in support of air pollution monitoring. The AAQD's organic and inorganic chemistry laboratories are able to measure ultra-trace levels of various compounds from a variety of environmental sources such as air sources, contaminated soils, and hazardous wastes. The Division is tightly linked to its departmental clients and develops new analytical methods to ensure the most appropriate procedures are available to support the development of environmental regulations. The Division

---

[5] Part of Canada's commitment under the Ozone Annex of the Canada-US Air Quality Agreement signed in December 2000.

is also involved in providing advice to, and promoting improvements in the capabilities of, private industry and other government analytical laboratories.

Emissions Research and Measurement Division

The Emissions Research and Measurement Division (ERMD) plays a leading national role in measuring polluting emissions originating from both mobile and stationary sources. The Division consists of approximately 27 staff, primarily engineers, scientists, and technicians, and 12 contractors. The Division's base budget is approximately $1.5 million which is split roughly 30% for stationary source R&D and 70% for mobile source R&D. The stationary side typically brings in an additional $30-40K per year in external funding while the mobile side receives an additional $300-500K per year. The ERMD conducts both laboratory and field studies in support of departmental activities related to climate change, smog, toxics, and regulatory compliance and enforcement. Major emphases include:

- characterization of emissions from such sources as cars and light-duty trucks, incinerators, boilers, smelters, industrial stacks, marine vessels, aircraft, off-road vehicles, and utility engines;
- measurement of greenhouse gases and emissions from municipal landfills;
- evaluation of process control technologies;
- evaluation of remediation and waste destruction technologies;
- quality assurance/quality control;
- development of Reference Methods; and
- advice and assessment.

In particular, the ERMD conducts the compliance and audit testing of new model, light-duty cars, trucks and motorcycles. Previously, this work was done under a collaborative agreement with Transport Canada which administered the regulations under the *Canadian Motor Vehicle Safety Act*. As of FY2000-01, the new-vehicle and engine emissions regulations are administered by Environment Canada under the 1999 *Canadian Environmental Protection Act (CEPA).*

Emergencies Science and Technology Division

The Emergencies Science and Technology Division (ESTD) conducts internationally recognized R&D related to the properties, behaviour, detection, measurement, and effects of spilled hazardous materials, and on the effectiveness and environmental benefits of in-situ countermeasures. The ESTD has a staff of about 17, primarily physical and chemical scientists and technicians, and about $26 million worth of facilities and equipment dedicated to spill studies. The Division serves as the primary centre of scientific advice on pollution emergencies to the regional offices of Environment Canada and other organizations. The ESTD typically conducts about 40 active projects a year, most in partnership with other agencies and industry. In fact, while its base budget amounts to approximately $1.2 million per year, the Division receives approximately an additional $1 million annually through joint projects and cost recovery. Major emphases include both R&D and operational aspects of:

- airborne remote sensing of spills;

- laboratory and field portable measurement techniques;
- oil properties, fate and behaviour;
- in-situ burning;
- spill treating agents;
- biological effects and toxicity; and,
- shoreline cleanup countermeasures.

Historically, ESTD was predominantly concerned with oil spills. Since 1979, Environment Canada also sought to improve the response and countermeasures technology for spills of materials other than oil. ESTD develops "Priority Lists" for chemical spills to focus R&D efforts on the most frequently spilled and most harmful chemicals. Efforts have focussed on the development of analytical techniques for top priority chemicals as well as the preparation of chemical-specific response manuals (Fingas et al, 2000). The Division provides training in the use of personal protection equipment and simple hazard-level measurement equipment to departmental emergencies personnel and to other responders and contingency planners. The Division also provides a 'scientific response' team for on-site measurement work at major spills of federal or national concern.

Emergencies Engineering Technologies Office

The Emergencies Engineering Technologies Office (EETO), along with a contractual arrangement with Science Applications International Corporation (SAIC) Canada, has essentially replaced the ETC's in-house capacity previously organized as the Emergencies Engineering Division (EED). Prior to the change, EED undertook engineering R&D and demonstration projects on technologies for cleaning up contaminated sites, either due to oil or chemical spills or insecure hazardous waste sites. EED served as the primary centre of specialized advice on pollution emergency cleanup to the department's regional offices and other organizations. Efforts ranged from direct involvement in cleanup operations to the provision of unique equipment.

Following Program Review, the EED budget was cut by 53%, making it difficult to sustain the effort internally. The Centre began to seek an Alternative Service Delivery approach. As of April 1998, the Division was privatized following an extensive study and competitively bid process. As a result, the EETO is now the ETC's one-person office responsible for managing the current five-year contract and providing the day-to-day technical liaison between the contractor and the department[6]. Under the arrangement, SAIC Canada matches the $600,000 per year it receives from the ETC. This unique relationship is further described later in Profile 2 under the section "ETC as Market."

[6] At the start of fiscal year 2001-02, the EETO was integrated into the ESTD.

Special Programs Division

The Special Programs Division (SPD) provides strategic, operational, and policy support to the Director's Office. Headed by the ETC's Assistant Director, the SPD consists of only about seven individuals but is responsible for two key inputs to Environment Canada's regulatory and policy processes. The SPD ensures the availability of scientifically sound test methods and develops a base of Canadian commercial laboratories that can generate internationally accepted data on new substances. The *Methods Development and Application Section* forecasts the need for and develops new toxicological methods required for the department's regulation function. The *Good Laboratory Practice (GLP) Compliance Monitoring Unit* provides support to Environment Canada and Health Canada scientists by inspecting Canadian laboratories involved in the generation of data used to assess new substances under CEPA, and for monitoring compliance status and auditing studies on new substances at the request of regulatory authorities in other countries. The Division is also responsible for supporting the good laboratory practice activities of the Organization for Economic Cooperation and Development and for in-house quality control and environmental management systems at the ETC.

Microwave-Assisted Processes Division

The Microwave-Assisted Processes (MAP) Division was formed in 1994 to accelerate the development and commercialization of various applications of Environment Canada's patented Microwave-Assisted Processes (MAP^{TM})[7]. This family of technologies offers environmentally-friendly processes employing microwaves for the preparation of analytical samples for subsequent biological, chemical and physical characterization and for the extraction of high value-added substances from a variety of items, including plant and animal tissues, soils, and drinking water. The Division's work emphasizes two main areas--the development of MAP-based analytical methods and of industrial-scale processes employing the MAP technology. The Division consists basically of two permanent staff, although they are often complemented by visiting scientists, often from other countries (currently two from South America), and interns through the Youth Internship Program. This small office has a base budget of about $300,000 which primarily covers salaries. In addition, the Division brings in approximately $1 million through royalties from the nine licensing agreements that the Division maintains with interests in Canada, the United States, Asia, and Europe.

[7] MAP is a Trade-mark of Her Majesty the Queen in Right of Canada as represented by the Minister of the Environment.

Key Institutional Trends

While the current mandate and descriptive features provided above are an important starting point for understanding the ETC, they do not sufficiently convey the key pressures and dynamics of change in the last decade. This section will briefly review major changes and trends in key institutional indicators such as formal organizational structure and culture, research emphases, funding, personnel, and infrastructure during recent years.

In the late 1980s, public concerns for environmental protection were raised following high-profile incidents such as the Exxon Valdez oil spill and the St. Basil le Grande PCB fire. In response, the Mulroney Government had earmarked additional funding for the ETC as part of the Green Plan in the early 1990s. However, this program was short-lived and was followed by the deep budget cuts of the mid-1990s.

Program Review in 1994-95 imposed a deep and serious review of, and reduction in, federal programs across the Government of Canada (Swimmer, 1996). Program Review required programs and activities to be assessed against several criteria including tests such as whether government should be involved in the activity at all, the relative role of the federal government compared to the provinces, and which activities were essential for the federal government as opposed to expendable. The Review was followed by major budget cuts. In the latter part of the decade the federal government made significant investments in S&T, including for environmental protection. However, the bulk of these investments were made to external performers, leading to a general erosion of federal intramural S&T efforts and a concern about a general "rust-out" of facilities and equipment (ETC, 2002).

As with most federal S&T establishments, which were particularly hard hit by Program Review, the ETC budget was cut following 1994 when its base budget had reached about $10 million. In the post-Program Review period, the ETC experienced a 44% reduction in A-base dollars. Since then the A-base has recovered somewhat to about $7.5 million per year. However, a key element of the ETC's operations is the additional funds it brings in from external sources. This portion of the ETC's operating budget has been increasing in the post-Program Review period. Although detailed ETC budget data was not available, the following budget figures illustrate the general trends in funding (ETC, 1994; 1996; 1998; 2000):

- 1992-94: $10 million base plus $4-6 million in cost-sharing
- 1994-96: $8 million base plus $3-5 million in cost-sharing
- 1996-98: $6 million base plus $5 million in cost-sharing
- 1998-00: $6-7 million base plus $5-7 million in cost-sharing
- 2000-02: $7.5 million base plus $3-5 million in cost-sharing

Another aspect of the funding context for the ETC was the rise over the last decade in the use of horizontal (inter-departmental) program funds such as the Program on Energy Research and

Development (PERD), the Toxics Substances Research Initiative (TSRI), and the Climate Change Action Fund (CCAF). The ETC has been successful in attracting some of this funding.

Personnel levels show a very different trend over the last decade from the budget trend. With some variation the ETC has maintained staff levels of about 100 throughout the last decade. In the four fiscal years from 1990-91 to 1993-94 the staff level averaged about 103. In the fiscal years 1994-96 to 1998-00 the average level was 96. This represents about a 7% reduction from pre-Program Review staff levels.

The government staff positions can be roughly broken down as 50% scientific, engineering and professional, 40% technician/technologist, and about 10% administrative/support. The ETC makes extensive use of contractors, around 50-60, who tend to be employed in the technician positions. At any given time, the total personnel working at the ETC will also include about ten research associates, post-doctoral fellows and students, bringing the total ETC workforce to about 160.

The vast dichotomy between trends in budgets and personnel (-44% versus -7%) through the mid-1990s Program Review period reflects a conscious decision on the part of the ETC management to protect the employees. During the period, no staff members were forced to leave involuntarily. On the downside, however, this approach meant that capital and operating expenditures were cut dramatically to bear the brunt of the budget reductions.

Indeed a major concern with respect to research capacity is the state of the ETC's physical assets. These include, among other things, a world-class oil laboratory, remote sensing aircraft, emergency response field equipment and vehicles, computers, and air pollution monitoring instruments. A key concern is the aging of these capital facilities and equipment. Throughout much of its history, a significant portion of the resources for building and scientific equipment recapitalization came from opportunistic sources, such as end-of-fiscal-year slippage funds from elsewhere in the Department. As a result of the Y2K concerns, some funding was made available in recent years for software and to check date stamps on analyzers but, in general, capital funds have been tightly constrained. While the government has in recent years devoted major new funding to address Canadian research infrastructure needs through mechanisms such as the Canada Foundation for Innovation, federal laboratories are not eligible to compete for these funds.

Another important shift in recent years relates to the nature of the S&T work performed by the ETC. Throughout the 1990s the S&T efforts at the ETC were roughly balanced between research and development (R&D), on the one hand, and related scientific activities (RSA), on the other. However, with the new resources coming from the Ozone Annex agreement, the balance is shifting from about 50:50 to closer to 25:75. It remains to be seen how this shift toward RSA will affect the long-term value and effectiveness of the ETC S&T programs. The ETC management believes strongly that it is the applied R&D work that has been a significant factor in the successful delivery and ongoing improvement of ETC's RSA programs, and in ETC's ability to leverage external resources.

ETC as Hierarchy

The first way to examine the institutional design of the ETC is to explore the extent to which it is structured and behaves along classic bureaucratic lines, as well as how it functions within a larger departmental and governmental hierarchy. Max Weber, the great German sociologist, was one of the most prominent early theorists on the nature of hierarchical bureaucracies. A Weberian bureaucracy is composed of a hierarchy of office holders and division of labour based on functional specialization. Authority is exercised primarily by vertical and impersonal superior-subordinate relationships, often referred to as a "chain-of command" (Weber, 1946; Starling, 1986). In these organizations officials are salaried and hold permanent positions with selection and promotion based on qualifications and technical competence. A hierarchy features a system of rules and procedures and engages in primarily written modes of communication to ensure accountability (Hood, 1998; Pollit and Bouckaert, 2000). Organization by hierarchy is intended to produce reliably predictable behaviour, a highly valued capacity especially when linked with responsible government (Doern and Kinder, 2000).

As a government entity it can be expected that the ETC would exhibit many of the characteristics of a traditional public bureaucracy. The organization chart shows classic hierarchical lines of authority and, indeed, given the disparate activities of the various divisions, the ETC is quite hierarchical. However, it must be noted that three of the six "divisions" consist of seven or fewer people. Thus, the organization chart is a bit deceiving as to the actual internal structure of ETC. The transfer of the Emergencies Engineering Division to SAIC Canada has served to "flatten" ETC's hierarchy and make it operate in a more horizontal manner. This is in line with the general trend and ethos of "reinvented government" promoted across the federal government in an attempt to de-emphasize hierarchical levels. (Aucoin, 1997; Swimmer, 1996)

Beyond the internal hierarchy, the ETC is situated within a departmental hierarchy. The ETC Director reports to the Director General of the Environmental Technology Advancement Directorate (ETAD) who, in turn, reports to the Assistant Deputy Minister, Environmental Protection Service (EPS). Proposals for significant new initiatives or program directions are channelled through the direct line management structure for external review--i.e., through the ETAD management committee, the EPS Executive Committee and the departmental Environmental Management Board (Thornton, 2001). In addition, the ETC is represented on the department's S&T Management Committee, the Laboratory Coordinating Committee, and the Laboratory Managers' Committee.

According to those interviewed, most of the interaction with these higher levels of the Environment Canada hierarchy is channelled up the chain-of-command through the ETC Director or division chiefs. The ETC staff also participates in a variety of departmental planning and coordination committees or working groups focussing on particular planning issues. In addition, steps have been taken to improve communication across the science / policy interface. For example, managers with the Transportation Systems Branch of the Air Pollution Prevention Directorate have recently relocated to the ETC "to strengthen further the linkages between the ETC S&T work and their policy and regulatory functions." (Thornton, 2001)

Even while "reinvented government" reforms were introduced in the federal government in an attempt to reduce certain pathologies common to hierarchies, they at the same time introduced new forms of bureaucratic requirements in the interest of greater public accountability and more business-like and performance-based management approaches. This is reflected in requirements for such things as business plans, annual reports, personnel performance appraisals, etc. The ETC produces an annual business plan with a detailed list of deliverables. The plan is integrated with all of the departmental environmental protection key deliverables in the Clean Environment Table Business Line Plan. The Centre also produces biennial reports that profile its activities and summarizes its contributions during the reporting period. Employees are assessed annually using the government's performance appraisal system.

The ETC documents the results of its projects in both informal (unedited) manuscript reports and formal (edited) reports. In addition, staff members contribute to the general scientific literature through scientific and technical works including journal articles, book chapters, conference proceedings and workshop presentations. Interestingly, the ratio of the latter to the former has increased markedly in recent years. In the early 1990s, ETC's publications were roughly balanced between, on the one hand, those of the "technical report" variety that were largely aimed at internal or governmental audiences and, on the other hand, publications and proceedings targeting the broader scientific community. In recent years, however, the ratio of edited and peer-reviewed contributions to unedited and internal documents has grown to 2 to 1.

Reflecting the international trend for accreditation, the ETC chemical labs have been accredited ISO 17025 (the technical equivalent to ISO 9000) and they are seeking to become ISO 9000 accredited. Nevertheless, there is still concern that too much of the project work planning is done by the "seat of the pants." According to one manager, better tracking and project management software is needed to provide reasonable record-keeping. It is believed this would improve the credibility of government science, rather than relying totally on scientific reputation. However, it is noted that this concern does not reflect negatively on the lab's documentation relating to the scientific work itself, where ETC has strict standards as per its Quality Management Manual. The lab's performance is assessed under its accreditation by the Standards Council of Canada and the Canadian Association for Environmental Analytical Laboratories.

The ETC employs internal peer review, though not much external review unless submitting a publication to a journal. The lab occasionally is involved in public consultation which provides important input but is viewed as a weak way to assess the science. Therefore, the lab will typically have the science reviewed first, then conduct public consultations, and then publish the overall results.

A final way to examine the ETC as hierarchy centres on human resources policies and processes. In order to continue to provide its clients with cutting edge science and science advice, a government laboratory must continuously renew the knowledge embodied in its human capital. The federal S&T workforce is facing a "demographic bulge" in which close to 20% of the S&T workers will become eligible to retire without pension penalty in the next five years. While the retirements may present opportunities to redirect S&T efforts towards new and emerging research areas, the loss of institutional knowledge and expertise may be staggering.

The ETC has not escaped this pending crisis. But whereas some government S&T establishments have been granted greater independence and flexibility with respect to hiring, the ETC must comply with and operate within the Public Service human resources system which is often seen as a barrier to effective human resource management. Clearly, based on its use of the ASD contract, individual contractors, students, and programs such as the Youth Internship Program, the ETC has been creative in taking advantage of what flexibilities it has available to it. Nevertheless, continuing to attract younger staff will be critical not only because they can bring new energy, different approaches and more recent S&T knowledge, but also because of their importance in maintaining a vibrant and stimulating research environment.

ETC as Network

In contrast to hierarchies, networks are a way of organizing that involve horizontal exchanges of information and expertise, shared accountability, and relations based primarily on trust and collegiality rather than rules and authority (Rhodes, 1997; Thompson et al, 1991). Networks can be formal or informal but, to be successful, must have conventions about how trust-based exchange is maintained and enhanced. Networked forms of organization are common among scientific and professional groups, and federal laboratories, as scientific institutions, were network-based historically long before networks and partnerships became managerial fashion.

Internally, the ETC includes informal networking based on discipline or project activity as officials at similar levels of the hierarchy learn to trust and interact with one another. But the more common notion of networks in the current era centres on what kinds of partnerships and other relationships of trust and exchange are fostered with key external stakeholders and S&T institutions such as in other government departments, provincial governments, universities, industry, and non-governmental organizations.

ETC scientists are closely networked with the broader environmental S&T community. An element of this broad-based networking is the participation of ETC staff at domestic and international conferences and workshops, "which brings staff into contact with old and potential new colleagues with interests and objectives that are often complementary to those of the ETC (Thornton, 2001)." ETC networks primarily involve other government departments, provincial governments, and industry. Other networking is evident with scientists in academe and internationally. Interactions and networking with non-governmental organizations are less common. This section will highlight some of the types of networking, both formal and informal, employed at the ETC. One formal network, the National Air Pollution Surveillance (NAPS) Network, is profiled at the end of this section.

Networking with Regional Offices, Provincial Governments and Other Government Departments

The ETC is involved in a variety of networks involving other parts of Environment Canada, other government departments, and provincial, territorial and regional governments. Examples include:

- In its role of coordinating the NAPS Network, the ETC regularly convenes the NAPS Management Committee that includes the participation of all of the NAPS Network partners, the Air Pollution Prevention Directorate, and the Meteorological Service of Canada. The collaborative, inter-jurisdictional nature of the NAPS program contributes to a uniform national database used for tracking Canada-wide Standards. (See *Profile 1* at the end of this section for more on the NAPS Network).

- For the environmental emergencies S&T effort, the ETC does extensive work with the regions and even has one staff member located at a sub-office in Edmonton. Annual planning and coordination meetings are convened with input solicited from the regional offices, as well as operational and R&D organizations in Canada and overseas.

- The Emissions Research and Measurement Division has cooperated with the City of Calgary to assess and quantify greenhouse gases from Calgary's three active landfills.

- Under the Canadian Council of Ministers of the Environment, ETC staff co-chair the federal-provincial Development Committee on the Canada-wide Standard for Petroleum Hydrocarbons-in-soil.

- ETC staff participate, and often play a lead role, in the activities of the federal-provincial Inter-governmental Eco Toxicity Group, which facilitates the development and implementation of ecological toxicity testing by governments in Canada.

Networking with the Private Sector

Linkages between the ETC and industrial firms are extensive. The Centre has key industrial sectors (e.g., automotive, petrochemical, pharmaceutical, cosmetics products manufacturers, agri-food processors) as major clients and partners. One way in which the ETC is closely tied to its industrial clients and partners is through joint research projects. For example, the Emissions Research and Measurement Division collaborates with industry, particularly the automotive and petrochemical sectors, on research and development of new technologies that help reduce pollution. Such projects have involved the ETC in the evaluation of:

- alternative and reformulated fuels for light-duty passenger cars and trucks;

- alternative fuels and after-market exhaust emissions control equipment for on-road, heavy-duty vehicles;

- electric and hybrid vehicles, both light- and heavy-duty; and
- new sampling and analysis instrumentation for stationary source emissions testing.

When developing a new analytical methodology the lab will often get it reviewed more informally by those who will put it in practice both within the department and the private sector.

The ETC also engages in industrial demonstration projects. For example, the MAP Division is undertaking a demonstration project in collaboration with CanAmera Foods and BC Research to test the use of the Microwave-Assisted Process in extracting cooking oil from canola. It is hoped that the project will eventually lead to limiting or eliminating the use of hexane, a contributor to greenhouse gases, in the canola oil production industry. Given MAP's potential for much more energy-efficient industrial processes, a number of companies in countries such as South Korea, China, Colombia, Malaysia, Pakistan and India are interested in the outcome of the project.

Networking with Universities

For the most part, universities are certainly not a key source of funds. In fact, in the last few years they have often been viewed as competitors for federal research funding. This perspective was enhanced by the government's creation of new foundations and funds for which universities were eligible to compete but federal laboratories were not. The ETC as an institution participates in few formal networks involving universities and does not exhibit particularly close ties with the academic sector. However, the ETC is involved in bi-lateral arrangements such as the collaboration with Carleton University on emissions from turbines and on environmental genomics. The ETC also participates in Auto 21, a Network of Centres of Excellence involving a number of universities.

In addition, many ETC scientists maintain personal, informal networks with academic researchers. The MAP Division conducts joint projects with researchers at McGill University and the University of Moncton. In addition, many ETC scientists serve as adjunct faculty at various Canadian universities (including McGill, Carleton, and Ottawa) and occasionally an academic researcher will spend time at the ETC. At any given time the ETC hosts about 10 graduate students or post-docs who are supervised by ETC scientists and are able to make use of its facilities. Students usually "bring their own money," typically through an NSERC grant or other forms of support. Increasing networks with universities is seen as desirable by ETC management.

International Networking

Beyond the normal, informal networking that occurs naturally with the international S&T community, the ETC is engaged in many more formalized international activities. Canada has a strong international reputation in environmental leadership, and Environment Canada has in place many bi- or multi-lateral agreements involving China, India, Pakistan, and a number of countries in Latin and South America. Through these programs, the ETC is involved in a wide range of activities such as conducting joint research projects, technology transfer, training, and institutional capacity building. A number of Memoranda of Understanding are in place with the U.S. Environmental Protection Agency, the U.S. Department of the Interior Minerals Management Service, and the U.S. Coast Guard, that facilitate the development and delivery of joint projects with the U.S. government.

The AAQD encourages international visits and collaborates with foreign scientists in developing reference materials. The Division has worked with scientists in the United States, United Kingdom, India, Hong Kong and Latin America. While there has not been a formal evaluation of the NAPS program recently, the Division anticipates bringing in international experts for this purpose. As mentioned, the Special Projects Division is responsible for supporting the good laboratory practice activities of the Organization for Economic Cooperation and Development. The MAP Division is involved in a CIDA-funded project to work with McGill University in the training of scientists at the Chinese Research Academy of Environmental Sciences and China's Nankai University. MAP also has a pilot plant operating in Beijing. The ESTD works with international committees to collaboratively set research agendas and is currently involved in a joint project with 25 parties to conduct research on the effects of oil on shorelines. The ETC is often the lead partner in these international networks.

Profile 1: The National Air Pollution Surveillance (NAPS) Network

Since the late 1960s scientists and the public became increasingly concerned about the effects of air pollution including urban smog and acid corrosion of infrastructure. Subsequently, governments began to measure the ambient levels of air pollution and to put in place controls to reduce certain gases, chemical compounds, and particulate matter in the air. The National Air Pollution Surveillance (NAPS) Network was created in 1969 as a joint program of the federal and provincial governments to monitor and assess the quality of the ambient air in Canada's urban centres. The network provides air pollution data to governments that allows them to assess whether National Air Quality Objectives are being met. The Network consists of some 600 air-monitoring instruments at 230 largely-automated sampling stations located in over 100 urban centres in Canada. Since 1980 the NAPS database has also included ozone observations from Canadian and U.S. rural monitoring locations to enable analysis of regional ozone episodes.

The coordination and operation of the network are the responsibility of the ETC's Analysis and Air Quality Division in collaboration with the NAPS Network co-operating agencies from the ten provincial, two territorial, and two regional/municipal governments. Indeed the inter-jurisdictional and cooperative nature of the NAPS program reflect the strengths of a network-based organization. Some of the research and development and technical support services related to NAPS are conducted with the participation of, or in collaboration with, other Environment Canada departmental organizations and regional offices, other government departments (particularly Health Canada and Agriculture and Agri-Food Canada), non-government organizations, academe, the private sector, and international organizations including the U.S. Environmental Protection Agency, the U.S. National Institute for Science and Technology, and the World Health Organization.

From its beginnings the NAPS Network was instrumental in contributing to the government's efforts to reduce air pollution. By the mid 1990s, however, the data showed a levelling off of the downward trends in air pollution and showed that ozone levels were not increasing. It was determined that the overall increases in transportation had overtaken the gains brought on from introducing controls and emissions-reducing technologies. The U.S. and Canadian governments recommitted their nations to fighting air pollution and in February 2001, the Environment Minister announced extra funding over four years for the NAPS Program as part of the Clean Air Strategy. This funding is to address the new equipment needs for the monitoring stations and is viewed as urgently needed for the revitalization of the ageing network.

ETC as Market

The final institutional design consideration is to examine how the ETC behaves as a market or market-like organization. In short, the ETC exhibits a substantial commercial orientation and has deep links to the private sector. This is not surprising given the ETAD's mandate to advance the environmental industry. Indeed, as described in an earlier section, the ETC's mission statement includes an explicit role "to foster a healthy and creative environmental protection industry in Canada through information and technology transfer." In addition, the ETC exhibits many market-oriented or business-like practices. Perhaps the clearest example of the ETC's market-like behaviour is its contract with SAIC Canada which is profiled at the end of this section.

The ETC is an institution within a traditional line department of government. It is not a more arms-length Crown Corporation such as Atomic Energy of Canada Ltd., nor a departmental corporation such as the National Research Council. These and other government labs[8] have in place or are experimenting with business-like independent boards of directors. The ETC is ultimately governed "up" the Environment Canada hierarchy and, thus, such governing boards would be inappropriate in this context. However, unlike some other government laboratories, ETC has not made use of an independent board of advisors, although the ETC would fall within the purview of Environment Canada's department-wide Science and Technology Advisory Board. More focussed and program-specific advice is obtained from external people with expertise in the various ETC program areas through various program-level committees.

[8] Such as the Communications Research Centre.

Another area of market-like change is in policies and practices regarding intellectual property. Management responsibilities for intellectual property were assigned to science-based departments in the early 1990s. The ETC began implementing technology transfer programs involving commercial licensing of intellectual property developed in-house (ETC, 2002). Since that time, intellectual property issues have become increasingly important to the way the ETC operates.

The chief of the MAP Division developed the initial MAP™ technology while at Agriculture Canada. In 1990, he moved to Environment Canada and later asked that the patent follow him. Since then, a number of new inventions and patents have resulted and, as has been noted, the MAP™ licensing arrangements have generated large revenues, all of which are fed back into the MAP Division and a portion of which go to the inventors. Moreover, the ERMD has applied for a number of patents and also licensed a couple technologies--the Multi-DS™ and the DOES2™--to Canadian companies. The ESTD is learning the importance of IP-generated revenues in the new funding environment. In the past it has developed new technologies but not pursued patents because it was never a concern.

Another area of market-oriented activity is in the realm of encouraging spin-off companies. Some federal S&T institutions such as the National Research Council have experimented with human resources policies and related IP practices which encourage and enable employees to take an idea/technology to market by leaving and forming spin-off companies. The ETC has not fostered such policies and, to date, no spin-off companies have been formed. However, it should be noted that the MAP Division may be privatized in the not too distant future.

Beyond these areas, the ETC certainly exhibits other business-like approaches. For example, the references to ISO certification, the use of business plans and performance indicators are evidence of this "business practice" ethos. The ETC occasionally does work on contract for industry but prefers to interact through joint R&D projects. The AAQD will at times do analytical work for companies although this represents only about 1% of their effort and the Division does not seek out such work given concerns of competing with private sector labs.

Profile 2: Alternative Service Delivery through SAIC

In the 1990s Environment Canada looked to experiment with Alternative Service Delivery (ASD) mechanisms as a way to deliver on its mandates through novel approaches. Its first attempt was to set up the Wastewater Technology Centre as a "government-owned, contractor-operated" or GOCO laboratory. In 1991, the WTC was privatized on a trial basis for three years and subsequently the transition was formalized. However, late in the decade this experiment was abandoned and the WTC was pulled back within the Environmental Technology Advancement Directorate to operate in a more traditional government laboratory mode.

Subsequently, at the ETC, another ASD study and a competitively bid transition process was initiated in January 1997. In the end only one firm, Science Applications International Corporation of Canada (SAIC Canada) bid on the contract. As of April 1, 1998, the ETC's Emergencies Engineering Division became a privatized organization known as the *Environmental Technologies Program of the Emergency and Safety Services Division of SAIC Canada*.

Under the arrangement SAIC Canada, which is located on the ETC campus, undertakes research studies and technical services as requested, specified, and approved by Environment Canada through an ongoing series of work orders. These work orders are managed through the one-person Emergencies Engineering Technologies Office of the ETC. However, SAIC is also free to make separate arrangements with external clients for the provision of similar technical services and studies (ETC, 2000).

The relationship is described as "arms-length" while at the same time SAIC is viewed as "part of the family". This is understandable since, in addition to being co-located with the ETC (and sharing the same cafeteria!), the SAIC unit consists of a large number of former ETC employees. Under the ASD contract, new intellectual property developed by SAIC Canada belongs to them although the ETC reserves the right to use the IP royalty-free for R&D purposes. The five-year contract is now nearing the end of its fourth year and will be up for review next year. SAIC was required to match the Department's annual investment by year three of the contract but did so in year one. ETC management seems pleased with the arrangement, describing it as a "win/win" situation, and indicate that they expect the contract to be renewed for an additional five years.

Key Challenges

Among the most important challenges facing the ETC is the need for additional and more stable funding. In particular, some of the cited program areas that require additional funding include the analysis of toxics, fixed sources emission testing, and on-site response to emergencies (including terrorism-related emergencies). The ETC has clearly had much success in attracting "soft monies" through collaborative agreements. While this approach has a number of benefits, the uncertainty of the funding creates a number of management challenges related to maintaining core capacities in both human and capital terms. There is a concern that the ETC has been operating in a "hand-to-mouth" mode and that more stable funding would be of great benefit to realigning capacity to meet emerging needs. The need for reinvestment in the physical assets of the laboratory is considered urgent. With the influx of the ozone money the AAQD will spend half of this new money on upgrading capital equipment with the other half going to operations.

While most of those interviewed felt the science / policy links were in place there were concerns that the relationship could be improved. People are involved at multiple levels but they need to make an effort to make the linkages to policy or risk missing out on opportunities (particularly for additional money through the new horizontal program-based sources of funding). It was suggested that a formal statement from the policy side of Environment Canada indicating their need for ETC data and demonstrating the effectiveness of regulations informed by ETC data would be useful.

Another key challenge is the ongoing renewal of the workforce. The ETC competes with industry in the recruitment and retention of high calibre laboratory scientists and technicians. As is the case across the public service, new hires are increasingly brought in either on contract or term assignments. While this is an understandable reaction and work-around in the post-Program Review staffing environment, such an approach makes it difficult to ensure the long-term integrity of the workforce.

In recent years there has been pressure, given the enthusiasm for the so-called New Public Management reforms, for the government laboratories to adopt more market-oriented approaches in their operations. As has been shown, the ETC has been in the forefront of pursuing such approaches. While its experiment with Alternative Service Delivery is viewed as a success, a key question here is to what extent the ETC could or should be expected to do more in this area. In considering the answer, it should be recognized that pursuing such practices further may alter the organizational culture to the extent of weakening the ETC's ability to conduct long-term public good research and related scientific activities, and to ensure its S&T feeds into departmental regulatory and policy missions. It is likely that the ETC will continue to face such pressures in the future.

Finally, the ETC has had considerable success in the commercialization of intellectual property, bringing in an estimated $2 million to date (ETC, 2002). However, since technology transfer is not the primary mandate of the Centre, such activity has been undertaken on an ad hoc basis with very limited dedicated resources. According to an ETC planning document, "Sustained pursuit of such intellectual property revenues requires significant managerial investments in marketing and business development activities" (ETC, 2002). If government policy signals that the ETC should move more aggressively in this direction, it can be expected that such an approach will not only present a steep learning curve for ETC managers and staff, but might very well raise serious concerns about the organizational culture and ongoing S&T effectiveness of the institution.

Conclusions

This paper has examined how the Environmental Technology Centre has changed in the last decade as a federal S&T laboratory and institution. We have not sought to assess the substantive S&T activities and contributions of the ETC's research groups but we have shown how the ETC has had to respond to, take advantage of, and in other senses adapt to and survive amidst changing policies at the federal level and in the underlying dynamics of environmental technologies research and development. Thus, the ETC has had to relate to: changes in budgetary support (e.g., the demise of the Green Plan, Program Review budget cuts, the increase in interdepartmental program funds, and the reliance on external funding); changes in public service delivery policies and expectations (e.g., cost recovery, leveraged funding, networking, partnerships, alternative service delivery); changes to environmental research priorities and approaches (e.g., ozone depletion, sustainable development, climate change, chemical and other hazardous materials spills); and changes in S&T policy in which views about the roles of labs were not first order concerns but where such changes had, perhaps unintended but often adverse, effects on the laboratories (e.g., the shift from science policy to innovation policy with emphasis on economic development roles of government S&T). We have shown that the ETC has certainly faced these pressures and sought to carry out good work in the context of its changing mandate, constrained resources, and ageing infrastructure.

In common with the larger CRUISE research study of three other federal laboratories, the paper has employed a "hierarchies-networks-markets" typology as an organizing and analytical concept to understand how the ETC has coped and changed as an institution. The use of this approach was based partly on a view that federal S&T policy towards government laboratories will not fully succeed if labs such as the ETC are not understood as individual institutions and if the institutional diversity across labs is not better understood and reflected in such policies.

Indeed, one of the concluding observations to make about the use of an explicit institutional analysis is that there is also great institutional diversity *within* a lab such as the ETC. Another observation which emerges immediately from thinking more concretely about institutional evolution is that it is not an easy thing to determine where the boundaries of the ETC as an organization lie and where the boundaries between the public and non-government sectors now reside. In a certain, albeit imperfect sense, the hierarchies, networks, and markets framework is designed to force us out of some of our possibly too easy interpretations about what goes on inside the various "black boxes" of government, in this case the "black box" of one government laboratory. As stressed from the outset a "lab" must be seen as an institutional melange of fixed laboratory assets, S&T specialists engaged in research and related scientific activities, policy-centred funding mechanisms, and complex brokerage activity involving dedicated public servants who, in the majority, consist of S&T experts.

In terms of a hierarchical organization, the ETC does exhibit many of the characteristics common to a public institution. It consists of five fairly distinct divisions organized along classic hierarchical lines with only occasional links across them. This is probably vestigial of the ETC's creation and early evolution as an amalgamation of various functions. Communications and relationships with the parent department are largely vertical through the chain-of-command. In addition, there are important kinds of procedural bureaucracy that emerge from the new array of partnerships, performance-based approaches, and rules accompanying new interdepartmental funds. Nevertheless, given its size and variety of mandates the ETC does not seem overly "bureaucratic".

The ETC is clearly a highly networked organization, particularly with partner organizations in other federal and provincial government departments and with industry. The ETC often serves in a lead position within these networks. Networking with academic institutions remains largely informal but is becoming increasingly important. Networks involving non-governmental organizations are virtually non-existent.

In terms of a market orientation or business-like operations there are quite a few examples to speak of at the ETC. The ETC managers know their departmental clients and collaborators and maintain contacts on a day-to-day basis. The Centre makes extensive use of both on-site and off-site contractors and employs cost-recovery approaches to service delivery. Through joint projects, the ETC receives substantial funding from external sources, including industry and other (including foreign) government departments. Intellectual property activity is large and increasing. No spin-off companies have been created from the ETC although SAIC created a Canadian subsidiary in part to compete for the ASD contract and it appears likely that the MAP division will spin off to a private entity at some point.

The ETC has changed and continues to change as an S&T institution. Over the last decade it has had to cope with budget cuts, an ageing workforce and infrastructure, changing research priorities and shifting government expectations, while continuing to provide unique and high quality outputs in support of environmental protection. The ETC seems to have fared quite well and is looking ahead to new growth areas that will surely present both new challenges and opportunities.

CHAPTER 3

THE NATIONAL WILDLIFE RESEARCH CENTRE (NWRC)

The purpose of this chapter is to examine how the National Wildlife Research Centre (NWRC) has changed in the last ten to fifteen years as a federal S&T institution and to highlight some of the key challenges it faces in going forward. The information on the NWRC was collected during the Fall of 2001 through interviews with NWRC managers, scientists and staff members and a review of Centre publications and other key documents. These are listed in the Bibliography.

The NWRC richly illustrates how the concept of a "government laboratory" must be viewed broadly to encompass more than the narrow image of a place with fixed assets where scientific research is conducted. In addition to traditional "bench" science, the NWRC engages in what could be called "distributed" S&T, for example through the Canadian Cooperative Wildlife Health Centre, through field work to monitor bird populations and habitats, and through the Canada-wide program in wildlife toxicology. It is unique among the three labs studied in the degree to which the lab engages in what can be called "citizen science", through the use of a vast network of volunteer birders. As with the other labs examined in this study, the NWRC is a complex S&T institution fulfilling diverse roles and functions.

Origins, Mandate and General Features

To understand the NWRC it is important to place it in the context of its parent agency, the Canadian Wildlife Service (CWS), and in the context of wildlife conservation efforts more generally. The term "wildlife" is typically associated with all wild mammals and birds, whether native to or introduced into a country. Usually not included under wildlife are sea mammals such as whales, seals and walrus which are traditionally managed under fisheries. Plants, terrestrial cold-blooded vertebrates[9] and invertebrates such as insects are not usually thought of as wildlife (Clarke, 1974).

Wildlife, unlike fisheries, was not specifically identified in the British North America Act of 1867 and thus, even while many wildlife species migrate across provincial, territorial and even international boundaries, their protection is largely a responsibility of provincial governments. Where wildlife became the subject of international treaties, as with migratory birds, the federal government assumed a role in their protection. Thus, federal/provincial cooperation is an

[9] Although more recently amphibians and reptiles have become subjects of interest to wildlife researchers.

important aspect of wildlife conservation in Canada. Referring specifically to waterfowl management, Dagg (1974) describes the nature of the cooperative relationship and the roles of the two levels of jurisdiction:

> "The federal government, through the Canadian Wildlife Service ... tends to supervise the collection of waterfowl population statistics from censuses and to organize research and management programs. With these data the hunting regulations ... can be set, in conference with the provincial, United States and Mexican governments. . . . The provincial wildlife agencies deal primarily with sportsmen, regulations, enforcement, hunting licences, land manipulation, crop damage and increasing survey research. They work closely with the federal government, advising it on the provincial requirements for the use and protection of waterfowl and discussing technical details of both research and management at all levels."

A component of Environment Canada, the Canadian Wildlife Service (CWS) is the federal agency responsible for providing advice and taking action to conserve Canada's wildlife based on sound scientific knowledge (CWS, 2001). The CWS refers both to the unit of Environment Canada located in Hull, Quebec, as well as the department's wildlife programs throughout the regions of Canada. It was created in 1947 as the Dominion Wildlife Service with fewer than thirty staff collected from diverse federal agencies. In 1950, the name was changed to the Canadian Wildlife Service. This name has become well recognized around the world and "has enormous value both within and beyond the department for its connotation of a long history of scientific expertise, commitment, leadership, and partnerships" (CWS, 2000).

Historically, the primary emphasis of the CWS has been the management of migratory birds. This work supports the international Migratory Birds Convention dating back to 1916. Migratory and resident birds have been viewed as important not only as valued components of Canadian ecosystems but also because the status of their populations can provide indications of overall environmental health. Of particular interest to Canadian wildlife scientists have been various species of waterfowl. Apparently the joke has been that, in practice, the 'W' in CWS stood more narrowly for 'waterfowl' than for 'wildlife' more generally. In recent years, however, the CWS mission has broadened to encompass a wider range of wildlife species and their habitats, species at risk and the broader biodiversity conservation agenda.

Indeed, a recent history of the first fifty years of the CWS documents the wide variety of research conducted by the Service (Burnett, 1999). This research has involved studies on elk, moose, and bison in National Parks; the dynamics of northern species such as caribou, muskoxen, polar bears, wolves, and arctic foxes; the population ecology and migration patterns of geese and ducks; songbird surveys; shorebird and seabird studies; major initiatives in the conservation of the Trumpeter Swan, Whooping Crane, and Peregrine Falcon; and limnological studies of the health of lakes to enhance fish production. In addition, the Service has been a leader in research on environmental toxicology and the effects of toxic substances on wildlife. Beyond the conduct of research, the Service manages federal sanctuaries and wildlife areas, contributed to the Canada

Land Inventory Program, and has developed innovative public education programs such as interpretative nature centres. The CWS promotes federal-provincial cooperation on wildlife conservation and is responsible for the enforcement in Canada of international treaties for the conservation of species.

According to the *Canada Wildlife Act* the Minister of the Environment may *inter alia* "undertake programs for wildlife research and investigation, and establish and maintain laboratories and other necessary facilities for that purpose." (Environment Canada, 2001) In 1976, the National Wildlife Research Centre (NWRC) was created as the research headquarters of the Canadian Wildlife Service. It is currently located in Hull, Québec, on parkland originally bought by Senator Richard Scott. In fact, Scott's home which was built in 1863 still stands on the property. The site was used by the Department of Agriculture's Animal Diseases Research Institute from 1918 until 1975 when it moved to Nepean. Environment Canada took over the site in 1976 and established the NWRC. In 2002, the NWRC will be relocated to a site on the campus of Carleton University in Ottawa.

The roles targeted by CWS to which NWRC science activities contribute include the following:

- **support for conservation and management activities**--providing scientifically-sound advice on operational activities undertaken by the department to ensure the effective protection and conservation of migratory birds, certain species at risk and their habitats;

- **support for regulations and compliance activities**--understanding the impacts of human activities which CWS regulates, such as hunting of migratory game birds, setting science-based limits on these activities, and assessing the effectiveness of regulations and control;

- **support for decision-making**--ensuring that decision-makers within and outside the department base decisions that affect wildlife on the best available scientific information, including those which mitigate, or preferably prevent, negative impacts on wildlife and their habitats;

- **understanding ecosystem functioning**--improving our currently poor understanding of ecosystem integrity and functions, bird-habitat relations, interactions among stressors, and identifying species, life cycle stages, geographic areas, or ecosystem processes that are particularly susceptible to impacts of human actions; and,

- **support for sustainable uses of the environment**--assisting other agencies and industries in understanding the effects of human activities, such as forestry or coastal resource harvesting, on migratory birds, species at risk and their habitats, and working to prevent or minimise these impacts. (CWS, 2001)

Reflecting the evolution of the CWS, the mandate of the NWRC has historically focussed on migratory birds but, more recently, research has extended to work on other types of wildlife including amphibians such as frogs and large mammals such as polar bears. Officially, the mission of the NWRC is:

> "To be the principal source of knowledge and expertise in the federal government on the impact of toxic substances on wildlife and the use of wildlife as indicators of environmental quality, to conduct national surveys and research on migratory birds, and to produce scientific publications on wildlife." (Environment Canada, 1998)

This mandate produces a potential tension between those who would study wildlife with a view towards conserving species for their own sake and those who would study wildlife as potential indicators of broader environmental problems that can affect ecosystems and, ultimately, humans. "Tension" may be too strong a word but the NWRC does seem to consist of two worlds that are influenced by these two perspectives.

Before proceeding further it is important to note that the Canadian Government distinguishes between research and development (R&D), as traditionally construed, and what it refers to as related scientific activities (RSA). RSA includes those activities that complement and extend R&D by contributing to the generation, dissemination and application of scientific and technological knowledge. Examples include data collection, testing, scientific and technical information services and museum services. Importantly, RSAs include many activities not normally performed by university or private sector researchers such as long-term monitoring and disease surveillance. As with many government laboratories, scientific activities at the NWRC extend beyond traditional research to include various related scientific activities.

The NWRC consists of two divisions: the Migratory Birds Populations Division and the Wildlife Toxicology Division.

Migratory Birds Populations Division

The Migratory Birds Populations Division (MBD) consists of approximately 14 individuals whose mission is to provide the science base for the conservation of migratory birds, their habitat, and the ecosystems of which they are a part, through research, surveys, and advice to other scientists, managers, and the public. The bulk of the Division's ongoing research programs, which are often conducted in partnership with CWS personnel in the regions, focus on four bird groups and on ecosystems.

Waterfowl--The NWRC conducts research to conserve populations and provide sustainable harvesting opportunities for 37 species of waterfowl in Canada. Historic emphasis has been on Mallard and Black Ducks but more recent research is focussing on other species of concern. Examples include the impacts of climate change on Arctic breeding geese, investigation of a decline in the White-winged Scoter, and the effect of wetland buffer strip width on proximity of waterfowl nests to wetland edges.

Landbirds--Since landbirds are among the species most directly affected by large-scale changes in land use resulting from human activities, such as forestry, agriculture, and urbanization, the NWRC contributes to the population monitoring of the over 200 species of migratory landbirds and 75 more that are resident in Canada. Scientific input includes ensuring that new surveys meet standards for statistical reliability, testing survey protocols, making recommendations for improvements to existing surveys, analyzing results and developing better analytical methods.

Seabirds--NWRC research contributes to increasing understanding of the approximately 50 species of seabirds that nest in Canada. Seabirds are strongly affected by oceanographic events such as the El Nino-Southern Oscillation and by commercial activities such as gill-netting, long-lining and aquaculture. Research and monitoring has focussed on the distributions and populations in the Eastern Arctic, with special emphasis on the heavily hunted Thick-billed Murres, and research on the impacts of racoons and other predators in the Queen Charlotte Islands (Haida Gwaii).

Shorebirds--Many of the approximately 50 species of shorebird species that nest in North America are highly migratory, flying as far as Europe, the southern tip of South America, or to Australasia to winter. Shorebird research and monitoring must therefore contain a strong international component. Research has focussed on the use of remote sensing for the identification and evaluation of key habitats, migration routes, biological requirements of the birds during breeding and migrating, and factors affecting populations such as climate change or pollution.

Landscapes/Ecosystems--In addition to research focussed on particular bird groups, MBD science includes research on biodiversity and the broader aspects of ecosystem functioning such as predator-prey and bird-habitat relations. Examples include research on the agricultural impacts on terrestrial wildlife and ecosystems, the importance of burned areas for the maintenance of forest biodiversity, and geospatial analyses for wildlife at risk.

Beyond traditional research, the Migratory Birds Division is also heavily involved in the following national monitoring surveys and other related scientific activities:

National Harvest Survey--the NWRC documents the annual kill of waterfowl and other migratory game birds as well as trends in hunter activity. This data is then used to set hunting regulations and bag limits for the following hunting season.

North American Breeding Bird Survey (BBS)--the NWRC coordinates the Canadian portion of the BBS which tracks and reports on the long-term population trends of songbirds.

Canadian Bird Banding Office--the NWRC administers all bird banding projects taking place in Canada and provides banding and recovery information on request.

Other bird monitoring activities--the NWRC promotes volunteer participation in various surveys of birds. As an example, the Canadian Landbird Monitoring Strategy is described in greater detail later.

Wildlife Toxicology Division

The Wildlife Toxicology Division (WTD) leads Environment Canada's National Wildlife Toxicology Program at the NWRC and in each of the department's five regions. The objective of the program is to provide information and advice on the factors influencing the health of wildlife and the impacts of toxic substances on wildlife and their ecosystems, and develop the scientific basis for recommendations for policies and programs for prevention, mitigation, and redress of these impacts on wildlife. Research focuses on effects at the biochemical to population levels, as well as impacts on loss of uses of wildlife such as for food. The program also aims to develop the use of selected wildlife as indicators of ecosystem health and damage and as early warning sentinels of potential impacts of toxic substances on humans.

The WTD consists of approximately 38 personnel organized into four sections with the following missions:

Pesticides Section--carries out or coordinates research relevant to the following activities: influencing the pesticide regulatory system to reduce impacts of pesticides on wildlife and wildlife habitat; providing expert advice on pesticide-wildlife habitat issues; and investigating wildlife and wildlife habitat problems arising from pesticide use and pest control programs and practices. Activities include assessing the in-field safety of pesticides in Canada and, where necessary, building the case for regulatory changes, exploring possible links between amphibian declines and pesticide use, and developing more accurate risk estimation methods.

Contaminants Section--identifies and interprets the impacts of contaminants (e.g., PCBs, lead shot) on Canadian wildlife, provides advice and recommendations to prevent or mitigate these effects, and informs the Canadian public. Activities include a national survey of contaminants in waterfowl, modelling contaminant exposure of wildlife, research on the effects of endocrine disruptors, and evaluation of risks posed to wildlife by regulated substances.

Research Section--provides scientific knowledge, expert advice, and specialized chemical and biochemical analyses in support of Environment Canada's roles:

- to identify existing environmental contaminants and their sources;
- to measure and predict impacts of toxic chemicals, such as endocrine disruptors, on wildlife and their ecosystems;
- to develop qualitative and quantitative indices of temporal and spatial trends in environmental quality.

Activities include the assessment of arctic ecosystem stress, contaminant dynamics and trends in the Great Lakes and the St. Lawrence River, and development of a bioenergetics-based model for contaminant bioaccumulation in birds.

Laboratory Services Section--provides analytical lab services in support of the research and monitoring activities of the rest of the Division. Current capabilities and expertise are focussed on the determination of trace and ultra trace chemical contaminants in wildlife tissues and in biochemical biomarker assays. The Section has been accredited by the Standards Council and the laboratory meets ISO requirements. Activities include receiving approximately 6,500 specimens per year, maintaining the CWS Specimen Bank containing more than 55,000 specimens, providing trace chemical analyses and biomarker services, and managing the NWRC's computer network and the database for the National Registry of Toxic Chemical Residues.

Key Institutional Trends

While the current mandate and descriptive features provided above are an important starting point for understanding the NWRC, they do not sufficiently convey the key pressures and dynamics of change in the last decade. This section will briefly review major changes and trends in key institutional indicators such as formal organizational structure and culture, research emphases, funding, personnel, and infrastructure during recent years.

Until recently the NWRC consisted of three divisions: the two described above and a Scientific and Technical Documents Division. A recent reorganization shifted the S&T Documents Division to the CWS headquarters, leaving two divisions at the NWRC. The S&T Documents group had been responsible for the Centre's publications, technical reports, and maintaining the web site. Consequently, some of these functions have fallen to other parts of the organization. In addition, the loss of this Division means there is one less senior manager on which to rely for Centre management.

A key institutional change over the last decade is in reaction to the gradual shift in wildlife research emphases. This has been characterized as a shift from a species-specific orientation and a focus on individual chemicals and toxins to a "landscape-level" or "whole ecosystems" orientation. Human activities such as urbanization, the intensification of agriculture, and forestry and other resource extraction industries have diverse and often negative impacts on wildlife habitats (CWS, 2000). In addition, less direct impacts include the long-term effects of acid rain, the expanding use of pesticides and other toxic chemicals, and the largely unknown effects of global climate change. An increasing awareness of these impacts on wildlife habitats is forcing a shift in conservation thinking from the individual to the systemic. The need for "landscape-level" approaches to conservation presented challenges to the existing modes of research and expertise directed at a single or a very few species. As will be further explored later, this has led to greater use by the NWRC of formal networking and partnerships to deliver on its mandates.

Program Review in 1994-95 imposed a deep and serious review of, and reduction in, federal programs across the Government of Canada (Swimmer, 1996). Program Review required programs and activities to be assessed against several criteria including tests such as whether government should be involved in the activity at all, the relative role of the federal government compared to the provinces, and which activities were essential for the federal government as opposed to expendable. As with most federal S&T establishments, which were particularly hard hit by Program Review, the NWRC budget was cut following 1994-95 when its budget had reached almost $7 million. Since then the budget has been relatively stable and flat between roughly $5 million to $6 million per year.[10]

Although detailed NWRC budget data was not available, the following data points were culled from various sources: $4.1 million in 1990-91, $6.9 million in 1994-95, $5.4 million in 1997-98, $5.2 million in 1998-99, $5.4 million in 1999-00, $5.8 million in 2000-01, and $5.5 million in 2001-02. These figures do not include the one-time influx of funds related to the new building and relocation that are not part of the regular operating budget. The cut in year 2001-2002 is due to the reorganization that sent the S&T Documents Division to CWS headquarters. Detailed statistics were not available but the vast majority of the NWRC budget is spent on the performance of in-house S&T rather than funding work external to the NWRC.[11] This intramural S&T is split almost equally between research and development (R&D) and related scientific activities (RSA). As of 1998-99 it was estimated that RSA accounted for a slightly higher proportion of the overall activity at 53% with R&D at 47%.

Personnel levels show a similar trend over the last decade. In 1990-91, NWRC had 56 personnel, in 1994-95 about 70 personnel and between 1997-98 and 2000-01 the level hovered around 60. This year, following the departure of the S&T Documents Division, the number of full-time equivalents is 53. The staff positions can be roughly broken down into about 30 scientific and professional, 17 technical, and 6 program and administrative. In the numbers quoted there are typically about 10 term employees who tend to be in technician positions. At any given time, NWRC staff will also include about ten on-site contractors and graduate students beyond the numbers quoted above. There is currently one Emeritus Scientist working at the NWRC.

---

[10] One commentator noted that while operating funds have been relatively flat, with no increases to cover inflation, computer and information technology costs have skyrocketed over the past decade resulting in declining "actual" operating budgets.

[11] Budget data provided for the year 1998-99 shows the following breakdown: salaries ($3.25 million), operating and minor capital ($1.09 million), capital ($0.24 million), grants and contributions ($0.25 million) and external ($0.94 million).

The relative stability of budgets and personnel through the mid-1990s Program Review period, during which most science-based departments experienced major cuts, is a reflection of the fact that more dramatic cuts had come earlier to the NWRC during the Mulroney Government. In 1986, budget cuts led to the NWRC losing about half of its personnel. Later, with the proposed Green Plan, it appeared for a time that there would be a substantial ramping up of resources. Given the long-term character of wildlife research, management planning and programming responded accordingly. However, the Green Plan was subsequently cut and the NWRC resources have remained relatively flat ever since. From a research management point of view, the proposed Green Plan followed by its quick demise may have been worse for long-range planning than if there had never been a Plan at all.

The NWRC has an informal environment where office doors are open and the staff are on a first-name basis despite the range of educational degrees and titles. One scientist, commenting on the low turnover rate, said, "people spend their careers here." However, a higher turnover in the staff is foreseen in the not too distant future as a large number of personnel are nearing retirement age. While these retirements will represent a loss of institutional memory and expertise, the situation is largely viewed as an opportunity to diversify the Centre's skill sets and gain expertise in the Centre's new areas of responsibility.

Also of concern with respect to research capacity is the state of the NWRC's physical assets. These include, among other things: 9 buildings[12] (including two designated as "heritage" buildings) which house offices, laboratories, an aviary, an auditorium, and storage space; analytical laboratory equipment; four walk-in freezers and other ultra-low temperature freezers used to store specimens; field equipment; and computers. A key concern is the ageing of these capital facilities and equipment. In 1998 it was estimated that the wildlife toxicology program equipment totalled about $2.5 million of which about $2.2 million worth was more than seven years old. The Canadian Council for Animal Care had closed down two of the NWRC's aviaries in the past and wanted upgrades to the third one which was also recently closed as part of more cuts. Other facilities gaps include an incubator room, an amphibian facility, a greenhouse, a library, field vehicles, and common areas for staff meetings and interaction. While the government has in recent years devoted major new funding to address Canadian research infrastructure needs through mechanisms such as the Canada Foundation for Innovation, federal laboratories are not eligible to compete for these funds.

The issue of "rust-out" not only harms research potential but is in danger of harming the health and safety of employees. At the NWRC government health and safety violations related to chemical storage and air handling are a concern. The lack of adequate laboratory facilities such as an animal holding facility, overcrowded laboratory and office spaces limits productivity and research effectiveness and increases down times due to health and safety concerns. The NWRC

[12] All of its building assets were sold to the new city of Gatineau as of December 2001. The NWRC is in a lease situation until it moves to Carleton University.

is attempting to address many of these issues by relocating to a new facility being built at Carleton University.

NWRC as Hierarchy

The first way to examine the institutional design of the NWRC is to explore the extent to which it is structured and behaves along classic bureaucratic lines, as well as how it functions within a larger departmental and governmental hierarchy. Max Weber, the great German sociologist, was one of the most prominent early theorists on the nature of hierarchical bureaucracies. A Weberian bureaucracy is composed of a hierarchy of office holders and a division of labour based on functional specialization. Authority is exercised primarily by vertical and impersonal superior-subordinate relationships, often referred to as a "chain-of command" (Weber, 1946; Starling, 1986). In these organizations officials are salaried and hold permanent positions with selection and promotion based on qualifications and technical competence. A hierarchy features a system of rules and procedures and engages in primarily written modes of communication to ensure accountability (Hood, 1998; Pollit and Bouckaert, 2000). Organization by hierarchy is intended to produce reliably predictable behaviour, a highly valued capacity especially when linked with responsible government (Doern and Kinder, 2000). As a government entity it can be expected that the NWRC would exhibit many of the characteristics of a traditional public bureaucracy. What one finds, however, is that most of these hierarchical features are a thin overlay on an otherwise largely non-hierarchical institution.

While the organization chart shows classic hierarchical lines of authority, the internal structure of the NWRC is, as with many scientific establishments, quite flat and it functions in a highly collaborative and horizontal manner. This is in line with the general trend and ethos of "reinvented government" promoted across the federal government in an attempt to de-emphasize hierarchical levels. (Aucoin, 1997; Swimmer, 1996) As described above, the NWRC consists of only two divisions: the Migratory Bird Populations Division and the Wildlife Toxicology Division. NWRC management consists of the Director, the two Division Chiefs, and three Section Heads within the Wildlife Toxicology Division (the Contaminants "Section" operates without a Section Head position). Below these levels, and even including these levels, superior-subordinate relationships appear to be quite informal.

Beyond the internal hierarchy, the NWRC is situated within a CWS and departmental hierarchy. Despite any attempts to use network or market-based approaches, the NWRC is ultimately governed "up" through the CWS and Environment Canada. Specifically, the NWRC Director reports to the Director General of the CWS who, in turn, reports to the Assistant Deputy Minister, Environmental Conservation Service. NWRC programming and planning must be approved within this hierarchy and is influenced by policies and the accompanying rules flowing from these higher levels, including from other parts of government as well. As indicated, the NWRC must also be responsive to specific legislation, international treaties and the federal / provincial jurisdictional considerations with respect to wildlife research.

It seems that there is very little interaction with the higher levels of the Environment Canada hierarchy for NWRC staff below the level of Division Chief. This pattern reflects the hierarchical characteristics of a vertical command-and-control reporting structure. However, it must be noted that the NWRC collaborates horizontally with other CWS scientists and officials both in the national capital area and the regions.
In addition to articles published in scientific journals some of the Centre's research is communicated through departmental publications and technical reports. However, the mechanisms by which NWRC science is communicated to the department's policy shop--across the science / policy interface--are not clear. Some scientists had little knowledge (or even interest) in how their research might potentially drive policy or regulation. Other scientists were indeed interested in the science / policy interface but felt that the existing mechanisms for cooperation and communication were woefully inadequate. Thus, relationships across the science / policy interface are not strong and the "science into policy" communication that does exist typically flows up the chain-of-command, thereby exhibiting the vertical flow characteristic of hierarchies.[13]

"Reinvented government" reforms were introduced in the federal government in an attempt to reduce certain pathologies common to hierarchies. At the same time, however, they introduced new forms of bureaucratic requirements in the interest of greater public accountability and more business-like and performance-based management approaches. Both the NWRC management and the scientific personnel commented that management attempts to "shield" the scientific personnel from the types of bureaucratic requirements such as producing business plans, annual reports, personnel performance appraisals, etc. In fact, unlike the other labs in this study, the NWRC apparently does not produce business plans and annual reports on a routine basis. As for the government-wide performance evaluation system, opinions at the NWRC are mixed: some of the scientific staff find it effective, others find it arbitrary. Many of the scientists with management responsibilities would prefer to be able to do more science. This is the case despite the fact that adding management responsibility to one's job description is one of the few avenues for career advancement for those not classified as research scientists.

This last point leads us to examine another aspect of the NWRC as hierarchy centred on human resources policies and processes. In order to continue to provide its clients with cutting edge science and science advice, a government laboratory must continuously renew the knowledge embodied in its human capital. Whereas some government S&T establishments have been granted greater independence and flexibility with respect to hiring, the NWRC must comply with and operate within the government-wide human resources system which is often seen as a barrier to effective human resource management. Clearly, based on its use of contract, term and student personnel, the NWRC has learned how to manoeuver within the system as it attempts to cope with its human resources challenges. Nevertheless, as with many laboratories, the NWRC faces

[13] It should be noted, however, that some 'science-into-policy' action takes place through network partners, through NWRC's roles in NABCI and continental bird strategies.

an ageing workforce. Attracting younger staff will be critical not only because they can bring new energy, different approaches and more recent S&T knowledge, but also because of their importance in maintaining a vibrant and stimulating research environment. It is hoped by the NWRC management that co-location with Carleton University may help attract more young people to the NWRC and into wildlife research generally.

NWRC as Network

In contrast to hierarchies, networks are a way of organizing that involve horizontal exchanges of information and expertise, shared accountability, and relations based primarily on trust and collegiality rather than rules and authority (Rhodes, 1997; Thompson et al, 1991). Networks can be formal or informal but, to be successful, must have conventions about how trust-based exchange is maintained and enhanced. Networked forms of organization are common among scientific and professional groups and federal laboratories, as scientific institutions, were network-based historically long before networks and partnerships became managerial fashion.

NWRC scientists are very closely networked with the broader scientific community. Indeed, of the three institutional design types the NWRC perhaps most exhibits the characteristics of a networked organization. Networks are evident with scientists primarily in academe and non-governmental organizations, with some collaboration with other government departments. Given the NWRC's research areas, interactions and networking with industry scientists are rare though not entirely non-existent. This section will highlight some of the types of networking, both formal and informal, found at the NWRC. Profiles of two formal networks involving the NWRC are provided at the end of this section as illustrative examples.

Networking with Universities

The NWRC has close ties with the academic sector and personal, informal networks are pervasive. At least seven NWRC scientists serve as adjunct faculty at six universities (Carleton, Ottawa, Trent, McGill, Guelph, and Oregon State University). This type of relationship is considered likely to increase after the move to Carleton. As a result of these connections, at any given time a number of graduate students are supervised by NWRC scientists and are able to make use of NWRC facilities. However, the students will typically have to "bring their own money," typically through an NSERC grant or other forms of support as the NWRC is unable to pay them.

Exhibiting the horizontal communication common to networks, the preponderance of NWRC knowledge products are communicated to the external scientific community through publication in academic journals rather than the more "up-the-line" style of communications common to hierarchical public bureaucracies (such as ministerial correspondences, departmental memoranda, technical reports, etc.).

For the most part, universities are certainly not a key source of funds. In fact, in the last few years they have often been viewed as competitors for federal research funding. This perspective was enhanced by the government's creation of new foundations and funds for which universities were eligible to compete but federal laboratories were not. Nevertheless, the NWRC is engaged in a number of formal networks involving universities, not as a way to get additional funds but as a way to access expertise and promote research collaboration. Formal networks involving academe include the Canadian Cooperative Wildlife Health Centre (see Profile 1 below), the Atlantic Cooperative Wildlife Ecology Research Network, and the Simon Fraser University Cooperative Research Unit. The NWRC is often a lead partner in these networks playing the role of coordinator and catalyst.

Networking with Non-Governmental Organizations

There are many non-governmental organizations (NGOs) involved in wildlife conservation in Canada. Among these are Ducks Unlimited, which spends millions of dollars improving the habitats of waterfowl in Canada, and the Canadian Wildlife Federation whose efforts are largely aimed at public education regarding the importance of conserving wildlife species. As with universities, however, these and other wildlife organizations do not represent major sources of funds for wildlife research. Nevertheless, linkages and partnerships between the NWRC and NGOs are becoming increasingly prevalent. The CWS Strategic Plan recognizes NGOs as increasingly important partners that bring expertise, resources and alternative service delivery approaches to the table. In fact, some NGOs have established themselves as essential wildlife actors fulfilling key conservation roles.[14] One example is Bird Studies Canada's activities in national and regional bird surveys and volunteer monitoring projects. Indeed, the main partners of the Migratory Bird Populations Division are NGOs, primarily local naturalist or bird enthusiast clubs and conservation groups (see Profile 2 below).

Networking with Other Government Departments

The Centre's scientists also work with other federal and provincial government departments with an interest in wildlife. At the federal level, the Migratory Birds Division has recently worked with Parks Canada and the Department of Indian Affairs and Northern Development. They have found that the traditional knowledge of local peoples can improve their bird monitoring techniques. As part of the Canadian Cooperative Wildlife Health Centre (CCWHC) described

---

[14] It is important to note, however, that NGOs such as Bird Studies Canada rely on fund raising for their operations and, hence, must focus on "interesting" functions that generate revenue. Consequently, NGOs may not be able to perform all of the required long-term monitoring or data management and analysis functions, which provides a rationale for NWRC involvement.

below, the Wildlife Toxicology Division has ties with other government departments interested in animal health.

International Networking

It is recognized that wildlife species do not necessarily respect geopolitical boundaries in their migration or habitats. Also, the rise of international trade has brought increasing challenges related to exotic species, pests and animal diseases to the conservation of wildlife in Canada. In the face of these pressures, as well as the normal networking that occurs naturally within the broader scientific community, NWRC scientists are engaged in both formal and informal international networks. Some participate in peer review panels for the U.S. Environmental Protection Agency or for wildlife research programs in Europe. One member of the NWRC staff is currently a visiting scientist in France. Another scientist collaborates with researchers in South America. NWRC management views these connections as important to maintaining and enhancing the scientific currency of the Centre's research.

Profile 1: The Canadian Cooperative Wildlife Health Centre (CCWHC)

One of the first formal networks involving the NWRC's Wildlife Toxicology Division was the Canadian Cooperative Wildlife Health Centre (CCWHC). The CCWHC is a network of centres of wildlife health services and disease surveillance located at the four veterinary colleges of Canada. Established in 1992, the CCWHC is the result of a collaboration of federal, provincial and territorial government agencies, the Max Bell Foundation, the Canadian Wildlife Federation and the veterinary schools at the Universities of Prince Edward Island, Montreal (St-Hyacinthe), Guelph, and Saskatchewan. In addition to Environment Canada, the CCWHC has relationships with other federal partners including the Laboratory Centres for Disease Control of Health Canada, Fisheries and Oceans Canada, Parks Canada, and the Canadian Food Inspection Agency.

The three fundamental principles that guided the establishment of the CCWHC reflect the strengths of a network-based organization:

1) Canada requires a coordinated national program in wild animal health;
2) A national program in wildlife health must rely heavily upon the existing cadre of wildlife biologists across the country;
3) A national program in wildlife health should integrate, not duplicate, work on wildlife health and disease that already is being done in Canada. (CCWHC, 1998)

In short, the CCWHC provides a network of formal and informal communications among the broadest possible spectrum of persons with expertise and/or interest in wildlife health issues to maximize the availability and use of information generated by wildlife health workers. (CCWHC, 1998)

The primary service provided by the CCWHC is the surveillance of wildlife diseases. This includes the detection and diagnosis of diseases, management and dissemination of disease surveillance information, and consultation. Given the increasing potential for the movement of diseases around the world, the need for such services is no longer merely a domestic concern. According to a recent CCWHC report, "Disease surveillance has become increasingly important in the arena of international trade and trade regulations to protect the health of Canadian wildlife." (CCWHC, 1998) The World Trade Organization has examined the erection of non-tariff barriers based on animal diseases. Consistent with the general trend toward science-based trade regulations (Browne et al, 2000), nations wishing to deny access of foreign animals to their domestic markets will now have to demonstrate that there is a true risk associated with their importation. This, in turn, requires complete and scientifically-sound information about the diseases present in the country. The CCWHC plays an important role in this regard. From the point of view of the NWRC, the CCWHC is able to provide the services related to wildlife health and animal pathology that the NWRC no longer has the capacity to provide in-house.

Profile 2: Partners in Flight and the Canadian Landbird Monitoring Surveys

While the status of game birds has long been a concern given their role in recreational hunting in Canada, there is also growing concern, according to NWRC documents, about the health of non-game bird populations in Canada. Developing sound conservation strategies for these landbirds requires an understanding of their status, population trends and the causes of population change. In turn, obtaining this information requires an extensive monitoring program well beyond the capabilities that any one institution could provide. As a consequence, the CWS adopted in 1994 the Canadian Landbird Monitoring Strategy as a component of its overall conservation program for birds. In its implementation the Strategy relies heavily on networking.

The Monitoring Strategy is intended to integrate the numerous monitoring activities conducted by various government departments and conservation organizations. The Strategy has three main goals. The first is to collect information to assess the health of landbird populations. Primarily, this involves detecting, monitoring, and assessing changes in the distribution and abundance of Canadian landbirds. Data is also collected on productivity, survivorship, and bird/habitat associations that are necessary to understand population dynamics.

The second goal is to identify species or species group that are a priority for conservation. This requires identifying and ranking species or groups of species that either exhibit large declines in populations or whose population increases may have negative effects on other species. The third goal is to ensure that accurate data and trends are readily available to wildlife managers and the public. This entails scientific review and evaluation of all techniques used in the Strategy and publication and dissemination of the results of the surveys (NWRC, 1994)

In pursuing these goals, the NWRC relies heavily on volunteer surveys conducted by a vast network of volunteer birders to provide data on bird populations. For example, in the Christmas Bird Count, which dates back to 1900, bird counts are provided by over 40,000 participants throughout North America. Another component of the overall Strategy is the Breeding Bird Survey (BBS) which is designed to detect and measure year-to-year and long-term changes in songbird populations. Unlike CWS's involvement with waterfowl, which has long been tied to hunting regulations, the Canadian involvement in the international BBS was not the result of legislation. Rather, ornithologists in the United States approached Canadian scientists with an interest in extending their ability to track songbirds following the call to action of Rachel Carson's influential book *Silent Spring*. From its beginnings in Eastern Canada in 1966, the BBS has subsequently grown to encompass 450 routes in Canada (of 3,000 overall in North America) with coverage in all provinces and territories. Over 90% of the routes are surveyed by volunteer birders.

With this growth the survey required greater coordination and quality control. This is being achieved through the creation of "Partners in Flight," an umbrella group that brings together representatives from NGOs, academe, and government to coordinate the program. Through its participation in the group, the NWRC assists in the identification of problems, sets priorities for research and coordinates conservation action. It is also becoming more involved with formal training of the participants. In the U.S., the desire for accuracy in the surveys has led to a certification process for the birders. In Canada, training is encouraged and volunteers can obtain training tapes and videos but there is as yet no certification test.

The reports of the birders are collected by regional coordinators and forwarded to the NWRC. Statisticians at the NWRC analyze the data and track long-term trends for approximately 172 species. The information is published in reports which are used by government scientists, academics and conservation groups. Public outreach to volunteer participants and school groups is also a part of the program. In this wonderful example of "citizen science" and a network form of program delivery, the desire for well-trained, competent observers is balanced by recognition of their voluntary status and the government's critical dependence on the volunteers to deliver on its mandate. From this section it is clear that the NWRC is increasingly heavily involved in employing network-based forms of program delivery. This is perhaps not surprising given the pressures in government to move away from hierarchical designs and given the inappropriateness of more market-oriented approaches in the NWRC context, as discussed below.

NWRC as Market

The final institutional design consideration is to examine how the NWRC behaves as a market or market-like organization. In short, the NWRC exhibits very little in the way of a commercial orientation and has very few links to the private sector. This is not surprising given the NWRC mandate to deliver public good science and the lack of any commercial interests in this type of research. Put simply, there is no market for NWRC research and related scientific activities. As for market-oriented or business-like practices these, too, are not very evident at the NWRC.

The NWRC is an institution within a traditional line department of government. It is not a more arms-length Crown Corporation such as Atomic Energy of Canada Ltd., nor a departmental corporation such as the National Research Council. These and other government labs have in place or are experimenting with business-like independent boards of directors. The NWRC is ultimately governed "up" the Environment Canada hierarchy and, thus, such governing boards would be inappropriate in this context. However, unlike some other government laboratories, the NWRC has not made use of an independent board of a more advisory nature, although the NWRC would fall within the purview of EC's department-wide Science and Technology Advisory Board.

There is some use of contracting for services across a range of functions including scientific analysis, field work, and support services. But, according to NWRC staff, the use of short-term contracts is more a result of the lack of full-time positions available for directly hiring people than it is a need to employ specific external expertise for a short period of time. This also is consistent with the overall trend across the public service towards greater use of non-indeterminate positions (term, contract, casual, etc.).

In the Migratory Birds Division there is very little commercial activity although contracting out is occasionally employed. For example, the Division worked with an external consultant on the development of training materials for the volunteer birders, and at times will contract out data analysis to external scientists (again, usually for reasons of workload, not lack of internal expertise). In the area of intellectual property rights, the group occasionally must purchase the rights to use photographs on the website, but otherwise is not impacted by IP concerns as it is not in the business of producing anything patentable.

In the Wildlife Toxicology Division, the Laboratory Services group performs laboratory testing and chemical analyses on tissues sent in from the regions, which could conceivably be viewed as a source of external (though still internal to Environment Canada) funds. However, this service is usually funded from the NWRC's base budget rather than on a cost-recovery basis. There is little or no use of the diagnostic laboratory facilities by the private sector or academic scientists (other than by the graduate students working with NWRC scientists). It is believed that any efforts to provide such analytical services would be viewed as inappropriately competing with private sector analytical labs.

In recent years there was briefly an attempt to "market" a wildlife contaminants exposure model created by the NWRC. By inputting potential exposure levels of various environmental contaminants the model provides the potential resulting impacts on certain wildlife species. It was thought that such a model may be of interest to the growing environmental consulting services sector by providing them an extra tool for the preparation of environmental impact analyses. However, this effort was abandoned by the NWRC when it was determined that it would not be cost-effective[15]. In the end the model was turned over to the U.S. Environmental Protection Agency under an agreement that allows free use by Canada.

---

[15] In particular, the costs of translating the model into French to comply with Government of Canada policies was found to be cost-prohibitive.

Linkages between industrial firms and the NWRC are minimal. The NWRC is unlike some of the other Environment Canada laboratories, such as the Environmental Technology Centre, which have key industrial sectors (e.g., automotive, petrochemical) as major clients and partners. If anything, there tends to be a tension between the NWRC and industry, given NWRC's role in identifying problems in the environment that are often a result of industrial processes. Technology transfer is not an activity of the NWRC as it creates no technologies to speak of and the generation of patents is rare. No spin-off companies have been formed from the NWRC.

Key Challenges

As the NWRC looks forward to a new beginning at the Carleton University site it faces a number of key challenges. Not the least of these is how the relocation to a university campus will impact the NWRC's organizational culture and research effectiveness. As would be expected, dealing with the challenges of the relocation will remain a primary consideration for NWRC management in the near term.

Many NWRC scientists expect the move be a positive development as it will create more opportunities for collaboration with academic researchers and students. On the other hand, one scientist mentioned that some of the on-site contractors are somewhat concerned that their jobs may be replaced by graduate students. From the government's point of view it will be of interest to examine what impact the relocation has on the communication of science for policy and the effectiveness of the science / policy interface within the department. Over time, the NWRC may find itself contending with two hierarchies simultaneously--the department's and the university's. NWRC's relocation represents a case worth watching by other government laboratories that may consider physically locating themselves on a university campus.

Beyond the relocation, other challenges exist as well. According to the CWS Strategic Plan, many of the conservation challenges that the CWS has faced are increasing in severity, scope, and impact on wildlife resources. By 1999, 340 species in Canada, including 52 species of birds, had formal national designation as species at risk, and three of the twelve species that have been confirmed as extinct in Canada were birds (CWS, 2000). "At the other end of the spectrum, some human activities that upset ecological balances have led to burgeoning populations of several species now considered overabundant, again presenting conservation challenges." (Ibid., p. 4) These changes also increase the susceptibility of wildlife to disease and other population health effects.

In response to these challenges, the government is currently considering new legislation for the protection and recovery of endangered wildlife. As proposed, the CWS will be responsible for much of the *Species at Risk Act (SARA)*. It is unclear at this time what will be the specific implications of SARA for the NWRC. But clearly, SARA will bring new requirements for research in support of conserving an increased number of wildlife species. The NWRC will likely require increased research capacity, beyond its historical emphasis on birds, to meet the challenges of SARA.[16] Indeed, improvements to research capacity, in terms of expertise, facilities, and funding, is a common challenge across many government laboratories. CWS has created the Wildlife Research Task Force which, among other efforts, is seeking opportunities to enhance CWS's science partnerships. The Task Force intends to examine university partnerships, in particular, as a strategy to address science capacity concerns.[17]

At the same time that SARA focusses attention on a range of individual species, another key challenge in wildlife research is the gradual shift in focus from a species-specific orientation and a focus on individual chemicals and toxins to a "landscape" or "ecosystems" orientation. An increasing awareness of the diverse impacts on wildlife habitats is forcing a shift in conservation thinking from the individual to the systemic. The need for "landscape-level" approaches to conservation challenges the traditional modes of research and expertise directed at a single or a very few species. The challenge of revitalizing research capacity at NWRC, therefore, is not necessarily a question of merely replacing "rusted-out" infrastructure or restoring lost expertise along historical requirements but identifying what capacity is required to meet current needs and emerging challenges. Meeting this challenge has implications for institutional design and is, at least partly, responsible for the NWRC's lack of a traditional "silo structure" common to hierarchies and its greater use of formal networking in recent years.

Another potential challenge referred to previously is the interesting tension between research oriented toward "wildlife conservation" for its own sake versus research on "wildlife as indicators" of broader environmental problems. It is not at all clear how the appropriate balance between these two emphases is determined at the NWRC. While other government laboratories have made use of external advisory bodies to provide independent, expert advice on such strategic issues, the NWRC does not currently have in place an advisory body that could provide laboratory-wide advice across its mandate and research objectives.

A final challenge facing the NWRC is one faced by all government laboratories. This is the persistent call that these institutions become more involved in industrial assistance and economic development. (Doern and Kinder, 2001) Given its research emphases, it is highly unlikely that the NWRC could contribute in any meaningful way to such a mandate. What is often overlooked in arguments for greater industrial relevance or more market-oriented approaches is the key role played by some government laboratories in providing "public good" science; the type of research that contributes to important regulation and risk management roles of government but that have little direct relationship to economic innovation.[18] A key question is to what extent should the

---

[16] Although there is some indication that much of the SARA-related research will be done via contract with academics and others, rather than in-house, it can still be expected that the NWRC will require additional capacity to deal with a broader range of species.

[17] Note that the adage "you need to bring money to get money" applies here. In order to have influence on the work done by partners, the NWRC will have to bring money to the table.

[18] Indeed, some science recommendations relating to risk management may even inhibit economic

value of government science be based on its potential to support economic development, risk management, development of policy and regulation, etc.

Even where it is accepted that some government laboratories will necessarily fulfill non-economic development roles, there may still be pressure, given the enthusiasm for the so-called New Public Management reforms, for these laboratories to adopt more market-oriented or business-like approaches in their operations. As has been shown, the NWRC has not for the most part adopted such approaches. A key question here is to what extent the NWRC could or should be expected to do more in this area, given its mandate for non-market-oriented, public good research. In considering the answer, it should be recognized that such practices may alter the organizational culture to the extent of weakening the NWRC's ability to conduct public good research and related scientific activities. It is likely that the NWRC will continue to face such pressures in the future.

Conclusions

This paper has examined how the National Wildlife Research Centre has changed in the last decade as a federal S&T laboratory and institution. We have not sought to assess the substantive S&T activities and contributions of the NWRC's research groups but we have shown how the NWRC has had to respond to, take advantage of, and in other senses adapt and survive amidst changing policies at the federal level and in the underlying dynamics of wildlife research and conservation. Thus, the NWRC has had to relate to: changes in budgetary support (e.g., the demise of the Green Plan, Program Review budget cuts, policy funds); changes in public service delivery policies and expectations (leveraged funding, networking, partnerships, alternative service delivery); changes to environmental and wildlife research priorities and approaches (e.g., sustainable development, climate change, species at risk, ecosystem-level approaches); and changes in S&T policy in which views about the roles of labs were not first order concerns but where such changes had, perhaps unintended but often adverse, effects on the laboratories (e.g., the shift from science policy to innovation policy with emphasis on economic development roles of government S&T). We have shown that the NWRC has certainly faced these pressures and sought to carry out good work in the context of its changing mandate, constrained resources, and ageing infrastructure.

In common with the larger CRUISE research study of three other federal laboratories, the paper has employed a "hierarchies-networks-markets" typology as an organizing and analytical concept to understand how the NWRC has coped and changed as an institution. The use of this approach was based partly on a view that federal S&T policy towards government laboratories will not fully succeed if labs such as the NWRC are not understood as institutions and if the institutional diversity across labs is not better understood and reflected in such policies.

---

development, or at least be seen to do so.

Indeed, one of the concluding observations to make about the use of an explicit institutional analysis is that there is also great institutional diversity *within* a lab such as the NWRC. Another observation which emerges immediately from thinking more concretely about institutional evolution is that it is not an easy thing to determine where the boundaries of the NWRC as an organization lie and where the boundaries between the public and non-government sectors now reside. In a certain, albeit imperfect sense, the hierarchies, networks, and markets framework is designed to force us out of some of our possibly too easy interpretations about what goes on inside the various "black boxes" of government, in this case the "black box" of one government laboratory. As stressed from the outset a "lab" must be seen as an institutional melange of fixed laboratory assets, S&T specialists engaged in research and related scientific activities, policy-centred funding mechanisms, and complex brokerage activity involving dedicated public servants who, in the majority, consist of S&T experts.

When looked at as a hierarchy, we conclude that the NWRC is a rather flat structure and functions in a more collaborative and horizontal manner than traditional hierarchical bureaucracies. But notions of lessened hierarchy cannot necessarily be associated with reductions in other kinds of bureaucracy. There are also important kinds of procedural bureaucracy that emerge from the new array of partnerships, performance indicators, and rules which accompany new interdepartmental funds. Thus, the NWRC is smaller and less hierarchical than in the past though still exhibits important features of hierarchies.

The NWRC is clearly a highly networked organization including both informal and formal relationships within Canada and internationally. In particular, networks involving universities, non-governmental organizations, and other government departments are important and are increasingly being formalized in order to support program delivery. The NWRC is often in a lead position within these networks. Networks involving business and industry are virtually non-existent. Indeed, the lack of any market orientation is probably responsible for the NWRC's heavy use of network forms of organization and program delivery along with some hierarchical characteristics.

In terms of a market orientation or business-like operations there is very little to speak of at the NWRC. However, it must be reiterated that this is not surprising given the NWRC mandate to deliver public good science and the lack of any commercial interests in this type of research. It makes some limited use of contracts but rarely employs cost-recovery approaches to service delivery. The NWRC has few if any relationships with, nor receives any funding from, business or industry.[19] There is very little intellectual property activity in terms of technology transfer, product development, patenting, or licensing. No spin-off companies have been created from the NWRC.

[19] Note that in the regions, industry occasionally contributes funds towards specific research projects.

The NWRC has changed and continues to change as an S&T institution. It has had to cope with budget cuts, an ageing workforce and infrastructure, changing research priorities and shifting government expectations, while continuing to provide unique and high quality outputs in support of wildlife research. The imminent relocation to Carleton University provides a new beginning that will surely present both new challenges and new opportunities.

CHAPTER 4

THE ATMOSPHERIC AND CLIMATE SCIENCE DIRECTORATE (ACSD)

The purpose of this chapter is to examine how the Atmospheric and Climate Science Directorate (ACSD) of the Meteorological Service of Canada (MSC) has changed over the last decade as a federal science and technology (S&T) institution and to highlight some of the key challenges it faces in going forward. The information on the ACSD was collected during the latter part of 2002 and early 2003 through interviews with ACSD managers, scientists and staff members and a review of MSC publications and other key documents. These are listed in the Bibliography.

As a directorate managed by a Director General with staff at multiple sites performing a variety of S&T functions, the ACSD is a somewhat different breed than the other "labs" studied. In addition, the ACSD is closely connected with the operations side of the MSC in the provision of weather forecasts and other science-based services. As with the other labs examined, the ACSD is a complex S&T institution fulfilling diverse roles and functions. Scientific activities at the ACSD extend beyond traditional research to include various related scientific activities.

Even what is included under "research"must be further examined in the ACSD context. In addition to the traditional scientific activities of making observations, conducting experiments and developing and testing theories, the ACSD engages in pioneering work in *modelling*. Modelling is a relatively new form of scientific endeavour quite distinct from traditional "bench" or "field" science. Obviously, researchers interested in understanding the dynamics of the earth's weather or climate over vast spatial and temporal scales are not able to "stop the world" in order to run controlled experiments. Fortunately, the vast increase in computing power in recent decades has enabled the use of supercomputers for modelling, or simulating experiments that could not be conducted in a laboratory. Indeed, the use of modelling "has become so great that it must now be considered a third pillar, along with theory and experiment, in the triad of tools used for scientific discovery" (U.S. DOE, 2003). The ACSD is at the forefront of the use of modelling to advance our understanding of the atmosphere and climate change.

Origins, Mandate, and General Features

The Meteorological Service of Canada (MSC) has evolved out of what was first established in 1871 as Canada's national weather service. After the Second World War, the need for weather information for aviation purposes grew substantially and the service came under the management of the Department of Transport. Then in 1971 the meteorological and hydrological functions of the weather service were transferred to the newly created Department of the Environment. In the mid-1990s there was consideration given to separating MSC as a special operating agency. This did not come to pass but in 1999 the MSC was designated a "departmental service organization" within Environment Canada.

The MSC has set as its long-term vision to be the recognized authority and source of science and information on weather, climate, water, atmospheric chemistry, and air quality. In achieving this vision the MSC faces major challenges related to limited resources and broadening mandates. The MSC has developed a strategy for R&D reinvestment that emphasizes severe weather, new observation strategies, environmental prediction, and science integration and communications. In implementing this strategy, the MSC will place greater emphasis on research networks and partnerships with universities and other collaborators.

Within the MSC, the Atmospheric and Climate Science Directorate (ACSD) is the focal point for atmospheric and climate research and development and related scientific activities. Although the ACSD does not seem to have a formal "mission statement" per se, according to its Web site the ACSD:

> "conducts research in climate, meteorology, air quality, and environmental impacts and adaptation. It produces science assessments on pressing environmental issues (such as climate change, acid rain, and the depletion of the ozone layer, etc.) for Canadians and government policy makers. Important components of this research are atmospheric and meteorological monitoring networks, process research studies (including field experiments), and the development of supercomputer models for environmental and weather prediction" (MSC, 2002e).

The Directorate's products are "used to forecast atmospheric changes and help Canadians adapt to them, and to prevent or mitigate atmospheric catastrophes" (MSC, 2002e).

Even more than the other EC labs studied, the ACSD is a dispersed entity located at multiple sites. The bulk of the Directorate's S&T activities are located at two sites: 1) the MSC headquarters and Thompson Laboratory in Downsview, Ontario, just north of Toronto, and 2) the Canadian Meteorological Centre in Dorval, Quebec, just west of Montreal (which also houses the operations side of the MSC). In addition, since 1993, the Directorate's climate modelling group has been located at the University of Victoria in order to better access the modelling expertise located there. Other sites include research stations and observatories in various, often remote, locations throughout Canada. Some of these facilities represent nodes of international atmospheric monitoring networks. Among these sites are:

- the Bratt's Lake Station, near Regina, Saskatchewan;
- the King Weather Radar Research Station, near King City, Ontario;
- the Centre for Atmospheric Experiments (CARE), in Egbert, Ontario;
- the Alert Global Atmospheric Watch Observatory, on the northeastern tip of Ellesmere Island, Nunavut;
- the Eureka Arctic Stratospheric Ozone Observatory, in Nunavut; and
- the Dry Deposition Research Centre at the Canadian Forces Station Camp Borden, Ontario.

In addition, as will be discussed further below, much of the Directorate's work is done in collaboration with academic research centres at universities across Canada.

The ACSD consists of the Director General's office and the following five units:

- the Air Quality Research Branch;
- the Meteorological Research Branch;
- the Climate Research Branch;
- the Adaptation and Impacts Research Group; and
- the Science Assessment and Integration Branch.

The basic characteristics and major functions of these units are briefly described below. While it is not possible here to describe each unit in full, what follows provides a flavour of the diversity of the S&T activities within the ACSD. For more details on the activities and accomplishments of each unit refer to MSC, 2002b.

Director General's Office

Consisting of the Director General and nine staff members, the Office provides strategic planning and research policy development, and manages the ACSD's financial and human resources functions. It manages the Visiting Fellowship Program, the MSC Scholarship Program, the Industrial Research Chairs Program, and youth employment programs. The office represents the ACSD on MSC and departmental management committees and on collaborative initiatives with external agencies.

Air Quality Research Branch

Consisting of 133 staff members, the Air Quality Research Branch (AQRB) is the largest in the Directorate. The AQRB was formed in 1971 with an initial emphasis on acid rain. Its R&D emphases have since evolved to address a broad range of air quality issues including smog, acid deposition, hazardous air pollutants, stratospheric ozone and greenhouse gases. However, rather than organizing its sub-units around specific issues, the Branch maintains four pools of expertise relevant to the R&D components common to all such issues—systematic measurements, field studies, data analysis, and numerical modelling. The Branch's divisions are organized largely around these components and the required expertise is combined as necessary, on a project basis, to investigate various air quality issues.

The *Measurements and Analysis Research Division* develops methods for routine monitoring of air quality. Through various observing networks it conducts systematic measurements of the long-term trends and variability of trace gases in the atmosphere, and analyses the potential impact of human activities on the atmosphere. In addition, the Division develops leading-edge data analysis techniques.

The *Processes Research Division* leads the Branch in the design and implementation of intensive field studies. Through these studies and the development of advanced measurement methods, the Division seeks to better understand the underlying physical, biological and chemical processes that determine the chemistry of the atmosphere. In short, the Division's scientists study "how chemicals enter, move through, and exit the atmosphere" (MSC, 2002b).

The *Modelling and Integration Research Division* carries out modelling research on the transport, transformation and removal of pollutants by the atmosphere. It develops air quality models that are used to support policy development in evaluating potential emissions scenarios. It also ensures that models are transferred to MSC Operations for service delivery through the production of air quality forecasts and advisories.

The *Experimental Studies Division* is the Branch focal point for the study of ozone depletion and the photochemical balance of the stratosphere. It conducts both ground-based and space-based measurements of radiation and maintains key international radiation measurement standards. In 1992, Canada became the first country to implement an Ultraviolet (UV) Index program that provides Canadians an indication of the daily sunburning power. This index has been adopted by the World Meteorological Organization and World Health Organization and is now operating in many countries.

Meteorological Research Branch

The Meteorological Research Branch (MRB) represents the Service's traditional core scientific effort in that it conducts the R&D that is needed to improve operational weather and environmental predictions and severe weather warnings in Canada. With 85 staff members, the Branch is organized into three divisions that focus on, respectively, cloud physics, data assimilation and satellite meteorology, and numerical predictions research.

The *Cloud Physics Research Division* studies fundamental atmospheric processes including the basic physics and chemistry of clouds, freezing processes related to aircraft icing, and fog/water processes. In addition to improving weather predictions and climate models, this research seeks to improve aircraft safety by determining safe operating conditions and safe aircraft design elements. The Division operates the doppler radar research facility near King City, Ontario.

The *Data Assimilation and Satellite Meteorology Division* focuses on the use of remote sensing technologies such as satellites and Doppler radars to monitor meteorological conditions and severe weather events. Canada does not operate its own weather satellites but rather relies on those operated by the United States and, increasingly, by agencies in Europe and Japan. These systems can provide measurements with greater frequency and over larger areas than traditional ground-based observers and weather balloons. Reflecting the increasing importance of remote sensing, the Division staff grew from 1 in 1988 to about 25 today. Additional research is concerned with developing advanced techniques for assimilating the data gathered through these remote sensing technologies with the data gathered through traditional in-situ observations. The Division also conducts R&D on remote sensing of sea ice in support of the Canadian Ice Service.

The *Numerical Prediction Research Division* advances numerical and statistical techniques to further improve the highly sophisticated weather prediction models run on the MSC's supercomputer to generate weather forecast information. Chief among these numerical models is the multi-scale Global Environmental Model used for short and mid-term operational weather forecasting. A recent international peer review of this model held it up as "a world leader," representing "the leading edge of the science" (MSC, 2002d). Among the Division's priorities is to further advance the atmospheric models by coupling them with oceanic and hydrology models in order to better predict flooding, ice cover, and climate change as well as developing integrated atmospheric and chemical models to better model air quality. The Division has also made significant progress in simulations of wind energy which are of interest to the nascent wind energy industry.

Climate Research Branch

The 63 members of the Climate Research Branch (CRB) conduct both field and airborne experiments as well as modelling research and development in support of advancing climate and climate change science. The Branch consists of three divisions directed at understanding the climate system—through modelling, investigating fundamental processes, and assessing the current state of climate—in support of policy development and decision-making on issues of climate change.

The *Climate Modelling and Analysis Division* was formed in 1993 when its predecessor organization in the former Canadian Climate Centre was relocated to the campus of the University of Victoria. This was done to better access the West Coast expertise in ocean and sea-ice modelling. The Division's mandate is to develop and use climate models that combine atmospheric, oceanic, land surface and sea-ice models in order to improve understanding of present, past and future climates. The Division makes more than 2800 years of climate model output available to researchers via its Web site. In addition, the Division works with the Meteorological Research Branch and the Canadian Meteorological Centre to improve seasonal forecasting.

The *Climate Processes and Earth Observation Division* recognizes that the interactions between the atmosphere and its underlying land surfaces need to be more realistically included in climate models. To this end, the Division conducts a combination of field and model studies to improve understanding of energy, water and carbon cycles, with an emphasis on cold climate processes. Particular attention is placed on the role of the cryosphere consisting of the world's ice masses and snow deposits.

The *Climate Monitoring and Data Interpretation Division* monitors and analyses the Canadian and global climate through the acquisition, adjustment and analysis of observed data. This data is collected from a network of observation stations which are increasingly being automated. In addition, the Division reconstructs climate indicators from proxy data such as through the analysis of tree rings or borehole data. The resulting datasets document climate trends and variations and are used by ACSD and external scientists to better understand and attribute these changes to global warming, ocean circulation changes, or other causes.

Adaptation and Impacts Research Group

Established in 1994, the Adaptation and Impacts Research Group (AIRG) conducts research on the impacts of climate, air quality, and weather on human health and safety, economic prosperity and environmental quality. The Group works with universities and stakeholders to develop research capacity, tools and methodologies in support of atmospheric change impacts research and new approaches for the evaluation of adaptation options and strategies. In short, the Group attempts to address the questions "So what?" and "What should we do about it?" and provide that information to decision-makers and the public in support of reducing vulnerabilities and seizing opportunities. To this end, the Group often publishes both technical and "plain language" documents. It also has co-hosted the first international symposium on communicating climate change to explore effective communication and outreach strategies and the role they play in responding to climate change.

The Group's research consists of a mix of the physical and social sciences. Rather than build up and maintain an in-house capacity in the social, behavioural and policy sciences, it was decided that the Group's work would be conducted largely through regional, national and international partnerships and collaborations. Through formal arrangements with the Universities of British Columbia, Waterloo, and Toronto, the Group's 11 staff members, all federal employees, are actually co-located in academic institutes and faculties. They report to the Branch Director, the only AIRG employee at the Downsview office. The Group is funded through A-base funds at approximately $1.1 million and receives another $1 million in soft money from sources such as the Climate Change Action Fund, the Canadian International Development Agency and United Nations agencies. Part of the research team also receives a small amount of industry funding.

Science Assessment and Integration Branch

The Science Assessment and Integration Branch (SAIB) is a small unit that provides a rather unique bridge across the science / policy interface. The 13 staff members view themselves as "advisors" who facilitate communication between, on the one hand, the ACSD's "researchers" (and the broader atmospheric scientific community) and, on the other, the "policy" staff within Environment Canada (and the broader policy community in federal/provincial venues, in the North American context, and internationally). The Branch is totally funded through A-base money from the Weather and Environmental Prediction business line.

The Branch performs three primary functions: 1) science assessments, 2) science advice, and 3) communications/knowledge management. Under the first activity, the Branch engages in formal, peer-reviewed assessments of the state of the science in areas such as smog, ground-level ozone, and climate change. These assessments do not generate primary research knowledge but rather seek to synthesize the results of existing research studies, identify the current knowledge gaps, and package the information in a way that will be useful for policy makers. The actual assessment *process*, which is considered to be as important as the *content* in establishing the credibility of the assessment, differs with each issue; it ranges from in-house advisors pulling together the results from published reports for a rapid turn-around assessment, to bringing together multi-disciplinary teams of researchers from multiple sectors for more medium-term assessments, to managing Canada's participation in major, long-term international assessments such as those coordinated through the Intergovernmental Panel on Climate Change.

The second function includes the more ongoing and ad hoc provision of science advice to the department's policy sector and other stakeholders. Activities range from preparing briefing notes for senior officials to participating in the department's consultation processes on new legislation. The Branch often serves as an entry point for those seeking advice by assisting them in identifying the most appropriate experts within the research branches.

The third, "communication" function involves a lot of "teaching" of the science behind a policy issue, whether for the Minister, departmental policy advisors, or the public. Indeed, the Branch has an explicit focus on public outreach. A Branch science advisor is identified as the spokesperson for each issue and the Branch provides multi-lingual products and services (e.g., Web sites, CD-ROMs, teaching aids) to facilitate information sharing.

Key Institutional Trends

While the origins, current mandate and descriptive features provided above are an important starting point for understanding the ACSD, they do not sufficiently convey the key pressures and dynamics of change in the last decade. This section will briefly review major changes and trends in key institutional indicators such as formal organizational structure and culture, research emphases, funding, personnel, and infrastructure during recent years.

One of the most basic changes of the last decade which affected many federal S&T institutions was the government's general shift in policy preference toward having basic research conducted in the university community rather than internally. Commenting on this shift, an international peer review panel viewed it as having a positive impact on the ACSD by expanding the science base but cautioned that the transfer does not negate the need to maintain a strong internal capacity in order for the ACSD to remain a "smart buyer" of science from academe. The policy shift is reflected organizationally in ACSD by the transfer of the Adaptation and Impacts Research Group to university locations and well as the general increase in networking and collaborative activity with universities discussed further in section IV below.

Another basic change to the organizational structure was the transfer into the ACSD of the Science Assessment and Integration Branch. Prior to 1999 the SAIB was located within the policy arm of the MSC. In January 1999 it was moved to be co-located with the ACSD researchers in order to ensure stronger linkages between the SAIB and the working scientists.

These structural changes have led to another important shift in recent years relating to the nature of the S&T work performed by the ACSD. Throughout the decade the ACSD's primary focus was on conducting, funding and facilitating research and development (R&D). In recent years, with the transfer of the science assessment and the impacts and adaptations analysis efforts into the Directorate, the ACSD's portfolio includes more social sciences research and S&T work categorized as "related scientific activities" (RSA). To some degree this changes the traditional organizational culture of the Directorate and introduces different challenges with respect to human resources management and performance measurement.

The evolution of the Directorate's research emphases also reflects shifting government priorities, new opportunities or simply the advancement of scientific understanding. One of the most obvious changes during the decade was the increased importance placed on the whole issue of climate change. With the declaration on climate change at the 1992 Rio Summit followed by the Kyoto Protocol in 1997, as well as a series of record warm years and severe weather events, the issue of climate change received increasing attention by policy makers and the public at large. This interest is reflected in part by the establishment in 1998 of the Climate Change Action Fund to help Canada meet its commitments under Kyoto to reduce greenhouse gas emissions. The ACSD has benefited from some of this targeted funding.

In addition, the advancement of technology has led to important increases in computing power that has enabled the steady advancement of modelling capabilities. Whereas earlier models tended to focus on a single physical or chemical process, researchers are now able to couple models of atmosphere, hydrology, sea-ice, wind, waves, etc., in order to obtain more realistic and reliable predictions. Similarly, advances in remote sensing technology have led to new opportunities. For example, prior to the 1990s some satellite data had been provided to the regional forecast offices as additional support for forecasting. Over the last decade remote sensing data has been increasingly integrated into the ACSD's numerical prediction models and the standard products of the Canadian Meteorological Centre.

The Program Review of 1994-95 imposed a deep and serious review of, and reduction in, federal programs across the Government of Canada (Swimmer, 1996). Program Review required programs and activities to be assessed against several criteria such as whether government should be involved in the activity at all, what the relative role of the federal government should be compared to the provinces, and which activities were essential for the federal government as opposed to expendable. The Review was followed by major budget cuts in many of the science-based departments and agencies including Environment Canada. The MSC was not immune from these cuts.

As with many federal S&T establishments Program Review negatively impacted the ACSD budget. Its total budget dropped from almost $47 million in 1994-95 to a low of $35 million in 1998-99 and has since recovered to about $40 million. A key element of the ACSD's overall budget is the additional funds it brings in from non-A-base sources. This portion of the ACSD's budget has been generally increasing in the post-Program Review period, growing from a low of

12% in 1995-96 to 22% in 2002-03. There is some concern about the potential for "mission drift" away from the Directorate's core research mission to activities that are more immediately responsive to these non-A-base funding objectives. However, it should be noted that non-A-base funding represented 41% of the total budget prior to Program Review.

In addition, it should be noted that for the ACSD most of this non-A-base funding was derived from other federal government sources, not external sources. Thus, it can be assumed that the associated funding priorities are consistent with federal government priorities. A key aspect of the federal S&T funding context over the last decade was the increase in the use of horizontal (inter-departmental) or targeted program funds. These include the Program on Energy Research and Development (PERD), the Great Lakes Action Plan, Science Horizons, the Ozone Annex, the Climate Change Action Fund (CCAF), and Action Plan 2000. Again, while the ACSD has been successful in obtaining resources from these various funds, there is some concern that the increased management costs associated with operating in this mode impinges negatively on the conduct of R&D.

In terms of personnel the ACSD actually grew in recent years. Unfortunately, staff data was unavailable from ACSD for years prior to FY1996-97 so it was not possible to analyze the effects of the 1994-95 Program Review on staff levels using a single consistent data set. Data from another source shows a decrease from 319 employees in FY1994-95 to 274 employees in FY1996-97.[20] And ACSD personnel confirmed in interviews that there were some involuntary departures during that down-sizing period. According to ACSD data, in 1996-97 the full time equivalent total was 279 and has since grown to 316 (as of October 18, 2002), or approximately back to its pre-Program Review level. This 13% increase is almost completely accounted for by an increase of scientific staff, particularly in the physical sciences and chemistry categories, while the levels of technical support staff and administrative staff remained basically flat. This staffing pattern has led to a current distribution of labour as follows: 66% "scientific" including (from greatest to fewest) research scientists, physical scientists, meteorologists, chemists, research managers, and mathematicians, 17% "technical" including (from greatest to fewest) engineering technicians, electronic scientific support, and engineers, and 17% "administrative support" including (from greatest to fewest) computer scientists, clerks and secretaries, administrative officers, and financial officers.

Also of note and consistent with the general trend across the public service is the steady increase in the number of term employees relative to indeterminate employees, from just 8 term employees or 3% of the total in 1996-97 to 66 term employees or 21% of the total currently. This shift towards term appointments was consistent across each of the three broad occupational categories listed above. Consistent with policy pressures to avoid the misuse of professional

[20] Data provided by Philip Enros on personnel levels in CARD, the Climate and Atmospheric Research Directorate, ACSD's predecessor organization.

service contracts, the ACSD does not make extensive use of on-site contractors. It will, at any given time, host a number of students (about 14 currently), post-doctoral fellows (about 21 currently), and visiting researchers.

A common concern for federal S&T institutions throughout the decade related to maintaining research infrastructures. The rapid pace of S&T advancements brings positive benefits but also leads to a more rapid obsolescence of R&D facilities and equipment. While the government has in recent years devoted major new funding to address Canadian research infrastructure needs through mechanisms such as the Canada Foundation for Innovation, federal laboratories are not eligible to compete directly for these funds. The Directorate benefited from larger budgets for capital investments earlier in the decade, probably related to the Green Plan investments. But maintaining the quality of research assets requires ongoing investment and there is some concern at ACSD about the need for additional capital investments. Many of the Directorate's research assets represent unique capabilities the loss of which would be difficult if not impossible to compensate for. Despite the recognized importance of the high-latitude Eureka observatory—measurements from this site have been credited with characterizing the 1997 Arctic ozone depletion event—the station was "mothballed" in June 2002 due to funding shortages. According to an ACSD document, "options for alternative funding and management are being explored" (MSC, 2002b, p. 49).

ACSD as Hierarchy

The first way to examine the institutional design of the ACSD is to explore the extent to which it is structured and behaves along classic bureaucratic lines, as well as how it functions within a larger departmental and governmental hierarchy. Max Weber, the great German sociologist, was one of the most prominent early theorists on the nature of hierarchical bureaucracies. A Weberian bureaucracy is composed of a hierarchy of office holders and division of labour based on functional specialization. Authority is exercised primarily by vertical and impersonal superior-subordinate relationships, often referred to as a "chain-of command" (Weber, 1946; Starling, 1986). In these organizations officials are salaried and hold permanent positions with selection and promotion based on qualifications and technical competence. A hierarchy features a system of rules and procedures and engages in primarily written modes of communication to ensure accountability (Hood, 1998; Pollit and Bouckaert, 2000). Organization by hierarchy is intended to produce reliably predictable behaviour, a highly valued capacity especially when linked with responsible government (Doern and Kinder, 2000), though it is not necessarily conducive to the creative environment desired for an organization concerned with advancing scientific frontiers.

As a government entity it can be expected that the ACSD would exhibit many of the characteristics of a traditional public bureaucracy. The organization chart shows classic lines of authority and a hierarchical structure consisting of five branches with 11 divisions under the big three research branches. However, it must be noted that below the division level the structure is quite flat. And two of the branches consist of 13 or fewer people and are essentially flat. Thus, the organization chart is a bit deceiving as to the actual degree of hierarchy in ACSD. Also, the transfer of the Adaptation and Impacts Research Group to academe makes it operate in a more horizontal manner. The general trend towards more integrated modelling of weather, climate and air quality requires more horizontal operations and is in line with the ethos of "reinvented government" promoted across the federal government in an attempt to de-emphasize hierarchical levels (Aucoin, 1997; Swimmer, 1996).

Beyond the internal hierarchy, the ACSD is situated within a departmental hierarchy. The Director General reports to the Assistant Deputy Minister in charge of the MSC who, in turn, reports to the Deputy Minister of Environment Canada. According to those interviewed, most of the interaction with these higher levels of the Environment Canada hierarchy is channelled up the chain-of-command through the Directors and Director General. However, the researchers do participate in a wide range of departmental planning and coordination committees or working groups focussing on particular issues. Furthermore, the recent addition of the Science Assessment and Integration Branch has provided a focal point within the Directorate for improving communications across the science / policy interface. This move is viewed positively by both the SAIB and the other branches; if anything, now the challenge for the SAIB science advisors is maintaining strong interactions with the policy side of the house, given the geographical separation between Downsview and EC headquarters and the regional offices.

Even while "reinvented government" reforms were introduced in the federal government in an attempt to reduce certain pathologies common to hierarchies, they at the same time introduced new forms of bureaucratic processes and requirements in the interest of greater public accountability and more business-like and performance-based management approaches. This is reflected in requirements for such things as business plans, annual reports, personnel performance appraisals, etc.

All R&D activities within Environment Canada are managed within a structure of four business lines which align the department's operations to the federal government's priorities and initiatives. The four business lines are 1) Nature; 2) Clean Environment; 3) Weather and Environmental Predictions; and 4) Management, Administration and Policy. The ACSD's budget and research agendas are closely tied to two of these, namely, Weather and Environmental Predictions (WEP) and Clean Environment (CE). According to ACSD documents, the WEP business line provides 75% of all salary and operating resources while the CE business line provides approximately 19% of total funding.[21] The ACSD aligns its S&T activities to support the key results and outcomes identified for each business line.

---

[21] The remaining 7% comes from other federal government departments and programs (5%) and from external sources (2%), including some licensing revenues.

The ACSD has recently produced a multi-year retrospective "annual report" summarizing the activities and accomplishments of the Directorate during the 1996-2002 period. This document contains significant technical content and is intended primarily for government S&T managers and key scientific collaborators. The Directorate is also preparing a shorter, more glossy companion document that celebrates the ACSD's accomplishments through stories of the impacts of atmospheric and climate science. It is intended for a broader audience including potential partners and the interested public. In addition, the results of ACSD research are published through a variety of channels including government publications, technical reports, Fact Sheets, Web sites and through peer reviewed journals, conference proceedings and presentations.

Employees are assessed annually using the government's performance appraisal system. A key element of the appraisal, as with most scientific institutions, is research productivity as demonstrated through the quality and quantity of scholarly publications. Over the period 1999-2001, scientists in the big three research divisions published 512 articles in 108 peer-reviewed journals, the Adaptation and Impacts Group published 52 peer reviewed publications, and the Science Assessment and Integration Branch published 14 peer-reviewed publications and prepared 11 major assessments over the 1996-2001 period. The importance placed on publication citations is illustrated by this passage from the annual report: "The importance of this discovery can be gauged by the remarkable 282 times that their paper, published in *Nature*, has been cited since its appearance in 1988" (MSC, 2002b, p. 43).

A final way to examine the ACSD as hierarchy centres on human resources policies and processes. In order to continue to provide its clients with cutting edge science and science advice, a government laboratory must continually renew the knowledge embodied in its human capital. The federal S&T workforce is facing a "demographic bulge" in which close to 20% of S&T workers will become eligible to retire without pension penalty in the next five years (CSTA, 2002). While the retirements may present opportunities to redirect S&T efforts towards new and emerging research areas, the loss of institutional knowledge and expertise may present a challenge in the short term.

The ACSD has not escaped this demographic problem and many of those interviewed view human resources management to be the chief challenge in coming years. The ACSD has been able to attract graduate students and post-doctoral fellows, many of whom stay on as employees. It also hosts visiting scientists as well as scientists seconded from other government departments. Nevertheless, continuing to attract younger staff will be critical not only to replace retiring researchers but also because of their importance in maintaining a vibrant and stimulating research environment by bringing new energy, different approaches and more recent S&T knowledge to the organization. But whereas some government S&T establishments have been granted greater independence and flexibility with respect to hiring, the ACSD must comply with and operate within the public service human resources system which is often seen as a barrier to effective human resource management. New legislation related to the government's HR Modernization Initiative may improve this situation.

ACSD as Network

In contrast to hierarchies, networks are a way of organizing that involve horizontal exchanges of information and expertise, shared accountability, and relations based primarily on trust and collegiality rather than rules and authority (Rhodes, 1997; Thompson et al, 1991). Networks can be formal or informal but, to be successful, must have conventions about how trust-based exchange is maintained and enhanced. Networked forms of organization are common among scientific and professional groups, and federal scientific institutions were network-based historically long before networks and partnerships became managerial fashion.

Internally, as has been discussed, the ACSD informally networks based on discipline or project activity as researchers across the branches and divisions collaborate with one another. For example, the Meteorology Branch collaborates with the Climate Branch on producing seasonal forecasts and it collaborates with the Air Quality Branch on development of air quality forecast models. Another indicator of internal ACSD networking are the 11 cross-branch journal publications (i.e., co-authors from two or more branches) published between 1999 and 2001. In terms of networking across the Meteorological Service there are many examples such as how the ACSD's numerical weather prediction modelling and data assimilation activities are performed in close partnership with the operational Canadian Meteorological Centre to ensure the smooth transfer of technology into operations.

But the more common notion of networks in the current era centers on what kinds of partnerships and other relationships are fostered with key *external* stakeholders and S&T institutions such as in the broader Environment Canada matrix, other government departments, provincial and municipal governments, universities, industry, and non-governmental organizations (NGOs). ACSD scientists are closely networked with the broader atmospheric and climate science community, both domestically and internationally. ACSD networks primarily involve other parts of Environment Canada including the Regions, other federal departments, and universities. Interactions and networking with the private sector and NGOs are less common. This section will highlight some of the types of networking, both formal and informal, employed at the ACSD.

Networking within Environment Canada and the Regional Offices

The ACSD collaborates with other parts of Environment Canada and its Regions. According to MSC 2002b, collaboration occurs among the department's three services—the MSC, the Environmental Protection Service, and the Environmental Conservation Service—on priority setting, policy development, international negotiations, method development and use of facilities and expertise. ACSD also collaborates with the EC Regions on priority setting, program development, research projects, measurement programs, publications, and service delivery. Examples include:

- The Air Quality Research Branch cooperates with EC regional staff in the operation of approximately 40 monitoring stations in locations ranging from the Pacific to the Atlantic, and from the Great Lakes to the high Arctic.
- The Meteorological Research Branch collaborates with EC regional science units and the EC regional weather centres on a continuing basis to improve the science underlying Canada's operational weather prediction and warning programs.
- The Atlantic Environmental Prediction Research Initiative involves the ACSD with collaborators at Dalhousie University and in industry to develop an environmental prediction capability in the Atlantic Region.

Networking with Other Federal Departments and Other Governments

The ACSD works collaboratively with a number of other federal government departments and, to a lesser extent, provincial and municipal governments. Examples include:

- Collaboration with the National Research Council's Institute for Aerospace Research to operate the Environmental Research Aircraft Facility. The ERAF has expanded the measurement capabilities of the Convair-580 and Twin Otter aircraft that are provided by NRC to support ACSD's research needs. In addition, an informal arrangement with the Canadian Forestry Service has been used to develop a small, inexpensive Cessna platform for certain specific requirements.
- The Aircraft Icing Research Alliance, of which MSC, NRC, NASA and Transport Canada are members, was formed after several aircraft disasters in which icing was the primary cause occurred during the past decade. Funding sources included Boeing, the National Search and Rescue Secretariat, NASA, the Federal Aviation Administration, and Transport Canada.
- In partnership with the Geodetic Survey Division of Natural Resources Canada, research is underway to evaluate the usefulness of water vapour information that is retrieved from ground-based Global Positioning System receivers. As one interviewee remarked, "Their noise is our signal."
- Collaboration also occurs with the Canadian Council of Ministers of the Environment and with provincial and municipal governments on the development and delivery of air quality indexes, forecasts, and advisories, Canada-wide Standards, monitoring and data exchange, and priorities and logistics for field studies (e.g., Pacific 2001, Toronto Niagara Region Study).

Networking with Universities

The ACSD exhibits particularly close ties with the university sector through personal, informal networks with academic researchers as well as more formalized relationships. Many ACSD researchers serve as adjunct professors and graduate student supervisors with a view to building capacity in atmospheric and climate sciences and in environmental impacts and adaptations research both in Canada and internationally. At any given time the ACSD hosts a number of graduate students and post-doctoral fellows who work with ACSD scientists and make use of its facilities. The MSC provides annually up to five graduate supplements to NSERC scholarships to encourage graduate research in areas of interest to the ACSD and to increase contacts with and training of potential candidates for future employment at the MSC.

For the most part, universities are certainly not a key source of funds. In fact, in the last few years they have often been viewed by the federal S&T community as competitors for federal research funding. This perspective was enhanced by the government's creation of new foundations and funds for which universities were eligible to compete but federal laboratories were not. However, the ACSD has established extensive bi-lateral arrangements with certain universities and has been instrumental in establishing broad-based partnerships involving the academic sector. The motivation for this networking activity was not (at least primarily) as a way to obtain additional funding but as a way to promote research collaboration in order to build capacity and access expertise.

One formal network involving the ACSD with academe is the Canadian Foundation for Climate and Atmospheric Sciences (CFCAS). The CFCAS was established by the government in its 2000 Budget with a one-time $60 million grant to be disbursed over six years. The Foundation supports research networks and projects centred around universities following consultations with MSC and other government agencies on their strategic scientific needs. ACSD researchers are active participants in many of the funded networks.

International Networking

Atmospheric and climate research, because of the transboundary nature of its subject, is of global interest and concern. Canada has a strong international reputation in atmospheric and climate science and the ACSD works closely with its counterpart organizations around the world. This collaboration works through both bi-lateral or regional agreements and networks such as the Canada-U.S. Air Quality Agreement, the tri-lateral North American Research Strategy on Tropospheric Ozone, and the Commission for Environmental Cooperation, as well as multi-lateral, international bodies and programs such as the World Meteorological Organization, the United Nations Economic Commission for Europe, and the Intergovernmental Panel on Climate Change. Many of the Directorate's scientists serve as Canada's representatives to these various international bodies. The partners benefit from collaboration on the development of research strategies, coordination of intensive field studies, monitoring protocols, data quality management and data exchange standards, and environmental assessments.

Another example of international networking is the use of experts from the U.S. and the U.K. on a recent peer review panel. The panel was invited to review all aspects of MSC R&D with particular emphasis on excellence, relevance and impact of the science and to provide recommendations to senior management. This form of networking not only provides an independent, expert assessment but allows for informative exchanges between the panel members, ACSD scientists, as well as external collaborators, clients and peers.

Networking with Non-government Organizations (NGOs)

In general, the ACSD does not have extensive collaboration with NGOs. The Adaptation and Impacts Research Group is perhaps the most closely connected to this community. In its research on human health and safety impacts the AIRG has collaborated with NGOs such as Pollution Probe and the Institute for Catastrophic Loss Reduction. In the area of natural ecosystem and water resources issues it has collaborated with the Soil and Water Conservation Society, Ducks Unlimited and the Great Lakes Coastal Wetlands Monitoring Consortium.

Networking with the Private Sector

Linkages between the ACSD and private sector partners are less common. This is not due, as with some laboratories, to an explicit concern about interacting with an industry for which the laboratory provides the scientific basis for regulation of that industry; rather, it is a reflection that there simply is not much of a commercial market for the results of ACSD R&D and RSA nor are there many private sector performers of atmospheric and climate science research. Unlike some of the other Environment Canada laboratories, such as the Environmental Technology Centre, which have key industrial sectors (e.g., automotive, petrochemical) as major clients and partners, the ACSD's major clients and partners are primarily within the public sector and academe.

There are, however, some exceptions. For example, ACSD works with The Weather Network, a private sector entity that provides value-added weather products. ACSD also enjoys some co-funding of research by the energy sector. In particular, the Meteorology Branch's growing expertise in the area of wind energy modelling has resulted in partnerships with engineering consulting firms and power-providers interested in the field of wind energy prospecting.

ACSD as Market

The final institutional design consideration is to examine how the ACSD behaves as a market or market-like organization. In short, the ACSD exhibits very little commercial orientation and has limited links to the private sector. This is not surprising given its predominantly "public good" mandate. The ACSD does exhibit some business-like practices which will be explored in this section.

The ACSD is an institution within a traditional line department of government. It is not a more arms-length Crown Corporation such as Atomic Energy of Canada Ltd., nor a departmental corporation such as the National Research Council. These and other government labs[22] have in place or are experimenting with business-like independent boards of directors. The ACSD is ultimately governed through the MSC and Environment Canada hierarchy and, thus, such governing boards would be inappropriate in this context. In addition, ACSD has not made use of

[22] Such as the Communications Research Centre.

an independent board of advisors, although it would fall within the purview of the MSC's service-wide Advisory Board.

Created in 2001, the Advisory Board consists of senior executives from various stakeholder and client groups. The Board provides client-focussed advice to the Assistant Deputy Minister on MSC's programs and priorities, reviews technical reports, and promotes cooperative efforts involving MSC and the private sector, other government departments, universities, and provincial governments. Although the Board's composition primarily reflects key clients (including "clients" within Environment Canada), a scientific perspective is provided by some members with a research background including the Special Science Advisor to the Deputy Minister. More focussed and S&T-specific advice is obtained by ACSD from external advisors through activities such as the recent formal Peer Review as well as more informally through ACSD's participation in various international programs and committees.

The discussion of clients above raises another way in which the ACSD acts in a more business-like way in that it has a clear view of who its clients are. Chief among these are MSC's Regions and the Canadian Meteorological Centre which draw heavily on ACSD R&D to provide services to the public, and aviation (e.g., NAV CANADA) and defence clients (e.g., Department of National Defence, the Canadian Coast Guard). Many of the Directorate's clients have been identified throughout this document. The MSC has conducted surveys of these and other clients to assess their satisfaction with the ACSD. Results from these surveys were provided as background to the peer review panel. Thus, a client-orientation and client-based performance metrics have been adopted by the ACSD.

Another area of market-like change in federal S&T is in policies and practices regarding intellectual property. Management responsibilities for intellectual property were assigned to science-based departments in the early 1990s. The ACSD has not been extensively active in the commercial licensing of intellectual property although it is the source of some additional revenues. The Air Quality Branch has developed the Research Data Management and Quality Control Software System or RDMQ™. This system provides a "formal objective system for quality controlling and managing environmental datasets" (MSC, 2002b). It has been licensed to the consulting industry, the World Meteorological Organization, the U.S. Environmental Protection Agency, and the department's Environmental Protection Service. The Air Quality Branch was also responsible for developing the Brewer instrument for measuring column ozone and UV radiation which was subsequently licensed to the private sector for production. This instrument has become the standard for ground-based measurements and is used in 41 countries around the globe. Finally, the Cloud Physics Division of the Meteorology Research Branch is supporting Version 5 of the Forecast Production Assistant software that is being used commercially by Weathernews International and the U.S.-based Surface Systems Incorporated (MSC, 2002b).

Another area of market-oriented activity is in the realm of encouraging spin-off companies. Some federal S&T institutions such as the National Research Council have experimented with human resources policies and related IP practices which enable, indeed encourage, employees to take an idea/technology to market by leaving NRC and forming spin-off companies. The ACSD has not fostered such policies and, to date, no spin-off companies have been formed.

Beyond these areas, the ACSD exhibits other business-like approaches. For example, the more explicit use of business plans and performance indicators are evidence of this "business practice" ethos. Nevertheless, the degree of market orientation should not be overstated.

Key Challenges

In considering the challenges being faced by the ACSD there clearly exist challenges of two types:1) scientific and 2) policy/institutional. An example of the first category is the challenge for the ACSD to align weather, climate and air quality models to allow for an integrated environmental prediction system. As discussed earlier, this has led to new research in the area of coupling a variety of numerical prediction models. Organizationally, this evolution to increasingly more integrated models will likely require greater internal networking across the Directorate as well as with a variety of external collaborators in order to draw on the necessary expertise wherever it resides.

The ACSD is also clearly experiencing many of the policy/institutional challenges common to many federal S&T institutions. Some of these flow from the trend toward decreasing A-base budgets and increasing reliance on "soft monies." While this approach has a number of benefits, the greater uncertainty of the funding creates a number of management challenges related to maintaining core capacities in both human and capital terms.

Indeed, among the most important challenges facing the ACSD, as with many government S&T institutions, are challenges related to human resources. The key problem as viewed by many of those interviewed is the ongoing renewal of the workforce. Given the large number of retirements expected in coming years it will be critical to renew the scientific staff in a way that maintains scientific excellence. The greater use of short-term employees, while beneficial in many ways, can make it difficult to ensure the long-term integrity of the research capacity. The need for capital investment in the physical assets of the Directorate is not yet considered urgent but it, too, remains a management concern.

Although the ACSD's dependence on soft money is not as great as some of the other labs studied, the International Peer Review Panel and many of those interviewed were concerned that the increasing reliance on soft money may diffuse the focus of the R&D program away from the Environment Canada mandate (MSC, 2002d, p. 3). Related to this concern, the push to operate much more in a networked mode has led to a concern that science management is being spread too thin across the many projects. Researchers believe that too often the organizational requirements–i.e., the need for administrative staff and junior researchers--are not fully taken into account when entering new collaborative arrangements resulting in scientists becoming increasingly involved in procedural paper work. This general increase in "process stuff" (e.g., seeking out and managing partnerships, attending program meetings, performance reporting and evaluations) is viewed as impinging negatively on the conduct of S&T.

In recent years there has been pressure, given the enthusiasm for the so-called New Public Management reforms, for government laboratories to adopt more market-oriented approaches in their operations. At the same time, government policies including human resource management policies limiting the use of in-house contractors and the Financial Management Act that governs how departments spend money present a number of real barriers to such practices. As has been shown, the ACSD has not been in the forefront of pursuing more market-oriented approaches. A key question here is to what extent the ACSD could or should be expected to do more in this area. In considering the answer, it should be recognized that pursuing such practices further would probably present a steep learning curve for most of the science managers and researchers who are unaccustomed to such approaches. There may also be resistance flowing from a concern that pursuing more market-oriented approaches would alter the organizational culture to the extent of weakening the ACSD's ability to conduct long-term public good research and related scientific activities, and to ensure its S&T feeds into departmental regulatory and policy missions.

Conclusions

This paper has examined how the Atmospheric and Climate Science Directorate has changed in the last decade as a federal S&T establishment. The paper did not attempt to assess the substantive S&T activities and contributions of the ACSD's research groups but has attempted to show how the Directorate has had to respond and adapt to changing policies at the federal level and in the evolution of atmospheric and climate science in particular and the conduct of government S&T more generally. The ACSD has had to relate to: changes in budgetary support (e.g., the demise of the Green Plan, Program Review cuts, and the changing mix of A-base, interdepartmental program, and external funding); changes in public service management and delivery policies and expectations (e.g., matrix management, cost recovery, leveraged funding, networking, partnerships, alternative service delivery); changes in research priorities (e.g., acid rain, smog, ozone, aircraft icing, climate change) and approaches (e.g., coupled models, remote sensing, international assessments); and changes in S&T policy in which views about the roles of labs were not first order concerns but where such changes had, perhaps unintended but often adverse, effects on the laboratories (e.g., the shift of basic research support to the university sector, the shift from "science policy" to "innovation policy" with greater emphasis on the economic development roles of government S&T). We have shown that the ACSD has certainly faced these pressures and sought to carry out good work in the context of its changing mandate, constrained resources, and an ageing workforce and infrastructure.

In common with the larger CRUISE research study of federal laboratories, the paper has employed a "hierarchies-networks-markets" typology as an organizing and analytical concept to understand how the ACSD has coped and changed as an institution. The use of this approach was based partly on a view that federal S&T policy towards government laboratories will not fully succeed if S&T institutions such as the ACSD are not understood as individual institutions and if the institutional diversity across labs is not better understood and reflected in such policies.

Indeed, one of the concluding observations to make about the use of an explicit institutional analysis is that there is also great institutional diversity *within* an S&T institution such as the ACSD. Another observation which emerges immediately from thinking more concretely about institutional evolution is that it is not an easy thing to determine where the boundaries of the ACSD as an organization lie and where the boundaries between the public and non-government sectors now reside. In a certain, albeit imperfect sense, the hierarchies, networks, and markets framework is designed to force us out of some of our possibly too easy interpretations about what goes on inside the various "black boxes" of government, in this case the "black box" of one government laboratory. As stressed from the outset a "lab" must be seen as an institutional melange of fixed laboratory assets, S&T specialists engaged in research and development and related scientific activities, policy-centred funding mechanisms, and complex brokerage activity involving dedicated public servants and collaborators and partners throughout Canada and the world.

In terms of a hierarchical organization, the ACSD does exhibit many of the characteristics common to a public institution. It consists of five fairly distinct sub-units organized along classic hierarchical lines with occasional links across them. Communications and relationships with the parent department are largely vertical through the chain-of-command. In addition, there are important kinds of procedural bureaucracy that emerge from the new array of partnerships, performance-based approaches, and rules accompanying new interdepartmental funds. Nevertheless, given its size and variety of mandates the ACSD does not seem overly "bureaucratic."

The ACSD is clearly a highly networked organization, particularly with partner organizations in other federal government departments, the academic sector, and with foreign national and international agencies. The ACSD often serves in a lead position within these networks. Networking with academic institutions is becoming increasingly important and formalized. Networks involving firms, provincial research organizations, and non-governmental organizations are less central. This is a reflection of where the research is being conducted with which the ACSD must connect. Thus, the type of scientific activities performed by ACSD heavily influences the types of networks it participates in.

In terms of a market orientation or business-like operations there are few examples to speak of at the ACSD. The ACSD makes little use of on-site or off-site contractors and does not typically employ cost-recovery approaches to service delivery. Although the ACSD relies increasingly on funding from external sources, the bulk of this comes from public funds. While there has been some licensing of products, intellectual property activity and revenue streams have not been a central concern. No spin-off companies have been created from the ACSD.

The ACSD has changed and continues to change as an S&T institution. Over the last decade it has had to cope with added functions, unsteady budgets, an ageing workforce and infrastructure, changing research priorities and shifting government policies and expectations. In response it has evolved as an institution, adopting different organizational characteristics, while continuing to provide unique and high quality outputs that advance atmospheric and climate science and support meteorological forecasting and environmental policy.

Appendix A

The authors would like to thank the following individuals for their assistance:

Michel Béland, MSC
Jacqueline Bélanger, ETC
Robert Benoit, MSC
Dan Bondy, NWRC
Hugh Boyd, NWRC
Carl Brown, ETC
Mike Bumbaco, ETC
Jean Coté, MSC

Jean-Guy Desmarais, MSC
Connie Downes, NWRC
Erica Dunn, NWRC
Philip Enros, EC
Merv Fingas, ETC
Fred Hendren, ETC
Paul Joe, MSC
Ramon Lachmansingh, NWRC

Maris Lusis, MSC
Keith Marshall, NWRC
Joan Masterton, MSC
Pierre Mineau, NWRC
Nathalie Morais, MSC
Ross Norstrom, NWRC
Francine Payne, ETC
Keith Puckett, MSC

Marjorie Shepherd, MSC
Dave Steenbergen, MSC
Roger Street, MSC
Dave Thornton, ETC
Richard Turle, ETC
Maud Voley, NWRC
Brian Wakeford, NWRC
Doug Whelpdale, MSC

Bibliography

Aucoin, Peter (1997) *The New Public Management: Canada in Comparative Perspective* (McGill-Queen's University Press).

Bozeman, Barry, and Dennis Wittmer (2001) "Technical Roles and Success of US Federal Laboratory-Industry Partnerships," *Science and Public Policy*, Vol. 28, No. 3 June, pp. 169-178.

Browne, Dennis, Ramesh Caitoo and Michael Hart (2000) "Can Eco-Labelling Undermine International Agreement on Science-Based Standards?" in Bruce Doern and Ted Reed, eds., *Risky Business: Canada's Changing Science-Based Regulatory Regime* (Toronto: University of Toronto Press), Ch. 5.

Burnett, J. Alexander (1999) "A Passion for Wildlife: A History of the Canadian Wildlife Service, 1947-1999," in *The Canadian Field-Naturalist, Vol. 113, No. 1* (Ottawa: The Ottawa Field Naturalists' Club), pp. 1-3.

Canadian Cooperative Wildlife Health Centre (1998) *Annual Report: 1997-98* (Saskatoon: University of Saskatchewan).

Canadian Wildlife Service (2000) *Canadian Wildlife Service Strategic Plan 2000* (Ottawa: Government of Canada).

Canadian Wildlife Service (2001) *Wildlife Science in the Canadian Wildlife Service: Current Activities, Report No. 1 of The CWS Wildlife Research Task Force* (Ottawa: Government of Canada).

Clarke, C. H. Douglas (1974) "Conservation of Wildlife in Canada," in J.S. Maini and A. Carlisle, eds., *Conservation in Canada--A Conspectus*, Publication No. 1340 (Ottawa: Department of the Environment, Canadian Forestry Service), pp. 189-224.

Council of Science and Technology Advisors (2002) *Employees Driving Government Excellence (EDGE): Renewing S&T Human Resources in the Federal Public Service* (Ottawa: Industry Canada).

Crow, Michael M. and Barry Bozeman (1998) *Limited by Design: R&D Laboratories in the U.S. National Innovation System* (New York: Columbia University Press).

Cybertec Consulting Group (1991) "Environment Canada R&D Profile," (slide deck dated 10 June 1991).

Dagg, Anne Innis (1974) *Canadian Wildlife and Man* (Toronto: McClelland and Stewart Ltd).

de la Mothe, John (2000) "Government Science and the Public Interest," in Bruce Doern and Ted Reed, eds., *Risky Business: Canada's Changing Science-Based Regulatory Regime* (Toronto: University of Toronto Press), Chapter 2.

Doern, Bruce (2000) "'Patient Science' Versus 'Science on Demand': The Stretching of Green Science at Environment Canada," in Bruce Doern and Ted Reed, eds., *Risky Business: Canada's Changing Science-Based Regulatory Regime* (Toronto: University of Toronto Press), Ch. 12.

Doern, Bruce (2002a) "The CANMET Energy Technology Centre: Key Features of Institutional Change" Carleton Research Unit on Innovation, Science and Environment, April.

Doern, Bruce (2002b) "The CANMET Mining and Mineral Science's Laboratory: Key Features of Institutional Change" Carleton Research Unit on Innovation, Science and Environment, April.

Doern, Bruce, Arslan Dorman and Robert Morrison (2001) "Transforming AECL Into an Export Company: Institutional Challenges and Change" in Bruce Doern, Arslan Dorman and Robert Morrison, eds. *Canadian Nuclear Energy Policy: Changing Ideas, Institutions and Interests* (University of Toronto Press), Chapter 4.

Doern, Bruce and Jeffrey S. Kinder (2001) "Federal Government Laboratories As Complex Institutions," A paper prepared for Industry Canada, (Ottawa: Carleton Research Unit on Innovation, Science and Environment).

Doern, Bruce and Richard Levesque (2002) *The National Research Council in the Innovation Policy Era: Changing Hierarchies, Networks and Markets* (Toronto: University of Toronto Press).

Environment Canada (1998) *National Wildlife Research Centre, Canadian Wildlife Service* (Hull: Environment Canada).

Environment Canada (2000) Weather and Environmental Prediction Research Agenda, 2000-2005.

Environment Canada (2001) *Canada Wildlife Act* at <http://laws.justice.gc.ca/en/W-9/text.html>.

Environmental Technology Advancement Directorate (2002) *Monthly Bulletin -- March 2002* (Hull: Environment Canada).

Environmental Technology Centre (2002) *Whence and Whither the ETC (&WTC)?--DRAFT* (Ottawa: Environment Canada).

Environmental Technology Centre (2000) *Environmental Technology Centre Biennial Report 1998/2000* (Ottawa: Environment Canada).

Environmental Technology Centre (1998) *Environmental Technology Centre Biennial Report 1996/1998* (Ottawa: Environment Canada).

Environmental Technology Centre (1996) *Environmental Technology Centre Biennial Report 1994/1996* (Ottawa: Environment Canada).

Environmental Technology Centre (1994) *Environmental Technology Centre Biennial Report 1992/1994* (Ottawa: Environment Canada).

Environmental Technology Centre (1992) *River Road Environmental Technology Centre Annual Activity Report 1991/1992* (Ottawa: Environment Canada).

Environmental Technology Centre (1991) *River Road Environmental Technology Centre Annual Activity Report 1990/1991* (Ottawa: Environment Canada).

Fingas, Merv, Kerry Ketcheson, Nanci Laroche, and Natalie Jones (2000) "Development of a New Chemical Spill Priority List," in Proceedings of the Seventeenth Technical Seminar on Chemical Spills (Ottawa: Environment Canada) pp. 211-263.

Guston, David H. (2000) *Between Politics and Science: Assuring the Integrity and Productivity of Research* (Cambridge: Cambridge University Press).

Hood, Christopher (1998) *The Art of the State* (Oxford: Oxford University Press).

Kinder, Jeff (2002a) "The Environmental Technology Centre: Key Features of Institutional Change" Carleton Research Unit on Innovation, Science and Environment, April.

Kinder, Jeff (2002b) "The National Wildlife Research Centre: Key Features of Institutional Change" Carleton Research Unit on Innovation, Science and Environment, April.

Lane, Jan-Erik (1993) *The Public Sector: Concepts, Models and Approaches* (London: Sage)

MacDonald, Mark (2000) "Socio-Economic Versus Science-Based Regulation: Informal Influences on The Formal Regulation of rbST in Canada", in Bruce Doern and Ted Reed, eds. *Risky Business: Canada's Changing Science-Based Policy and Regulatory Regime* (Toronto: University of Toronto Press) Chapter 7.

McIlroy, Anne (2003) "Tough times forecast for weather service," *The Globe and Mail*, January 18.

Meteorological Service of Canada (2000) *Meteorological Service of Canada: providing service to Canadians since 1871.*

Meteorological Service of Canada (2000) *Canadian Meteorological Centre: 2001 in Review.*

Meteorological Service of Canada (2001) *The Meteorological Service of Canada Annual Report 2000-2001.*

Meteorological Service of Canada (2002a) *The Meteorological Service of Canada Annual Report 2001-2002.*

Meteorological Service of Canada (2002b) *Atmospheric and Climate Science: Report to 2002*, Draft version, October 2002.

Meteorological Service of Canada (2002c) *Atmospheric and Climate Science: Impacts*, Draft version, October 2002.

Meteorological Service of Canada (2002d) *2001 Peer Review Research and Development Program.*

Meteorological Service of Canada (2002e) Web site < www.msc-smc.ec.gc.ca/msc/ >.

National Wildlife Research Centre (1994) *Canadian Landbird Monitoring Strategy* (Hull: Canadian Wildlife Service).

National Wildlife Research Centre (1999) "Environmental S&T Capacity in 2002: Gaps and Rusting Infrastructure," (Hull: Canadian Wildlife Service), slide deck dated February 3-4.

Pollitt, Christopher and Geert Bouckaert (2000) *Public Management Reform: A Comparative Analysis* (Oxford: Oxford University Press).

Rhodes, R. A. W. (1997) *Understanding Governance: Policy Networks, Governance, Reflexivity and Accountability* (Buckingham: Open University Press).

Starling, Grover (1986) *Managing the Public Sector* (Chicago: The Dorsey Press).

Swimmer, Gene ed. (1996) *How Ottawa Spends 1996-97: Life Under the Knife* (Carleton University Press) Chapter 1.

Thompson, Grahame, Jennifer Frances, Rosalind Levacic, Jerry Mitchell (1991) *Markets, Hierarchies and Networks: The Coordination of Social Life* (London: Sage Publishing).

Thornton, D. E. (2001) "ETC Program Planning & Reporting Approach & Mechanisms".

U.S. Department of Energy, "The Challenge and Promise of Scientific Computing" Occasional Paper #1 available at < http://www.science.doe.gov >.

Weber, Max (1946) "Bureaucracy," in H. H. Gerth and C. W Mills, trans., *From Max Weber: Essays in Sociology* (New York: Oxford University Press).

Wolfe, David (2002) " Innovation Policy For the Knowledge-Based Economy: From The Red Book to the White Paper", in Bruce Doern, ed. *How Ottawa Spends 2002-2003: The Security Aftermath and National Priorities* (Oxford University Press) Chapter 8.

Science Policy Branch - Environment Canada

Working Paper Series

1 *Environment Canada's Scientific Research Publications in 1995*

2 *Science for Sustainable Development*

3 *Communicating Science at Environment Canada: A Brief Review of Lessons Learned from Communications on Acid Rain and the Depletion of the Stratospheric Ozone Layer*

4 *The Precautionary Principle, Risk-Related Decision Making, and Science Capacity in Federal Science-Based Regulatory Departments: A Discussion Document*

5 *Strengthening Environmental Research in Canada: A Discussion Paper*

6 *Environment Canada's Scientific Research Publications 1980-1997*

7 *Research & Development and Related Science Activities at Environment Canada*

8 *Measuring The Impacts Of Environment Canada's R&D: A Case Study of Pulp & Paper Effluent Research*

9 *Measuring The Impacts Of Environment Canada's R&D: A Case Study of Stratospheric Ozone Depletion Research*

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

11 *Science Advice in Environment Canada*

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

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

14 *National Environmental R&D Agenda-Setting: A Commentary on Issues, Options, and Constraints*

15 *Science in the Public Interest: Values and Ethics in the Management, Use and Conduct of Science at Environment Canada*

16 *Bibliometric Profile of Environmental Science in Canada: 1980-1998*

17 *Implementing the Principles and Guidelines of the Framework for Science and Technology Advice: A Guide for Science and Policy Managers*

18 *Role of a Renewed 5NR MOU in the Evolving Spectrum of Horizontal Federal S&T Management*

19 *Toward a Canadian Stewardship Framework for GMOs - A Discussion Paper*

20 *S&T Excellence in Environment Canada: A Self-Assessment Tool based on the CSTA STEPS report*

21 *Environment Canada's Research Laboratories: Institutional Change and Emerging Challenges - Three Case Studies*