Planning to Protect Groundwater: Toward an Ecosystem Approach

By

David Alexander Neufeld

A thesis
presented to the University of Waterloo
in fulfillment of the
thesis requirement for the degree of
Doctor of Philosophy
in
Planning

Waterloo, Ontario, Canada, 1997

0-612-30636-4

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ABSTRACT

The fundamental assertion of this study is that the ecosystem approach provides a principled and coherent basis for addressing current deficiencies in planning for groundwater. Two basic questions frame the investigation: *What strategies have emerged to address deficiencies in planning for groundwater protection?*, and *How might an ecosystem approach inform the development of such strategies in Ontario?* Groundwater presents unique challenges to applying an ecosystem approach. As a neglected area of environmental planning, the limited appreciation of its human benefits and ecological functions is compounded by groundwater's hidden complexity and variability.

Based on a review of the literature, an Ecosystem Approach Framework is designed. Eight principles and twenty-one attributes together describe an ecosystem approach to groundwater protection. A case study of a leading example of a regional groundwater strategy in Ontario: *the Water Resources Protection Strategy* for the Regional Municipality of Waterloo is undertaken using the conceptual framework as a heuristic guide.

The case study reveals evidence of continuing challenges related to planning on the basis of multiple groundwater system boundaries; the need to integrate goals of sustainable use with maintaining essential ecological processes and functions; assessing and monitoring potential cumulative threats; transforming reactive controls into preventative planning strategies; ensuring the accountability of core actor groups for groundwater protection; and addressing limited institutional capacity for implementation. The broader institutional context in Ontario is impacting negatively on the ability to address many of these challenges. Specific measures are recommended to support an ecosystem approach to groundwater protection.

ACKNOWLEDGEMENTS

I thank my advisor, Professor Larry Martin, and the rest of my committee, Professors Robert Gibson, Richard Thomas, Terrence Downey and Murray Haight, for their thoughtful guidance throughout. Their diverse professional backgrounds and perspectives helped to illuminate the complexity of this area of research.

I sincerely appreciate the financial support received from the Eco-Research Project, under the direction of Professor George Francis, and from the Ministry of Environment, which made this endeavour possible. I also want to thank my colleagues at the Ministry for their words of encouragement.

Finally I thank my wife and family for their steadfastness throughout the thesis research process.

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INTRODUCTION

...groundwater is more than a resource. It is an important feature of the natural environment; it leads to environmental problems, and may in some cases offer a medium for environmental solutions. It is part of the hydrologic cycle, and an understanding of its role in this cycle is mandatory if integrated analyses are to be promoted in the consideration of watershed resources, and in the regional assessment of environmental contamination (Freeze and Cherry 1979:3)

1.1 Introduction

Groundwater provides for important benefits and plays a critical role in sustaining healthy ecosystems.[1] However, for too long it has been taken for granted, ignored and abused. Groundwater is a reliable source of potable water for almost three million Ontarians (Hess 1986). Approximately 1.4 million people are served by over 330 municipal groundwater-based water systems (MOEE 1995a). These aquifers provide drinking water for residential users and service the industrial, commercial and institutional sectors.[2] Another 1.3 million Ontarians, including ninety percent of the rural population, rely on groundwater for drinking water and other uses (Hess 1986). Each year between 14,000 and 22,000 new wells are added to the 500,000 private water wells already in existence in the Province (Singer 1990).

Groundwater plays a critical role in supporting healthy ecosystems.[3] At the most basic level,

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1 Groundwater is defined as water below the surface of the ground occupying a zone of the earth's mantle that is saturated with water (O.Reg. 358/90).

2 An aquifer is defined as "a saturated permeable geologic unit that can transmit significant quantities of water under ordinary hydraulic gradients" (Freeze and Cherry 1979:47).

3 An ecosystem has many attributes. Broadly stated, it is an open system defined by a given physical-chemical environment and associated assemblages of microbes, plants, and animals, including humans. (cf. Great Lakes Advisory Board 1978:3; Kormondy 1976:1; Likens 1995:19).

ecological systems provide for the capture, conversion and flow of energy and nutrients. Ecosystems regulate essential processes on which all life depends, produce materials and useable energy, re-absorb many of the by-products of economic activity, and provide for intellectual and spiritual development (Sproule-Jones 1994:211-212; Manning 1994:374; Christensen et al. 1996:667).The hydrologic cycle, of which groundwater is a part, acts as an agent of nutrient distribution, energy transfer, and geological change (Kormondy 1976:42).[4] The cycling of water is influenced by such processes as collection, infiltration, storage, channelization, movement and discharge. Its quality is influenced by such processes as retention, filtration, evapo-transpiration, adsorption, and chemical uptake (Price 1985). In Ontario, the annual contribution of groundwater to streams ranges from under 20% to 60% of total stream flow, depending on soil conditions and surficial geology (MNR 1984:46). During drier periods, such as the summer months, up to 100% of the total flow in some streams is provided by groundwater discharge. This discharge sustains aquatic habitat and moderates the effect of periods of low precipitation on surface water flows and water quality. In periods of high precipitation, streams and rivers may recharge the groundwater system, and gradually raise the groundwater table. In turn the groundwater will support the stream at a higher level for an extended period following these precipitation events (Driscoll 1986:57).

Groundwater systems function within boundaries and time scales that are not co-terminus with human institutions. They occur under many geological and hydrological conditions, and vary considerably in age, distribution and physical and chemical properties. Groundwater is like a three-dimensional layer cake. It can be found below surface waters and lands at multiple depths

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[4] The other major cycles include geochemical cycles having a prominent gaseous phase (e.g. carbon and nitrogen) and sedimentary-type cycles which release elements through weathering and related processes (e.g. phosphorus) (Kormondy 1976:42).

in the form of shallow localized systems and deeper regional systems. It can occur under unconfined conditions where it is recharged by precipitation that infiltrates the soil zone and percolates down to the saturated zone beneath the water table. Groundwater may also be confined by impermeable or semi-permeable material, and be recharged at great distances from where it discharges to the surface, or is withdrawn.

Groundwater-ecosystems are dynamic and ever-changing in response to stressors of both natural and human origin. Changes vary from the catastrophic to the very subtle, and span wide ranges of time intervals. Landforms and soils develop over tens of thousands of years, through such processes as weathering, transport, erosion, deposition, and incorporation of nutrients and organic materials. Human activities can change the landscape and alter ecosystem functioning and degrade or permanently contaminate groundwater in the span of years, or less.

Shallow groundwater systems, overlain by permeable material, can be vulnerable to contamination resulting from the individual and cumulative effects of human activities. Their vulnerability lies in the potential for contaminants to migrate downward from surface and near-surface contaminant sources to the water table. From there, contaminants may spread laterally and downward, depending on their specific characteristics and hydrogeologic conditions (Cherry 1987:11). Groundwater systems overlain by less permeable materials also may be vulnerable to contamination where fissures and fractures provide pathways for rapid downward movement of contaminants (Cherry 1987:12).

Sources of potential contamination include large point sources, such as municipal and industrial waste sites, as well as distributed sources such as storage tanks and pipelines containing petroleum products, sewage sludge disposal, road de-icing, dry cleaning operations, pesticide applications, mining activities, spills, and urban drainage (Howard, Eyles and Livingstone 1996, Cherry 1991, DOE 1986, Office of Technology Assessment 1984). Groundwater degradation has occurred in many areas where on-site sewage disposal is used (Aravena, Evans and Cherry 1993:180; Canter and Knox 1987:59).

While there is no comprehensive documentation of groundwater contamination in Ontario, the following contaminants have been found in groundwater supplies: bacteria, nitrates, chlorides, petroleum products, trichloroethylene, chromium, benzene, toluene, polychlorinated biphenyls, atrazine, nitro so-dimethylamine, dioxin, and various other chemical wastes (MOEE 1995a). There also appears to have been a general decline in the quality of shallow groundwater systems across much of the province. In the first-ever province-wide survey of water quality in Ontario farm wells, 37% of the wells tested exceeded acceptable levels of coliform bacteria, while 13% exceeded acceptable nitrate concentrations (OSCIA 1992).

Potential cumulative effects of urban development encroaching well fields and major recharge areas are also of concern (Boylan 1990; Francis 1991; Howard et al. 1992). In addition to the potential for introducing contaminants to the subsurface, clearing and grading land surfaces combined with the erection of structures, buildings and impervious surfaces can alter processes of groundwater recharge, storage and discharge. These activities can produce a reduction in baseflow to local streams and headwater areas, increase sedimentation in local tributaries and reduce direct discharge of groundwater to streambeds, decrease infiltration to recharge areas for intermediate streams and associated wetlands, and also lead to long term decreases in recharge to regional groundwater flow systems (Blackport, MacGregor and Imhof 1995:16-17).

1.2 Planning for Groundwater Protection

The focus of this inquiry is applying an ecosystem approach to planning for groundwater protection in Ontario. Two basic questions frame this inquiry: *What leading strategies have emerged to address deficiencies in planning for groundwater protection?*; and *How might an ecosystem approach inform the development of such strategies?* Of particular interest is the development of regional scale strategies that will sustain healthy groundwater-ecosystems and the human uses and benefits they provide.

The need to adopt more holistic and encompassing approaches to groundwater management and protection has recently emerged as a public policy issue in Canada (Pupp 1987; Karvinen and McAllister 1994). Growing demands for secure water supplies, incidents of contamination, and concern that groundwater resources are not being adequately protected have given rise to significant concern (cf. DOE 1990a, 1990b; Ryan 1995; Cherry 1989; Roman and Ferris 1990; Spek 1995).

Responsibilities for managing and protecting groundwater are divided among different agencies and levels of government. The federal government exercises jurisdiction in specific areas such as fisheries and the regulation of toxic contaminants that may affect groundwater. It also exercises a modest research function related to groundwater. Provincial governments have constitutional responsibility for the supervision of groundwater resources and for governing human activities which affect the environment within provincial borders. This includes regulating most emissions from industrial activities, controlling use of private lands, extraction of resources, and environmental standards.

Municipalities have delegated responsibilities that impinge on groundwater management and protection in a number of important areas including: providing water supplies, sewage works and waste management services for their communities, controlling use of private land, and protecting public health. A handful of communities in Canada are pursuing policies to better protect municipal groundwater supplies from contamination. Most of these efforts are in developmental stages (Karvinen and McAllister 1994; Ouellet 1993; Dames and Moore 1996).[5]

In Ontario only a limited set of instruments have been used to regulate the use of groundwater and control the release of contaminants that may degrade or impair it (Karvinen and McAllister 1994; Roman and Ferris 1990, Neufeld 1987). A few regions and local municipalities have initiated groundwater investigations as a precursor to developing protection strategies and some have addressed groundwater issues through watershed studies. In many cases, this action has been prompted by recognized threats to the quality of public water supplies or development pressures. Some of the current issues in the Province include lack of a long term vision for groundwater, unclear roles and responsibilities, limited groundwater information, and lack of a framework for community-based protection activities (cf. MOEE 1996b; GWG 1990; Cherry 1989).

Other jurisdictions have made significant advances in articulating new strategies for groundwater protection. While groundwater protection in Europe is not well documented, available evidence suggests that progress is being made to increase the level of protection of valued groundwater resources (cf. UNECC 1989; NRA 1992; Headworth 1986; Brommssen

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5 Three examples of individual communities who have adopted zoning to restrict land uses and practices in areas delineated around municipal wells include Regina, Saskatchewan, Sussex, New Brunswick, and Amherst, Nova Scotia (Dames and Morre 1996).

1991). Working examples of groundwater protection strategies at federal, state and local levels in the United States are well documented (cf. National Research Council 1986; Conservation Foundation 1987; Page 1987; Jorgenson 1989; Jaffe and DiNovo 1987; Liner et al. 1989). This experience offers insights into the groundwater protection strategies that have evolved to address deficiencies of past practice (Neufeld and Mulamoottil 1991).

1.3 Toward an Ecosystem Approach

The ecosystem approach reflects an evolution in how relationships among institutional and ecological systems are addressed. Its fundamental premise is that human activity systems and decision making must be considered within the context of ecological functions and processes (Norton 1992:24; Jaackson 1987). The ecosystem approach integrates consideration of human uses and benefits within the framework of healthy ecological systems, by acknowledging that human health and welfare ultimately rely on them. It also affirms fundamentally that there are limits to the degree of stress ecosystems can accommodate before they are irreversibly degraded or destroyed. As Christensen et al. (1996:666) note:

> Ecosystem management acknowledges the importance of human needs while at the same time confronting the reality that the capacity of our world to meet these needs in perpetuity has limits and depends on the functions of ecosystems.

The ecosystem approach has been advocated for many different contexts: urban and regional planning, management of forests, fisheries and watersheds, and use of public lands (Lee 1993; Gunderson, Holling and Light 1995; GAO 1994; Cowan, Vallentyne and Muir 1990; Slocombe 1993; Brugmann 1993; Wessel 1993). It has been endorsed at all jurisdictional levels in Canada and abroad. For example, Young (1994) found that in international negotiations, it was beginning to displace conventional goals such as achieving maximum sustained yield. He concludes that ecosystem-thinking is having a noticeable affect on institutional bargaining in the international arena. At national and provincial levels, the ecosystem approach has been endorsed as a preferred strategy for environmental decision making (cf. National Task Force 1987; Environment Canada 1995a; Royal Commission 1992; EAAC 1989; ORTEE 1990). There is also evidence that the ecosystem approach has influenced planning and decision making in a range of local and regional contexts (Puddister and Nelischer 1994; Tomalty et al. 1994; Smith 1989; Yip 1994).

Ecosystem science has engendered considerable interest in the research community (cf. Woodley, Kay and Francis 1993; Golley 1993; Costanza, Norton and Haskell 1992; Kay and Schneider 1994; Bocking 1994). The institutional dimensions of an ecosystem approach have received much less attention. Broadly speaking, institutions have to with systems of formal and informal rules that guide decisions, the roles assigned participating actor groups, the interactions among occupants of these roles and the processes through which decisions are implemented (cf. Young 1994:26; Ingram et al. 1984:323; Craine 1972:84, de Bruijn and Heuvelhof 1995:162).[6] The literature presents many challenges: the theoretical development is weak, there are diversity of variables subject to investigation, key variables are often unknown or not operationalized, different research designs and measurements abound, and disparate evaluation criteria are used (cf. Mitchell 1989; Ingram 1990; Gormley 1987; O'Toole 1993; Cortner and Marsh 1987). This complicates the challenge of identifying requisites for strengthening institutions to implement

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6 The terms *institutions*, *institutional arrangements*, and *governance* are used inter-changeably. Ingram et al. (1984:323) define *institutions* as " ... those legal, political and administrative structures and processes through which decisions are made with respect to public policy." Craine (1972:84) describes *institutional arrangements* as "... a definable system of public decision-making ... that includes specific organizational entities and governmental jurisdictions, but transcends conventional emphasis upon definition of agency structure, per se." Francis and Regier (1995:248) define *governance* as "...the exercise of authority and control through institutional structures and decision-making processes ..." .

an ecosystem approach. The limited application of these principles to planning for groundwater protection heightens the need for, and difficulty of, research in this area.

The ecosystem approach calls for institutions to adopt new approaches which manage more integratively across jurisdictions and functions, and to take into account the complexity and connectedness of ecological and human activity systems (Gunderson, Holling and Light 1995; Gerlach and Bengston 1994). It eschews narrow solutions and the "react and control" measures of the past. This implies a more anticipatory and preventative approach built on recognized relationships among human well-being and ecosystem functioning. It also suggests the need for strategies that mobilize the collective abilities of key actors to forge partnerships which overcome the barriers of divided jurisdiction and fragmented authority.

Similarly, the need to develop regional-scale strategies to protect groundwater systems are well recognized (DOE 1990c; Liner et al. 1989; Jaffe and DiNovo 1987). The term *groundwater strategy* is used to refer to a formal plan of action directed toward protecting and sustaining valued groundwater functions. Strategies encompass a broad range of activities, including defining goals and objectives, collecting information, developing rules and instruments to influence human activities, and strengthening the institutional mechanisms for implementation. Strategies can provide a coherent and integrated framework for protecting and managing groundwater (cf. Buresh 1987; Libby and Kovan 1987; Page 1987). However, there has been little analysis of their potential application in Ontario and virtually no substantive analysis of how an ecosystem approach might be applied to sustain healthy groundwater ecosystems and the human uses and benefits they provide over the long term (Neufeld and Mulamoottil 1991; Karvinnen and McAllister 1994, Pupp 1987).

1.4 Goal and Objectives

The goal of this research is to enumerate and apply principles of an ecosystem approach to regional-scale groundwater protection strategies in Ontario. There are six research objectives:

- identify a key concepts and guiding principles of an ecosystem approach;
- examine emerging groundwater strategies, with reference to the United States, to identify strategic activities and continuing challenges in light of an ecosystem approach;
- design a conceptual framework that integrates guiding concepts of an ecosystem approach with comprehensive groundwater protection;
- review current institutional arrangements for groundwater protection in Ontario;
- undertake a case study of a leading regional-scale groundwater protection strategy in Ontario, using the conceptual framework as a heuristic guide; and
- enumerate implications for theory and practice in applying an ecosystem approach to groundwater protection in Ontario.

The dissertation is organized into nine chapters that generally follow the objectives outlined above. Chapter Two describes the research strategy and methods applied in this inquiry. Chapter Three reviews the ecosystem approach literature in four related topics: integrated resource management, integrated pollution control, ecological land use planning and adaptive environmental management. Key concepts and guiding principles of an ecosystem approach are enumerated.

Chapter Four examines groundwater protection strategies at federal, state and local levels in the United States. Critical issues and persistent challenges are enumerated in light of an ecosystem approach. Chapter Five synthesizes the findings from Chapters Three and Four into a conceptual framework. It provides a normative framework for describing and analyzing an ecosystem approach to groundwater protection.

Chapter Six summarizes current institutional arrangements for groundwater protection in Ontario, at federal, provincial and municipal levels to provide the context for considering progress toward an ecosystem approach. Chapters Seven and Eight report on a leading case example of a regional strategy being developed in the Regional Municipality of Waterloo, Ontario.

Chapter Nine discusses the implications of the research findings for theory, practice and future research. A set of theoretical propositions are presented as well as recommendations for implementing an ecosystem approach to groundwater protection in Ontario.

CHAPTER 2
RESEARCH METHODS

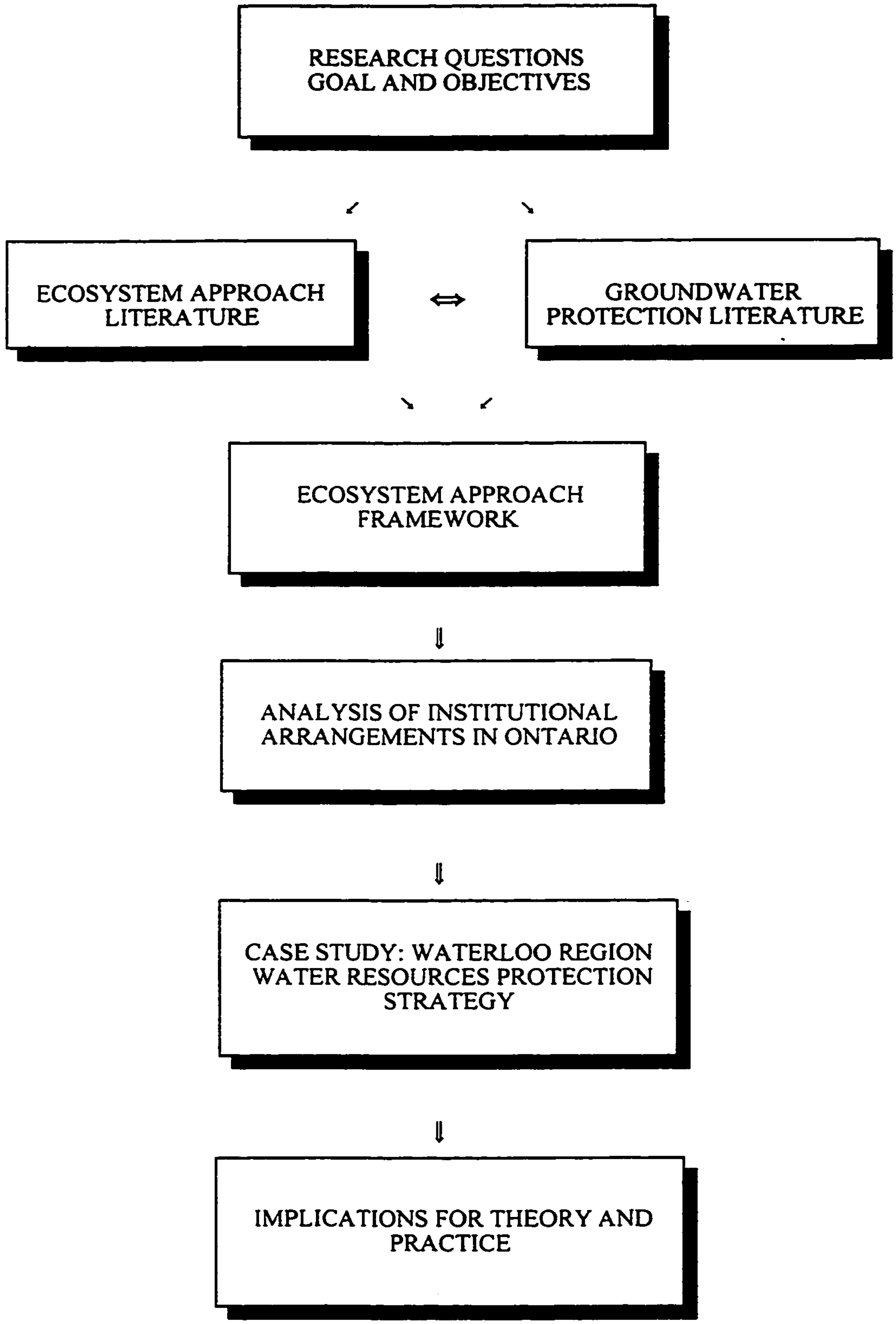
2.1 The Research Strategy

As noted in the first chapter, two basic questions frame this inquiry: *What strategies have emerged to address deficiencies in planning for groundwater protection?*; and *How might an ecosystem approach inform the development of such strategies?* The research strategy used to pursue answers to these questions follows an approach that is characterized as deductive, evaluative and exploratory. It is deductive insofar as general principles are used to provide a framework for understanding specific observations (Patton 1982:8). As Ostrom et al. (1994:25) note: "At the conceptual level of a framework, theorists identify broad working parts and their posited relationships that are used in an entire approach to a set of questions." The inquiry is evaluative in that it seeks to determine the adequacy of past approaches relative to some pre-determined objectives (Mitchell 1979:35). However, given the limited theoretical development and practical applications to groundwater protection, the research is exploratory, (Patton and Sawicki 1993:23; Neuman 1994:18).

As recommended by Gormely (1987) and others (cf. White 1994; Yin 1984) multiple methods are used, including literature reviews, analysis of public policy documents, case study and interviews. A series of iterative steps are followed which cumulatively provide insights into an ecosystem approach to planning for groundwater protection (Figure 1). The process begins with a preliminary review of the literature to develop the research questions and objectives.

Theoretical grounding to the inquiry is provided by a thorough review of the environmental planning and management literature. The ecosystem approach is an emerging paradigm which

FIGURE 1: RESEARCH PROCESS



reflects an amalgam of concepts and ideas that are not fully mature.[7] The main area of agreement in the literature is that there are few examples where the major characteristics of an ecosystem approach have been implemented fully. In addition, there is no substantive literature applying ecosystem principles to groundwater management and protection. Diverse themes and recurring ideas are integrated to provide a more coherent and complete representation of an ecosystem approach.

Various jurisdictions have taken substantial steps to address past deficiencies in groundwater protection planning. Literature documenting this experience is instructive of the challenges facing groundwater protection and progress toward an ecosystem approach. A comprehensive survey of the literature on groundwater protection strategies is undertaken, with special reference to the United States.

The review of theoretical and applied literature aids the conceptualization process, that is "defining the nature of the problem and identifying its parts and their relationships" (Mitchell 1979:36). There have been few previous efforts to apply the ecosystem approach paradigm to groundwater protection. As part of the research process, a conceptual framework is developed that integrates key principles of an ecosystem approach with the building blocks of a comprehensive groundwater protection strategy. The framework is an evaluative tool applied in the case study, based on guiding principles and attributes of an ecosystem approach to groundwater protection. It also is the vehicle through which the research findings are generalized (Yin 1984:49).

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7 A paradigm is defined as: "... a series of principles or assumptions which guide action and suggest solutions in a given policy field" (Doern and Conway 1995:235).

While the focus of the inquiry is on regional-scale application of an ecosystem approach to groundwater protection, it is necessary to appreciate the broader institutional context. For example, the system of constitutional rules that define broad authority structures and the allocation of resources constrains the capacity for action at lower levels and circumscribes the alternatives available (cf. Sproule-Jones 1994, Ostrom et al. 1994). Accordingly, a review of the larger institutional arrangements for groundwater management and protection provides the starting point for considering progress toward an ecosystem approach in Ontario.

A case study is used to examine the extent to which an ecosystem approach has informed the development of a leading regional groundwater strategy in Ontario. It is used to test and reflect upon the implications of an ecosystem approach to planning for groundwater protection. The case study approach is reviewed in the following sections.

2.2 The Case Study

The purpose of a case study is to examine contemporary phenomenon within its real-life context, where a series of interventions have occurred (Yin 1984:25). One alternative to the case study was to undertake a survey of regional groundwater strategies across Ontario, and in other jurisdictions. It was determined, however, that a general survey would not yield additional insights into the research questions beyond what could be garnered from a review of existing survey research. Multiple surveys of groundwater protection across Canada have been completed. In 1990, the *Chicago-Kent Law Review* published a detailed review of laws regulating groundwater contamination in Canada (Roman and Ferris 1990). In 1993, the *Intergovernmental Committee on Urban and Regional Research* released the results of an analysis of environmental strategies, policies and programs, including protection of groundwater supplies, from a selection of municipalities across Canada. In 1994, the *Centre for Resource Studies* at Queen's University published an analysis of groundwater policy trends in all provinces of Canada (Karvinnen and McAllister 1994). In that same year, the *National Hydrology Institute* of Environment Canada released a detailed study of groundwater protection in Ontario (MacRitchie et. al 1994). Most recently, Dames and Moore (1996) profiled six municipal groundwater supply protection approaches across Canada.

The evidence from surveys in Canada suggests that the few communities active in this area have undertaken one or more of the following activities: adopted general policies recognizing the importance of protecting groundwater supplies, begun to collect information on these resources, developed restrictions on the use of hazardous contaminants, and developed servicing policies. The evidence suggests that few could be described as comprehensive regional strategies. An additional survey would likely add little new information to the existing literature and would not provide the basis for an in-depth analysis of how key ecosystem principles are applied in a real-life context in Ontario. Groundwater protection activities in other jurisdictions, particularly the United States, are well documented in the literature, including survey research, case studies, commentaries and policy analysis (cf. National Research Council 1986; Conservation Foundation 1987; Page 1987; Jorgenson 1989; Jaffe and DiNovo 1987; Liner et al. 1989). This literature is reviewed in Chapter Four.

The case study presents an opportunity to examine the application of ecosystem concepts in Ontario, in a leading example not previously documented or critically evaluated. The case study also is ideally suited to the task of expanding and generalizing concepts of how an ecosystem approach should inform the development of such strategies. It can help to advance understanding of the potential for an ecosystem approach to operate as the new paradigm for groundwater protection planning. Each of the elements of the case study process are identified in Figure 2.

2.2.1 Selection Criteria

The following criteria were developed to guide the process of selecting the case study:

- the case should be exemplary in its efforts to develop a comprehensive groundwater strategy;
- the process of developing the strategy should involve multiple actor groups;
- it should demonstrate efforts to manage multiple stresses and growth pressures; and
- there should be ready access to written evidence.

The key criterion in selecting the case study is that it represent a critical case for helping answer the basic research questions underlying the study (Yin 1984:42-43; 80). Discussions with municipal groundwater managers in Ontario currently pursuing groundwater protection confirmed there are few examples in the province of comprehensive strategies.[8] Further investigation indicated that the Regional Municipality of Waterloo is exemplary in its scope and comprehensive approach to protecting groundwater resources. A review of secondary sources confirmed that Waterloo's progress is unmatched in the Province and indeed elsewhere in the country (cf. Dames & Moore Canada 1996; Federation of Canadian Municipalities 1995; Karvinnen and McAllister 1994). The selection of the case was finalized when access to written materials was confirmed.

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8 This includes representatives from the regions of Halton, Peel, Ottawa-Carleton, Waterloo, as well as from Wellington County, Guelph, and Paris, Ontario.

FIGURE 2: CASE STUDY APPROACH

CASE STUDY SELECTION

- define selection criteria
- confirm selection through preliminary investigation

⇓

DATA COLLECTION

- assemble written materials
- identify core actor groups and secure cooperation
- develop interview guide and conduct interviews

⇓

CASE DESCRIPTION

- prepare chronological description
- confirm facts with key informants
- document interview responses

⇓

CRITICAL ANALYSIS

- analyze evidence for representation
- analyze evidence for significance
- report conclusions and recommendations

⇓

REPORTING CASE STUDY

- provide documentation

2.2.2 Data Collection

Data collection procedures were established such that they could be repeated with the same results (Yin 1984:36). The data collection phase of the case study process includes the following key tasks: gain access to written materials, identify core participants, contact core actors to secure their agreement to participate in the study, develop interview guide, conduct interviews and document responses. Multiple sources of evidence are used to provide a complete and consistent basis for documenting the evolution of the Strategy. Written materials are the main source of evidence for the case study. This includes policy documents, technical studies, reports to Regional Council, minutes of Liaison Committee meetings and miscellaneous documents. Based on this evidence a time-series analysis is used to establish a chronology of events and milestones, from the time the Strategy was initiated in 1990 through September 1996. To confirm accuracy, a key informant is provided with a draft of the written description to review (Yin 1984:36)

Interviews with core participants corroborate and supplement evidence from written sources (Brannigan 1985:198). This approach is based on the premise that the perceptions of core actor groups and their prescriptions for action are a critical source of evidence (Doern and Phidd 1983:57).[9] The perspectives of those with direct knowledge and experience in the case are essential in reaching valid conclusions about successes and limitations (cf. Yin 1984:142; Serafin, Nelson and Butler; 1992:285-6; Roe 1994; White 1994). As Yin (1984:84) notes:

> ...because most case studies are human affairs [they] ... should be reported and interpreted through the eyes of specific interviewees, and well-informed respondents can provide important insights into a situation.

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9 Core actor groups are those organizations involved on a continuing basis in the case (Fischer and Keith 1977).

During the month of November, 1996, fourteen of seventeen members (82%) of the Water Resources Protection Liaison Committee were interviewed, including: municipal officials (4), Regional Councillors (3), provincial officials (3), and non-government organizations, including the Waterloo Federation of Agriculture, APT Environment, Waterloo Centre for Groundwater Research, and Kitchener-Waterloo Chamber of Commerce.[10] Interviews could not be arranged with one municipal official and one Regional Councillor because of persistent scheduling conflicts. One member of the business community declined to be interviewed because of limited participation on the Committee. While unfortunate, the loss of three members of the Committee was not irreparable. Each of these actor groups were adequately represented in the interviews.

Interviews were conducted over the phone at pre-arranged times and lasted an average of 45 minutes. Interview data were collected by having each respondent answer a consistent set of questions, using a semi-structured, probing interview style. An interview guide provided uniform coverage and consistency to increase precision and reliability of interviews. In addition, a blend of open-ended questions as well as closed or pointed questions allowed for unanticipated responses (cf. Brannigan 1985:201; Yin 1984:83; MacHovec 1989:107). This interview style is intended to elicit unambiguous, complete and meaningful information. It also allows for alternative perspectives and different interpretations. The potential for recall or bias is dealt with by comparing responses among interviewees and by corroborating interview data with other sources of evidence (Yin 1984:85).

Interview questions were formulated on the basis of the following principles: use simple and

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10 Because the approach focuses on those with direct knowledge and experience in the case, formal interviews were limited to groups who were core actors in the Strategy development process. Personal communications with various other individuals having direct knowledge of groundwater issues are documented throughout the text.

precise wording, avoid leading questions, and appear naive to the topic to allow respondents to provide a "fresh commentary" (Yin 1984:83). Jargon is minimized and every effort made to limit the number of concepts covered in each question (Brannigan 1985:201). Pre-determined response categories are avoided, but respondents are probed for clarity and completeness where their responses were ambiguous or incomplete. This interview method is based on MacHovec's (1989) "ARC" approach, which involves being attentive to respondents, not anticipating certain responses, reflecting back responses to ensure understanding, and confirming what was meant by each response. Notes were taken during the course of the interviews, and were reviewed and finalized immediately following each interview.

2.2.3 Data Analysis

Because the case study is exploratory it does not set out to establish causal relationships whereby certain conditions are known to lead to other conditions (Yin 1984:36).The case is intended to lay the necessary groundwork for future investigation in this area. Current research lacks clear and consistent measures for evaluating examples of an ecosystem approach. This inquiry breaks new ground by developing and applying a conceptual framework derived from identified principles and attributes of an ecosystem approach to groundwater protection. The framework ensures that a consistent and clear standard of comparison is used for evaluating the evidence (cf. Yin 1984:49; Carney 1972:51).

The analysis is structured around eight questions linked to the key principles of an ecosystem approach. It is based on an understanding of an ecosystem approach as a composite whole made up of complicated and interconnected parts. Twenty-one interrelated attributes together describe an ecosystem approach to groundwater protection. Attributes are defined as abstractions belonging to or characteristic of a particular entity. In this case they represent the constituent parts of the ecosystem approach to groundwater protection. The attributes provide reference points against which to evaluate the consistency of a regional groundwater strategy with the principles of an ecosystem approach.

The facts and conclusions reached are based on convergent evidence from complimentary data sources (cf. Yin 1984:52; Carney 1972:43). Written materials and verbal communications are analyzed in a deductive process involving a two-step analysis. The first is a test for presence/absence of key attributes associated with an ecosystem approach. It involves looking for representational, or manifest, meaning contained in the sources of evidence (i.e. *it means what it states*). This establishes whether or not there is evidence that specified principles and attributes are incorporated in the Strategy. The second step in the analysis is a qualitative judgement regarding the significance, or importance, accorded a given ecosystem principle. It involves an assessment of the adequacy with which an attribute is addressed in a groundwater strategy. While the first step of the analysis reflects a more or less straight-forward test for presence or absence, the latter requires judgement concerning the degree of emphasis given a particular theme or characteristic. The significance or *intensity of expression* is inferred from terminology used, the relative attention given to something in the evidence, and the justification provided for certain decisions or actions. This type of analysis presents a challenge since, as Carney (1972:85) notes, "words do not have 'meanings' in the sort of way children have parents. They have uses, identifiable in particular places and periods." Inferences are cross-checked by considering supportive or contrary evidence from additional sources, particularly interview responses (cf. Yin 1984:90, 142; Carney 1972:42, 54, 175).

Initially, an ordinal scale rating system was developed that assigned a grade to the Strategy to indicate the priority and emphasis given to each of the guiding principles. An ordinal scale is one where the direction and relative position for points along an ordinal scale are known, but the distance between any two points on the scale are not measured by a common unit of measurement (Mitchell 1979:46). For each principle the Strategy was initially assigned a *high, medium* or *low* rating, based on the presence and importance accorded specific attributes in the evidence. After testing, the rating system was rejected since it did not add value to the analysis. Instead of clarifying the results, "totalling the scores" for each principle camouflaged the specific strengths and weaknesses identified through the two-step analysis. In addition, the rating could imply a level of specificity that is lacking in the data.

2.2.4 Reporting

A data base is created for the case study to document evidence used, and to facilitate future analysis by other researchers. This evidence includes the following:

- key written materials (see 10.0 Literature Cited);
- letter to core participants introducing purpose of study (Appendix A);
- interview guide (Appendix B);
- summary of interview responses (Appendix C);

2.3 Summary

A deductive and exploratory research strategy is adopted for this inquiry, consisting of a series of iterative steps. A comprehensive review is undertaken of the environmental planning and management literature. A set of guiding principles are distilled from the literature which, taken together, describe an ecosystem approach. A detailed review also is undertaken of the groundwater protection literature, with reference to the United States. It documents progress toward an ecosystem approach and highlights critical elements of a groundwater protection strategy.

An ecosystem framework is developed on the basis of the literature reviews. It is based on an understanding of an ecosystem approach as a composite whole made up of interconnected parts. Twenty-one attributes represent the individual parts or constituents that together describe an ecosystem approach to groundwater protection. The framework provides a normative guide to critically evaluating Waterloo Region's Groundwater Strategy. The findings from the case study identify important implications for the ecosystem approach paradigm and for its application in Ontario.

CHAPTER 3
THE ECOSYSTEM APPROACH: A REVIEW OF THE LITERATURE

3.1 Introduction

The purpose of the chapter is to provide theoretical grounding for addressing the question of how an ecosystem approach might ultimately inform the design of new strategies for protecting groundwater. As noted in Chapter One, the ecosystem approach is an emerging paradigm in environmental planning and management. It has arisen in response to the failure of conventional approaches to address human-ecological considerations holistically (cf. Regier; Mason and Berkes 1989; Caldwell 1987; Bell 1994; Norton 1992; Yaffee 1996).

> The confident assertion of the 1950s and 1960s that man would find solutions to all his problems has been supplanted by a new humility, born of the realization that even man's most astonishing achievements cannot offset his disastrous devastation of the earth, its plants and animals. ... We must recognize that we are a part of nature and must resolve that our actions take this into account. Only on that basis can the fragile life-support systems of our planet be safeguarded and only thus can development of our own species go forward. (Scott in Allen 1980:4)

In 1980 the International Union for Conservation of Nature and Natural Resources, in cooperation with the United Nations Environment Programme and the World Wildlife Fund released the *World Conservation Strategy*. It is one of the first consensus statements among government and non-government organizations of the need for an ecosystem approach. The *World Conservation Strategy* enunciated three basic principles that frame much of the writing and analysis that followed: maintain essential ecological processes and life-support systems; preserve genetic diversity; and use species and ecosystems sustainably (Allen 1980:12-14).

This chapter is structured on the basis of four interrelated concepts in the literature that inform the author's conception of what constitutes an ecosystem approach: integrated resource management, integrated pollution control, ecological land use planning, and adaptive environmental management. While these are not hard divisions, the categorization highlights different components of the ecosystem approach paradigm. The contribution of each of the four groupings of literature is consolidated and synthesized into a set of principles that, taken together, define an ecosystem approach.

3.2 Integrated Resource Management

The concept of integrated resource management (IRM) emerged in response to concerns about the intense pressures being placed on natural resources by a wide range of users (Lang 1986; Cairns and Crawford 1991). Conventional approaches to resource management typically focus on a narrow range of consumptive goals, view multiple users in isolation, and ignore relationships between different interests, policies and environmental media (Born and Sonzogni 1995:168).

An enduring theme in IRM is the need to manage more comprehensively by integrating all relevant biophysical factors, management objectives, resource uses, and actors (Born and Sonzogni 1995:175). A recent definition of IRM illustrates this direction toward a comprehensive approach:

> ... coordinated control, direction, or influence of all human activities in a defined environmental system to achieve and balance the broadest possible range of short- and long-term objectives (Cairns and Crawford 1991:5).

At the same time, many early efforts at IRM foundered due to multiple and conflicting objectives, limited information and uncertainty about future conditions. After reviewing the experience with integrated water management in 7 countries, Mitchell (1990) concludes there is strong support for the principle of integration but numerous difficulties in implementing the concept. Most examples tried to address too many factors, created lengthy processes, produced poorly focussed plans, and ultimately addressed only a narrow range of functions. In response, Mitchell (1990:4) argues for a two-stage approach that adopts a broad perspective early in the process and that becomes progressively more narrow as the focus turns toward implementation. He describes a comprehensive approach at the strategic level as "... trying to identify and consider the broadest range of variables that may be significant for coordinated management of water and associated land and environmental resources". At the operational level he argues for an integrated approach, where fewer variables are targeted for attention.

> The key distinction is that while an integrated approach maintains the interest in considering the mix of variables and their interrelationships, the focus is more selective or narrow than in the comprehensive approach. (Mitchell 1990:4)

Another important theme in IRM is the need to coordinate the decisions and activities of a range of actor groups. A common institutional strategy to promote integrated water management has been to re-organize organizational mandates and responsibilities. The traditional public administration approach advocated hierarchical control of decisions through centralized decision structures (Ostrom 1972:55). As noted by Wengert (1972:3-4):

> For the common complaint of the lack of coordination in water management, the almost universal cure has been to suggest administrative reorganization on the assumption that this could result in coordinated policies and lead to more rational ways of achieving goals using various forms of coercion to affect behaviour, such as law or administrative regulation.

In seeking integrated water management, many jurisdictions created centralized river basin authorities. However, river basin authorities have had limited success in achieving integrated water management (Mitchell 1990:214). . Many such agencies found themselves with limited ability to effectively promote integrated management. This has been the experience with conservation authorities in Ontario. They were established for 38 different watersheds in Ontario with the goal of furthering the conservation, restoration, development and management of natural resources (*Conservation Authorities Act* s.20). Although given a broad mandate, conservation authorities have been pressured to focus on a narrow range of functions and lack the tools required to address water and land management issues comprehensively (Shrubsole 1990). Various observers have concluded that any centralized approach to IRM will meet with limited success. Pitkethly (1990:136-7) observes:

> ... any bureaucracy set up to handle the orderly co-ordination and planning of all relevant inputs tends to find its task humanly impossible ... Central planning is a well documented failure world-wide, not least with regard to multi-functional and large scale water resource development.

In response to the limits of centralized coordination, an alternative institutional strategy is to create mechanisms to coordinate planning and management decisions among key actor groups. However, coordinating mechanisms often lack authority to make decisions that are binding on the network participants (Mitchell 1986:23). In his analysis of international regimes for managing shared natural resources, Young (1994) finds a lack of institutional mechanisms that allow parties to make authoritative collective choices. This has certainly been the experience in managing the Great Lakes Basin (Francis and Regier 1995; Donahue 1987). Consultation and collaboration among separate groups and organizations is facilitated where coordinating mechanisms are given some authority by member organizations to render decisions on their behalf.

> If these interests are to be 'integrated' into a systematic management strategy, it is essential to develop mechanisms through which different values and interests can be identified and articulated, and then decisions made which reflect these different and often conflicting aspirations. (Mitchell 1990:206)

Following a review of case studies of water management across Canada, Mitchell (1991) identifies four strategic elements for IRM: balancing a mix of social, economic and environmental dimensions, taking an ecosystem perspective to address interrelationships and complexity in a holistic manner, adapting to uncertainty and surprise, and using teamwork involving partnerships and cooperation among multiple interests. Similar principles have been proposed by others. For example, Born and Sonzogni (1995) propose a framework for integrated watershed management that has the following principles: comprehensive, inter-connective, strategic, and interactive.

IRM: In Review

A driving force behind much of the literature on integrated resource management is the need to address multiple and fragmented resources, stakeholders, responsibilities, and decision making. It is a direct response to overlapping and competing interests and responsibilities among different agencies and organizations. Some of the central themes of integrated resource management include:

- comprehensive - considering complexity, major issues, linkages and processes, while focussing on strategic objectives that fall within the capacities and resources of existing agencies;
- interactive - incorporating and balancing the interests of multiple actors in the development and implementation of policies and programs;
- coordinated - using mechanisms which facilitate consultation, negotiation and collaboration among separate groups and organizations. The value of such mechanisms increases as their decision making responsibilities are increased.

3.3 Integrated Pollution Control

Over 25 years ago, Grava (1969) observed that there were three major policy alternatives for integrated pollution control (IPC): removing or dispersing pollutants, changing the nature of the activities producing pollutants, and changing the location, type and intensity of activities and populations. Since that time the increasing pervasiveness and number of hazardous contaminants in the environment, despite significant pollution control programs, has generated considerable interest in integrated pollution control and environmental management (Conservation Foundation 1985; Rabe 1986; Fiorino 1995).

The traditional practice of regulating the "residual outputs of production processes" has been the policy instrument of choice (Rinquist 1993:202). Direct regulation of emissions is the foundation for most legislative frameworks, and it continues to be seen as the most direct and visible means for reducing pollution (Fiorino 1995:173). Direct regulations are based on a *command and control* approach. Actions are prohibited or required by means of rules, standards, licenses, product bans, etc. (Tuohy 1989). The traditional command and control approach has been criticized on a number of grounds.

Some concerns relate to the technical limits of regulating thousands of contaminants and point sources, the marginal costs of pollution control by different sources, and the tendency of end-of-pipe regulations to discourage innovation (Fiorino 1995; Rinquist 1993; Kuusinen, Lesperance and Bilyard 1995). Additional arguments have been put forward concerning reduced fiscal capacity of governments, the off-setting impacts of population and economic growth, the transfer pollutants from one environmental medium to another, and the impact of non-point sources which may not be subject to direct controls. As Rinquist (1993) notes in his review of environmental policy approaches, there has been a marked failure to address ecological principles:

> ... nowhere in the present set of pollution control regulations do we find recognition of the interconnectedness of the biosphere or the intrinsic value of an intact and healthy

> ecosystem. Until environmental policy embodies these concepts, in addition to concerns of human health and economic costs and benefits that are presently employed, improving and protecting environmental quality will remain a slow and difficult task characterized by uneven results. (Rinquist 1993:196)

There have been moves to broaden the focus of pollution control by managing contaminants on a life-cycle basis, issuing single permits for all emissions from one source, and assessing all contaminant sources impacting a large receptor such as a watershed (Irwin 1990:11). In addition there is increasing interest in moving away from strict reliance on traditional pollution control instruments to applying a broader set of policy instruments (Anderson 1992; Fiorino 1995; Paelkhe 1990; Environment Canada 1992). This includes economic or market-based incentives, planning and assessment processes, and various voluntary instruments to promote positive environmental actions.[11]

Regulatory controls have been criticized for their coercive approach. Arguments have been made that regulatory controls should be based on the participation and consent of free and informed individuals that make up society (Tuohy 1989; Paelkhe 1990). This is expressed in terms of concern about the limited accountability of regulators and the right of affected interests to be part of the decision making process. It has also increased calls for maintaining democratic values and providing effective participatory mechanisms (Fiorino 1994:4).

Environmental regulation in Canada and the United States varies in the degree to which decisions are the product of open and consultative processes (Harrison and Hoberg 1994). In Canada, decisions related to pollution control remain focussed on a dialogue between the regulator and the regulated source. Salter (1990) considers the democratic potential of

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11 Voluntary instruments rely on information and education to advance arguments that seek to persuade actors to modify behaviour (Tuohy 1989).

regulation by examining four types of governance. These include joint participation in decision making between government and industry (*co-management*), direct public involvement in regulatory decision making (*direct democracy*), legal rights associated with fairness (*due process*), and defining the public interest through policy making processes (*policy making*). Some of the limitations she identifies include: the potential for regulatory capture by industrial interests in co-management, the tendency to replace social norms with legal norms, capture of public participation processes by experts, rampant proceduralism constraining public debate, and the difficulty of dealing with silent interests not represented by major stakeholders.

Salter argues for counter-balancing current emphasis on co-management with allowing a broader range of actors meaningful roles in the decision making process. On example of increasing accountability and inclusiveness in policy making in Ontario is the *Environmental Bill of Rights*, adopted in 1994. It requires a *Statement of Environmental Values* from provincial Ministries to guide decision making , increases notice requirements and public participation for proposed policy changes, and increases access of private citizens to the courts to sue for damages to a public resource. Also, the Bill resulted in creation of an Office of the Environmental Commissioner to review implementation and report on compliance to the Provincial Legislature.

In the United States increased participation has been provided through judicial rules of standing, court reviews, legislative oversight, public hearings, citizen review panels, advisory commissions, site-specific dispute mediation and written comment processes (Fiorino 1994:96). Gormely's (1987) review of control strategies in the United States identifies two types of regulatory strategies at work in the environmental bureaucracy: coercive and catalytic controls. Coercive strategies prescribe means and restrict or compel action through mechanisms such as vetoes, external audits, and sanctions or rewards. In contrast, catalytic controls require action toward goals, but did not limit opportunities for creative problem solving. The latter relies on the power of persuasion to stimulate action and innovation.

Market-based instruments include direct and indirect fiscal incentives to augment and compliment traditional regulation (Anderson 1992). These instruments induce compliance and influence behaviour by offering something of economic value. A good or service may be purchased through direct expenditures, or behaviour may be influenced through taxes, fees, fines, subsidies, loans, compensation, and pricing mechanisms (Patton and Sawicki 1993:10). The United States and various European countries have instituted market-based approaches, such as emission charges and emissions trading. In Canada economic instruments have been limited primarily to capital cost allowances on purchase of air and water pollution control equipment, taxes on certain products (tires and fuel), user charges for water use and waste disposal, deposit-refund systems for beverage containers, and local sewer use charges for industrial sources (MOEE 1995).

Environmental assessment processes have been in place in the United States and Canada since the 1970's.[12] These review and approval processes generally produce a technical analysis of the potential environmental impacts of public works, such as roads, water projects and electrical generating stations. They also provide a public record of comments received from participants in the review process. Various analysts have been critical of the narrow focus of most assessments and the failure to integrate environmental assessment at broader policy and program levels (cf. Sadler 1986; Sadler and Jacobs 1990; Bregha et al. 1990). In Ontario, recent changes to the environmental assessment process emphasize reduced time-frames, project

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12 See Chapter 6 for a brief description of environmental assessment in Ontario.

scoping and increased certainty in the process. Issues such as integrated environmental management and protection were not addressed.

Rabe (1986) analyzes four programs to increase integrated environmental management. These include coordinating the review of all environmental permits, environmental assessment and cumulative effects analysis, use of an independent Rule-making and Adjudicatory Board, an integrated toxins control strategy, and multi-media permit processing. Rabe (1986) found that the prime objective of these efforts was to achieve increased administrative efficiencies in processing permit applications rather than increasing effectiveness of environmental protection policy. Similarly, in his review of environmental protection policy at the state level in the United States, Rinquist (1993) found that the drive to provide regulatory relief spurred most attempts at integrated pollution control. The trend to reduce environmental regulations is widespread.

> Most governments in North America ... have made policy statements against new environmental regulations, and some are removing a host of regulations. This is unfortunate. Regulation is not only vitally important to maintaining environmental standards, but also promotes eco-efficiency. (NRTEE 1996:10)

In tandem with reduced regulation, the orientation of environmental regulation is slowly shifting from treatment and removal of contaminants in waste streams to reducing or eliminating the creation of pollutants through process modifications, and substituting materials or products at the source (cf. Thorpe 1994; Bresnan 1994; Rasmussen 1994; Wynne 1992). A concept gaining currency among the international business community is the term *eco-efficiency*. The World Business Council on Sustainable Development defines it as follows:

> Eco-efficiency is reached by the delivery of competitively-priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle, to a level at least in line with the earth's estimated carrying capacity. (NRTEE 1996:1)

Environmental management practices of leading international companies are changing in response to a need to be able to satisfy customers, investors, creditors, suppliers, regulators and the public at large that they are operating responsibly toward the environment. New environmental management systems are providing a framework for adopting processes that help an organization manage its environmental agenda and document its environmental performance in response to regulatory requirements, social, economic and competitive pressures, and environmental risks. A key characteristic is a shift in emphasis away from end-of-pipe activities that control pollution after it has been created to proactive and preventative strategies. Practices that eliminate or reduce the use of hazardous and non-hazardous materials, energy, water, or other resources as well as those that protect natural resources through conservation or more efficient use represent a major evolution of environmental management.

Numerous European countries and the United States have developed prevention programs based the *precautionary principle* (cf. Thorpe 1994; Hassabeh, Thompson, Bahaviolos 1995; Environment Canada 1994). In brief, it promotes policies and actions to prevent serious loss or harm to the environment even where causal links between contaminants or actions and ecological effects has not been demonstrated unequivocally from a scientific perspective. The precautionary principle was first enunciated in Germany in the late 1970s, and has subsequently been incorporated in many international environmental agreements related to toxic substances as well as to fisheries and forestry management. For example, the 1992 International Convention on Biodiversity states:

> [W]here there is a threat of significant reduction or loss of biological diversity, lack of full scientific certainty should not be used as a reason for postponing measures to avoid or minimize such a threat. (quoted in Environment Canada 1994:5)

An international movement that reflects similar principles is *The Natural Step* approach, which began in Sweden in the late 1980's by Dr. Karl-Hendrik Robèrt (Holmberg, Robèrt and Eriksson 1994). The Natural Step is founded on the laws of entropy and thermodynamics, which define requirements and limitations on the use and disposal of renewable and non-renewable resources.[13] Each jurisdiction uses a different mix of regulatory and other incentives to promote improved environmental management systems. For example, in Holland the government imposed specific targets and timetables for major sectors, and provides financial support for energy conservation and research activities (Steffen and Atkisson 1995). Industry is afforded "customized implementation" that allows it to pursue policies and technologies best suited to achieve defined targets. Other jurisdictions, including many U.S. states, have adopted laws that prescribe pollution prevention planning by sector, define the process by which sectors and individual enterprises make decisions, and stipulate mechanisms for public reporting on prevention measures (Anderson 1992; Roy 1994; Sullivan and Floyd 1991). In Canada, pollution prevention is being promoted through voluntary instruments rather than being mandated by law.

The Great Lakes pollution prevention initiative of Environment Canada provides a model approach for integrating control of contaminant discharges with a broader set of policy instruments (Environment Canada 1992). The *Canada-Ontario Agreement,* which underlies federal environmental action in the Great Lakes Basin, focuses on three objectives: to conserve and protect sustainable ecosystems with their aquatic and terrestrial communities, including people; to restore ecosystem health and beneficial uses in degraded areas; and to prevent and

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13 The four "system conditions" that define an ecologically sustainable society according to The Natural Step include: substances from the Earth's crust must not be systematically increasing in nature; materials produced by society must not be systematically increasing in nature; the physical basis of nature must not be systematically diminishing; and fair and efficient use of resources to meet human needs (Holmberg et al. 1994).

control pollution (COA 1994). Environment Canada's pollution prevention initiative is defined in terms of four basic activities: control, remediation, conservation, and prevention.

Similarly, Kussinen, Lesperance and Bilyard (1994) outline a model for integrated environmental management that includes the following: pollution prevention, mitigation, protection and restoration. They describe pollution prevention in terms of continuous improvement in the efficiency of energy and materials use at all stages from resource extraction through product use and disposal. Impact mitigation is described in terms of pollution control regulation as well as market-based approaches for reducing emissions of contaminants. Environmental restoration is described in terms of restoring damaged habitats, cleaning up contaminated areas and taking various measures to off-set unavoidable losses. Resource protection is described in terms of providing preferential protection for sensitive or critical areas through land use controls.

IPC: In Review

The literature on integrated pollution control is driven by a concern over the increasing costs and limited success of end-of-pipe regulatory controls. It also is concerned with the fragmentation of policy and administration on the basis of environmental media (air, land, water). Some of the central themes include:

- coercive controls versus catalytic strategies- linking regulatory controls that compel action with innovative strategies that incorporate market-based incentives and voluntary measures to persuade, stimulate and encourage innovation toward clear goals;
- developing improved methods for evaluating and controlling cross-media transfers of pollutants;
- prevention - shifting the focus from controlling and managing the by-products of

> industrial activities to anticipating and preventing their creation, influencing the location, type and intensity of activities and populations, and protecting and restoring the natural environment.

3.4 Ecological Land Use Planning

Ecological land use planning (ELUP) has its genesis in early writers such as Patrick Geddes, Frederick Olmstead, and Benton Mackaye, who expressed significant concern about the negative environmental effects of un-managed land development (Toner 1988). Ian McHarg's seminal work in 1969, entitled *Design with Nature,* signalled renewed interest in this subject by the planning profession (Galloway and Huelster 1971). McHarg developed a method for assessing the intrinsic suitability of areas for different types and intensities of land use. Environmental conditions, such as hydrology, soils, vegetation and wildlife, are evaluated for the constraints they pose to various uses. A composite map is produced that classifies the relative suitability of areas for the proposed activities. The final product is a set of recommended land use controls, intended to be scientifically-based, which protect the values inherent in the natural systems present (McHarg 1969).

In the same year that McHarg's seminal work was published, Bob Dorney was producing parallel insights into what he termed *ecoplanning* (Dorney 1969).[14] He outlines a general methodology that involves inventory and analysis of past and present environmental conditions, potential incompatibilities of proposed development activities, and mitigation measures. The

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14 Also, in Ontario, during the 1960's, Angus Hills was pioneering methods for regional-scale land classification for agriculture, forestry and other uses. He subdivided areas into geographic units based on physiographic features and biological relationships. These were then evaluated on the basis of existing conditions (suitability), potential (capability) and forecast socio-economic conditions (feasibility) (Belknap and Furtado 1967).

purpose of ecoplanning is to enable environmental considerations "... to be an equal input amongst the usual economic, engineering and design considerations" (Dorney 1977:13). At the heart of his approach is integrating consideration of the living (biotic) and non-living (abiotic) components of the ecosystem with an evolving landscape where human activities (culture) display varying levels of dominance. As he notes: "Ecoplanning initiates understanding on how an acceptable human nature fit can be made at both the urban and regional level of detail for both aquatic and terrestrial ecosystems (Dorney 1989:63).

The process of ecoplanning includes a series of steps: project administration, development of goals and objectives, ecosystem inventory, ecosystem synthesis, impact assessment, and ecosystem monitoring (Dorney 1977). Ecoplanning is distinguished from traditional land use planning on the basis of a number of attributes:

- it examines historic ecosystem structure in order to understand current patterns of natural resource use, and present and future ecosystem function;
- it enlarges on static mapping of land and resource use by examining human-ecological interactions in the context of landscape evolution;
- it enumerates potential environmental gains as well as losses;
- it links environmental analysis activities to specific protection measures to ensure the quality envisioned is achieved, and relevant regulations and expectations satisfied; and
- it explicitly includes inter-professional and public communication.

(Dorney 1989:63-65)

Dorney was adamant that these activities were not a separate exercise from formal land use planning, but rather provided important improvements in the evolution of from *flat earth planning* to *ecoplanning*.

... Ecoplanning is not another new environmental planning methodology but a

> comprehensive procedure for developing an ideal environmental information and management system which builds on existing and well-established planning processes. (Dorney 1989:65)

In the early 1970's growing concern over urban sprawl, air pollution, energy shortages, loss of farmland and natural areas and degraded water resources led to pressures for better management of growth in the United States (Sinclair 1988:7, Deakin 1991:4). Additional objectives being addressed in growth management include: reducing public sector costs of providing infrastructure and services by promoting compact growth, managing traffic levels, preserving farmlands, and addressing quality of life concerns of communities (cf. Deakin 1989:11; Banta 1989; Beatley et al. 1988; Hamill et al. 1989; Sinclair 1988; Yaro 1991).

Nelson et al. (1995) identify a range of growth management tools: resource lands preservation; critical area programs; rural growth management; urban containment; and infrastructure planning and financing. Some combination is generally used to achieve growth management objectives. Resource lands, such as prime agricultural areas, have been protected through exclusive-use zoning, supportive tax policies, and various land acquisition and conservation programs (Aberger 1991). Public and private land acquisition of valued agricultural, forested, and other areas also have been used as an important supplement to land use regulations.

Acquisition of easements has often been preferred to fee simple ownership, and almost all states have passed specific statutes authorizing conservation easements to facilitate their use.[15] A large number of private land trusts have been established in the United States which participate in the real estate market as representatives of the public interest and use the full range of voluntary

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15 Easements are limited interests in real property held by public agencies or private individuals, rather than the principal property owner (Platt 1991:121).

land conservation techniques available to private trusts (Mantell, Harper and Propst 1989:188). Critical area programs have been established in some areas deemed to be especially vulnerable to the effects of development. Most of these programs include promulgation of a land use plan, a development control system, and various techniques to protect valued ecosystem functions[16]

In rural areas subject to urban development pressures, jurisdictions have adopted a range of growth management tools. Open space zoning, or cluster zoning, requires that development be clustered on a defined area of a site to reduce infrastructure requirements and limit encroachment onto environmentally sensitive areas (Mantell, Harper and Propst 1989; Arendt 1991). Another technique is overlay zoning for areas having important ecological functions. Within these areas, environmental performance standards are applied, which may limit paved surface area, restrict use of hazardous contaminants or decrease development density. Others have required the preparation of environmental inventories and impact assessments as part of the development review process (Mantell, Harper and Propst 1989; Yaro 1989).

Urban growth boundaries have been used to try and contain the expansion of urban areas and restrict development outside serviced areas. Many growth management programs also have policies that require that necessary infrastructure to service new development is in place (Nelson et al. 1995:95). This includes shifting more of the cost of development to developers, through impact fees and development charges. For example Florida has a "pay as you grow", or concurrency requirement, for infrastructure to avoid deficit financing of growth, prevent large infrastructure backlogs and paying the cost of growth as it occurs (Sinclair 1988:14; Fulton 1991:122).

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16 Two U.S. examples include the New Jersey Pinelands, and Florida's Critical Areas Program.

There are few systematic evaluations of the success of growth control measures (Deakin 1989). It has been suggested that some approaches, such as conservation programs for resource lands and use of overlay zoning in sensitive areas, have provided increased environmental protection (Beatley et al. 1988:36; Aberger 1991:68). On the other hand, urban growth boundaries have sometimes intensified development pressures outside urban areas (Fulton 1991:130). Other negative charges against growth management relate to the mis-use of exclusionary zoning, the diversion of development to other locales, and increased land costs and housing prices (Deakin 1989).

In 1980, Lang and Armour released a comprehensive review of environmental planning in Canada. They define environmental planning as "... preparing for purposeful action directed towards specific environments or environmental resources for the overall purpose of optimal enhancement of environmental capacity" (Land and Armour 1980:21). As had others before them, Lang and Armour review the impacts of different types of land use activity, such as agriculture, urbanization, transportation, and recreation, on air, land and water resources (cf. Cross, Genetelli and West 1975; Edington and Edington 1977; Wilson, Tabas and Henneman 1979). They describe environmental planning as part of a larger environmental management framework including: information and monitoring, plans and policies, impact assessment, regulation and review processes, fiscal measures, organizational arrangements and public participation. Some of the defining characteristics associated with environmental planning include: a systems orientation, analysis of the dynamic interaction of human activity systems and natural systems, local environmental change within a regional context, impact-oriented and preventative (Lang and Armour 1980:21-22).

In 1989 a report was commissioned by the federal government on sustainable land use planning in Canada (Richardson 1989). The review concluded that land use planning could contribute to sustainability in a number of ways: by protecting lands, resources, and features of special value; resolving competing demands for land in relation to predetermined goals, criteria and priorities; facilitating environmentally sound economic development; reducing pollution through location, siting and design controls on development; and promoting sustainable urban development through regulating its form and density (Richardson 1989:38).

In 1990 the Canadian Institute of Planners convened a workshop to discuss the implications of sustainable development for planning (CIP 1990). Some key conclusions about making sustainability a central operating principle included:

- need for a vision with quantified limits and measurable performance indicators;
- better coordination across disciplines, jurisdictions and planning levels;
- linking integrated resources planning, land use planning and environmental impact assessment;
- recognizing the rights of the ecosystem and species as well as rights of individuals;
- developing new tools for policy design through to decision making; and
- supporting healthy communities initiatives and sustainability reporting.

(CIP 1990)

In their work for the *Royal Commission on the Future of The Toronto Waterfront*, Barrett and Davies (1991) developed a framework for ecosystem-based planning. Their framework differs from conventional planning practice as follows:

- greater emphasis on ecosystem health, sustainability and quality of life;
- attention to interactions among components of the ecosystem;

- a longer-term perspective and expanded planning boundaries to encompass ecosystem processes;
- examination of alternatives and prediction of effects; and
- direct participation by all stakeholders in planning.

Critical activities include defining the scope of the plan and its goals, identifying roles and responsibilities, assessing ecosystem health values and limits, examining alternative scenarios, reaching decisions, implementing plans, outlining performance requirements, monitoring implementation, and revising the plan. The watershed is the ecological unit commonly recommended for ecological land use planning (Odum 1971; Barrett and Davies 1991; Imhof et al. 1991). Two primary reasons are that physical boundaries can be readily defined with the hydrologic regime acting as the pathway through which the physical, chemical and biological components of the ecosystem are integrated; and because objectives and strategies can be formulated to guide planning decisions concerning the location, rate, density, nature and timing of development. In the last five years watershed studies have become an important vehicle in Ontario to facilitate consideration of natural resource features and functions associated with the protection of water quality and quantity. It can provide a consistent approach across municipal boundaries and improved direction to municipalities, landowners and developers before land use decisions have been made (see sections 6.3.2.5, 6.4.2, 6.5, and 8.3.1).

ELUP: In Review

The interest in ecological land use planning is driven by the recognition that growth and development decisions can undermine the health and long term viability of the ecosystems upon which humans rely for their well-being. Some of the underlying themes include:

- cross-boundary - planning on the basis of ecosystem units rather than administrative divisions of the landscape;
- objectives - defining ecosystem objectives to guide decision making through direct participation by all stakeholders in planning;
- information- investigating and monitoring processes and interactions among living and non-living components of the ecosystem within an evolving landscape;
- assessment - examining the cumulative environmental effects of multiple stresses of ecosystem processes and functions.

3.5 Adaptive Environmental Management

Over the past two decades the concept of adaptive environmental management (AEM) has gained currency (cf. Holling and Goldberg 1971; Lee 1993; Dovers and Handmer 1992; Gunderson, Holling and Light 1995). The concept emerged out of concern over the increasingly stressed interdependencies between human activities and ecosystem functioning, and a crisis of confidence in the sustainability of traditional resource management methods (Dovers and Handmer 1992:274; Holling 1995). Adaptive environmental management is characterized by its focus on the ecosystem as a whole, its attempt to span jurisdictional boundaries and link previously separate functions, and by its use of time scales more in keeping with ecological cycles, rather than economic or political time-lines (Lee (1993:62-3).

The literature emphasizes the importance of continually adapting planning and management decisions to new understanding of the complex and evolving behaviour of ecosystems. Adaptive management has been described as:

> ... continually researching, monitoring and evaluating the ecological conditions of ecosystems and, where necessary, modifying management on the basis of new information to better accommodate socio-economic considerations while ensuring that

a minimum of desired ecological conditions are being achieved (GAO 1994:49).

Following examination of seven regional resource management cases, Gunderson, Holling and Light (1995) develop a model of institutional change and a set of postulates related to system crises, actor collaboration, and institutional renewal. The four stages of ecosystem functioning identified by Holling (1995) are matched with a parallel model of the institutional system consisting of policy decisions, implementation activities, emergent crises, and alternative responses.[17] Most environmental management strategies control for few variables and eliminate natural fluctuations to provide a continuous flow of resources consumed by society. Bureaucratic/administrativestructures are established to implement short term and single target policies. These administrative structures develop rigid approaches that are unresponsive, fail to test hypotheses or re-evaluate the assumptions behind such policies. This can reduce ecosystem resiliency and lead to unanticipated ecosystem collapse.

Subsequent crises emerge when policies fail to achieve targets or the underlying management assumptions change. Crises present an opportunity for the renewal of institutions. Following a crisis, various forms of formal and informal collaboration develop among groups within and outside major organizations. This fosters a shared understanding and identification of a variety of options for addressing the crisis. Out of this process issues can be re-framed, a new vision created with redefined goals and objectives, new policies developed, and management institutions restructured (Francis and Regier 1995:281; Gunderson, Holling and Light 1995:492).

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17 The four stages of ecosystem functioning are represented by a continuous flow between *Exploitation* (few stored nutrients and carbon, weak connectedness among variables) *Conservation* (many stored nutrients and carbon, strong connectedness), *Release* (through fire, storm, pest), and *Reorganization* (accessible carbon and nutrients) (Holling 1995:22).

The adaptive approach emphasises improved ecological science as a basis for planning and management, grounded in experimentation and monitoring. The dynamic nature of ecosystems and the uncertainty in accurately predicting their response to human stresses present singular challenges (Briassoulis 1992; Lee 1994; Gunderson, Holling and Light 1995). Ecosystems are complex systems that evolve and change unpredictably. Components of an ecosystem are connected in selective ways with a few processes generating its complexity and diversity. As a result, stresses do not lead to uniform responses (Holling 1995:32). The need to continually test and modify understanding of ecosystem conditions and management measures acknowledges the persistence of significant gaps in information, theory and understanding. These conditions suggest the need for a corresponding adaptive capacity in planning and management systems. As noted by Briassoulis (1992:386):

> ... the adaptive approach, grounded on systems analysis, recognizes the dynamic character of ecosystems, the uncertainty associated with describing them and predicting environmental consequences of human activities, and the existence of both sensitive and robust elements in ecosystems that should be identified properly so that human uses of environmental resources can be accommodated without, however, jeopardising the complexity, stability and resilience of ecosystems.

There is a conscious attempt to build capacity to respond to unexpected events as part of the ongoing planning and management process. This places emphasis on monitoring, experimentation, learning and innovation in planning and management (Holling 1995:30; Lee 1993; Bardwell 1991:611). The adaptive approach is reminiscent of the precautionary approach referred to previously. Under conditions of uncertainty, policies and practices are treated as working hypotheses, rather than fixed solutions, and are tested and closely monitored for their consequences (Christiensen 1985). As noted by Ringold et al. (1996:745):

> This adaptive approach acknowledges that action is necessary or appropriate with imperfect knowledge ... and that initial actions can be refined as more information becomes available.

The adaptive approach encourages and supports flexibility and innovation in adjusting policies to the exigencies of a particular context (Berman 1980:212). Rules and practices are designed with flexibility to adapt to variable and changing conditions in specific ecosystems (Briassoulis 1992:386; Westley 1995:394; Dovers and Handmer 1992:270). Frequent adjustments in management techniques are the norm and diverse, flexible and integrative policies are needed that provide increased understanding (Holling 1995:30).

A related characteristic of adaptive environmental management is the commitment to foster continuous learning, renewal and improvement in the institutions governing environmental management by involving actors within and outside formal governing structures. The development of creative and adaptive solutions requires the involvement of affected people and groups who are part of the system. These actors serve as a pool of creative ideas, provide reframing strategies, and provoke opportunities for cooperation (Gunderson, Holling and Light 1995:531). The interactive dimension of adaptive management plays an important role in the approach taken to implementation. It is particularly critical where one or more of the following conditions exist: the scope of change in behaviour is large, the validity of policy theory or technology uncertain, there is disagreement or conflict over policy goals and means, there is a low level of coordination among organizations, and where exogenous events are forcing change (Berman 1980; Christiansen 1985). In their research on adaptive environmental assessment institutions, Mulvihill and Keith (1992:409) highlight the importance of engaging the participation of system members to contribute to collective knowledge of the system and to generate policy options through exchange and negotiation processes. They identify a set of principles and institutional design criteria that emphasize flexible processes, minimal critical specification, the ability to link diverse interests and functions, continuous learning/self-evaluation, semi-autonomy/multiple accountability, and integration and coordination of related processes.

In his analysis of adaptive management in the Columbia River Basin, Lee (1993) emphasizes the importance of mechanisms and forums for actor groups to participate and debate issues. With reference to the work of Sabatier (1988) and others, Lee argues that differing perspectives within a policy system will drive the learning processes by keeping attention focused on key policy/problem areas (Lee 1993:87, 98, 100).

In their discussion of monitoring and assessment , Nelson and Serafin (1994) describe the movement toward an adaptive approach. It is characterized by an expanded scope and high degree of involvement by a wide range of groups and interests to achieve improved understanding of environmental change and human-ecological dynamics. Nelson and Lawrence (1994) describe a human-ecological approach as comprehensive (linking all activities, features and processes), dynamic (understanding changing processes and patterns), and adaptive/interactive (communication and learning from as many sources as possible).

AEM: In Review

The interest in adaptive environmental management evolved in response to the failure of conventional management approaches to sustain healthy functioning ecosystems. Rigid structures and unresponsive institutions have not successfully accommodated complex ever-changing ecosystems nor anticipated their collapse. The central themes include:

- adaptive - recognize dynamism and uncertainty associated with continually evolving ecosystems and build capacity to respond to unexpected events as part of the ongoing planning and management process;
- interactive - benefit from differing perspectives and knowledge within a policy system

to drive the learning processes and keeping focused on key issues and policies;

- continuous learning - treat policy as working hypothesis, test through monitoring and experimentation, and modify on the basis of new information and understanding

3.6 Ecosystem Frameworks

Various investigators have proposed frameworks for ecosystem management that share common themes (Table 1). Neufeld et al. (1992) propose a framework for an ecosystem approach to planning that includes five key characteristics: ecosystem boundaries are used as a basis for planning, rather than political or administrative boundaries, ecosystem objectives are developed to guide decision making, information on ecosystem processes and functions is integrated and shared among participants, potential cumulative effects associated with human activities considered, and ecosystem integrity is monitored over time.

Slocombe (1993) proposes an ecosystem framework consisting of the following characteristics: a trans-disciplinary and systems approach to description and analysis, use of multiple theories and methods, anticipatory and adaptive, hypothesis-generating and ecosystem modelling, long-term oriented and goal-directed, cooperative and integrated, and broad dissemination and use of ecological information. Tomalty et al. (1994) identify seven principles of ecosystem planning. These include: use of natural boundaries for planning, designing with nature, considering cumulative effects, inter-jurisdictional decision making, consultation and cooperation, long term monitoring and feedback for plan adaptation, and an interdisciplinary approach to information.

TABLE 1 : SELECTED ECOSYSTEM FRAMEWORKS

	Neufeld et al. (1992)	Slocombe (1993)	Tomalty et al. (1994)	Grumbine (1995)	Christensen et al. (1996)
Boundaries	Ecosystem boundaries are used as a basis for planning, rather than political or administrative boundaries		use of natural boundaries for planning	recognize connections among a hierarchy of ecosystem levels	reconcile spatial scales by seeking consensus within ecosystem and across administrative boundaries
Objectives	humans are part of an interconnected, and interdependent global ecosystem where changes in one part of the system affects other parts in unexpected ways ecosystem objectives developed to guide decision making	long-term oriented and goal-directed	designing with nature	recognize embednedness of humans in the ecosystem, acknowledge role of human values in ecosystem management goals set clear ecosystem management goals	acknowledge humans as part of the ecosystem, adopt long term planning outlook define measurable goals and objectives
Information	ecosystem processes and functions are analyzed ecological information is integrated and shared among participants	a transdiciplinary and systems approach to description and analysis, use of multiple theories and methods, hypothesis-generating and ecosystem modelling broad dissemination and use of ecological information.	an interdisciplinary approach to information	improve research and data collection and management	sound ecological models, understand complexity and interconnectedness, dynamic character of ecosystems,,
Monitoring	ecosystem integrity is monitored over time		long term monitoring and feedback for plan adaptation	monitor results of actions	commit to adaptability and accountability of management to research and monitoring,
Cumulative Effects	potential cumulative effects associated with human activities considered		consideration of cumulative effects		
Adaptive		anticipatory and adaptive		adapt management to uncertainty	make system accountable to changing ecosystem characteristics and knowledge base
Coordination		cooperative and integrated	consultation and cooperation interjurisdictional decision making,	manage across administrative/political boundaries, cooperate among different groups and agencies	

In his review of ecosystem management literature, Grumbine (1994) identifies ten dominant themes: recognize connections among a hierarchy of ecosystem levels, manage across administrative/political boundaries, set clear ecosystem management goals, improve research and data collection and management, monitor results of actions, adapt management to uncertainty, cooperate among different groups and agencies, recognize embededness of humans in ecosystem, and acknowledge role of human values in ecosystem management goals. Recent work on ecosystem management of federal lands in the United States identifies the following principles: managing along ecological rather than political or administrative boundaries, coordination among public agencies, increased collaboration with other stakeholders, considering natural and human components and their interactions, monitoring and assessment, and use of the best available science (Thomson 1995:45).

The Ecological Society of America recently concluded that ecosystem management includes eight elements: a long term sustainability focus; measurable goals related to process and outcomes; sound ecological models; biological diversity; understanding the dynamic character of ecosystems; attention to complexity and scale; acknowledging humans as ecosystem components; committing to adaptability and accountability of management to research and monitoring (Christiensen et al. 1996). The Society outlines four specific steps to move from concepts to practice: define sustainability goals and objectives; reconcile spatial scales by seeking consensus within ecosystems and across administrative boundaries; adopt long term planning outlook; and make system accountable to changing ecosystem characteristics and knowledge.

> Ecosystem management is management driven by explicit goals, executed by policies, protocols and practices, and made adaptable by monitoring and research based on our best understanding of the ecological interactions and processes necessary to sustain ecosystem composition, structure and functions. (Christensen et al. 1996:668-669)

Following an analysis of 77 case studies of ecosystem management in the U.S., Yaffee (1996) identifies five key tasks: collaborative decision making, sharing knowledge through effective information networks, organizational change and innovation across disciplines and organizations, education and outreach to foster increased understanding and modify attitudes of the public and stakeholders, and empowering individual entrepreneurs to achieve on-the-ground innovation (Yaffee 1996:725). Yaffee notes the importance of a common vision of human-ecosystem dependencies in order to sustain political support for allocating resources among competing interests:

> Such concurrence requires building a shared understanding of the importance of healthy ecosystems and how humans can benefit from the long term economic and ecological sustainability that can derive from them. (Yaffee 1996:726)

The suggested roles of government are to act as a catalyst for change by:

- providing information and resources to facilitate on-the-ground activities;
- promoting ecosystem scale perspectives through incentives in land use planning, environmental policy and tax policy;
- using statutory requirements to protect elements of biodiversity as an incentive to multi-party discussions critical to achieve ecosystem management;
- managing public lands well; and
- developing and implementing a set of long term performance indicators.

3.7 Guiding Principles

There is no single interpretation of an ecosystem approach. Some suggest that the conceptualization process "...remains in a state of considerable confusion" (Norton 1992:24). Others see advantage in a more loosely structured set of concepts, arguing that this "constructive ambiguity" allows it to be adapted to specific circumstances (Doern 1993). Regardless, it is unlikely that the ecosystem approach will ever be tightly fixed in a limited operational sense (Gerlach and Bengston 1994:35). Indeed Yaffee (1996:724) observes that those who have adopted an ecosystem-based perspective rarely have done it *a priori*:

> ... they pursued these approaches in order to solve problems evident in their traditional approaches or that faced them on the particular site.
>
> Fortunately, on-the-ground managers are not waiting for either scientists or policy makers to come to consensus on a definition of ecosystem management or how to change public policies to bring it about. They recognize the need to stumble forward.
>
> (Yaffee 1996:725)

This review of the literature reveals a collection of recurring ideas that together reflect current thinking about an ecosystem approach to planning and management. The concepts associated with an ecosystem approach have been organized under eight key principles: boundaries, objectives, functions, cumulative effects, integrated, adaptable, coordinated, and catalytic. Each of these contrast sharply with conventional approaches to environmental planning and management (Table 2).

Boundaries

Fundamental to an ecosystem approach is the recognition that ecosystems provide the context for all human activities, and that they are the ultimate mediator of planning and management decisions (Jaackson 1987; Norton 1992). It expands planning boundaries to include whole

TABLE 2:CONVENTIONAL & ECOSYSTEM APPROACHES CONTRASTED

CONVENTIONAL APPROACH	ECOSYSTEM APPROACH
Uses administrative, political and site boundaries as basis for planning.	Uses ecological boundaries for planning, recognizing a hierarchy of nested systems with variable physical and temporal scales.
Focuses on human uses and benefits (quality and quantity)	Places human uses in context of defined ecosystem objectives and targets for sustaining valued functions.
Collects data on discrete physical, chemical, biological parameters.	Informs decisions through analysis of ecosystem structure, functions and linkages.
Assesses environmental impacts at site level. Monitors for individual contaminants.	Assesses potential cumulative effects of multiple stressors and land use change on ecosystem functioning at multiple scales.
Applies uniform prescriptions and requirements with limited flexibility.	Accommodates diverse conditions and is responsive to new information and understanding, technological developments, and changing conditions.
Emphasizes control and remediation through patchwork of rules for individual sources and activities.	Supports preventative strategies with integrated set of regulatory, economic, and information-based instruments.
Centralizes authority and responsibility for solving environmental problems.	Secures the participation and accountability of core actors for defining and achieving collective outcomes.
Uses closed decision systems rather than engaging and empowering actor groups to find workable solutions.	Develops the institutional capacity to sustain implementation.

ecosystems. Gerlach and Bengston (1994:30) refer to this idea as the 'systemic imperative':

> To manage more comprehensively and integratively on ever larger scales and inclusive scopes to serve system demands dictated by how nature and society work as complex and interdependent systems.

The ecosystem approach uses regional-scale ecological processes as the context for considering human-ecological relationships. It applies ecological boundaries for planning, recognizing a hierarchy of nested systems with variable physical and temporal scales. The boundaries principle expands the scope of conventional management from site-specific contexts to the larger boundaries provided by ecosystems. It suggests that boundaries for planning and management should encompass the processes and functions most directly related to the goals and objectives being pursued. It also should encompass, to the extent possible, the land uses and activities that are impacting valued ecosystem functions. This requires attention to both local and regional scales. Temporal boundaries and scales are important since the ability of ecosystems to accommodate human stresses changes over time and space. No single set of boundaries are sufficient as ecosystems operate within a hierarchy of interacting scales and processes.

Ecosystem Objectives

An ecosystem approach is governed by shared vision of the ecosystem that includes specific goals and measurable objectives. These objectives should be based on the goal of ensuring sustainable uses within a dynamic and healthy ecosystem. It affirms the need to broaden the conventional focus on short term human benefits to include the concept of ecosystem integrity, recognizing that human health and welfare ultimately rely on the life support systems and natural resources provided by healthy ecosystems. As Christensen et al. (1996:666) note, "...[it]

acknowledges the importance of human needs while at the same time confronting the reality that the capacity of our world to meet these needs in perpetuity has limits and depends on the functions of ecosystems."

The concept of ecosystem health, or ecosystem integrity, relates to the notion of a self-sustaining system that can cope with external stresses and that evolves and changes over time (cf. Francis and Regier 1995:273). It has recently been described using three characteristics: the ability to maintain normal operations under normal conditions; the ability to cope with exogenous stress or change; and the ability to continue the dynamic processes of self organization i.e. to evolve, develop and cycle through birth, growth, death, renewal (IJC 1996:20). Human values are integral to the process of defining ecosystem objectives:

> Ecosystem integrity can be interpreted in terms of the viability of the natural system and human uses of that system. Indeed, human uses and human values, which are essential components of ecosystem integrity, have been, and will continue to tremendously influence the viability of the natural system and hence, overall ecosystem integrity (IJC 1996:20)

Objectives may be defined which correspond to the different scales at which planning and management is being undertaken. It requires combining discussion among core actor groups of human preferences with technical-scientificanalysis. Ecosystem objectives should be translated into qualitative and quantitative indicators and measurable targets to provide benchmarks against which proposed human activities can be assessed and ecological conditions can be monitored over time.

Ecosystem Functions

An ecosystem approach has significant implications for the type of information collected. In contrast to the conventional practice of collecting data on discrete physical, chemical or biological parameters, decisions should be informed through analysis of integrative ecosystem processes and functions. Healthy ecosystems perform a range of functions, which in turn provide services and goods benefiting human society as well as other components of the ecosystem. The functional principle directs analysis to the processes linking ecosystem components and that support critical functions. It requires analysis of the functions being performed by the ecosystem as well as the attributes that support key functions such as biochemical cycling and storage, hydrologic flux and storage, biological productivity and diversity (Christiensen et al. 1990:667; Manning 1994:380).

Until recently, even relatively progressive approaches, such as that pioneered by McHarg (1969), suffered from static environmental analysis that was orientated to ecosystem structure rather than ecosystem function, and lacked a framework for considering cause-effect relationships between human activities and ecosystem processes (cf. Lee 1982; Gordon 1985). Ecosystems are moving targets with processes functioning at different scales and rates, and multiple potential future states (Holling 1996). This requires ongoing analysis of the dynamic and interacting processes that link components of the ecosystem.

> The structural and functional properties of ecosystems change over time because of natural ecological succession and other factors such as long-term shifts in climate and hydrology, as well as the impact of intrinsic human values. (IJC 1996:22)

Improved understanding of ecosystem functioning in turn provides a sound basis for considering the potential impacts of land use change on ecosystem functions.

Cumulative Effects

An important component of the ecosystem approach is assessing and monitoring the potential cumulative effects of multiple human stresses on ecosystem functioning over time. All environmental effects can be described as cumulative because an ecosystem has successive and multiple stresses acting upon it (Contant and Wiggins 1991; Irwin and Rhodes 1992). The response of ecosystems to stress may be manifested in changes to ecosystem structure as well as partial or complete loss of ecological functions at different scales (EPA 1992a). Cumulative effects assessment attempts to predict the response of ecosystems to existing and potential human stresses. This principle seeks to overcome the limitations of traditional approaches which do not operate within an ecological framework, nor considers the cumulative effects of past, present and proposed activities.

In the United States, the U.S. Environmental Protection Agency (1992a), the World Wildlife Fund (Frances and Rhodes 1992) and others have made significant progress in defining frameworks for assessing cumulative effects. In Canada, most work in this area has been done for the Federal Environmental Assessment Office (Davies 1991), Parks Canada (Woodley 1991; Kalff 1995), and the Niagara Escarpment (Macviro 1995; Whitelaw, Neufeld and Carty 1995). There are many technical challenges associated with assessing potential cumulative effects. It requires an understanding of how groundwater-ecosystems function as well as the cause-effect relationships which lead to cumulative environmental effects. The complexity of groundwater ecosystems and the functional pathways through which effects are manifested over time has made it difficult to develop a broadly applicable cumulative effects assessment methodology. As well, knowledge regarding matters such as the structural and functional attributes of ecosystems, and the major determinants of stress on ecosystems must continue to expand.

Ongoing monitoring is needed to document ecosystem response to the cumulative effects of multiple stresses over time. It should provide information that can be used to evaluate the success of policies and programs and to document progress toward long term goals. As Woodley (1991:i) notes:

> Ecosystem management depends upon a continuous flow of relevant information from various monitoring systems. In order to manage ecosystems and ensure their integrity, detailed monitoring of the state of the ecosystems is a prerequisite.

A recommended approach to monitor cumulative effects is based on developing a set of questions that guide monitoring activities, identifying specific indicators to be monitored, defining the temporal and spatial characteristics of interest on a bio-regional basis, linking it to specific ecosystem management needs , and accounting for issues of policy and ecological significance (cf. Ringold et al. 1996; Whitelaw, Neufeld and Carty 1995). The suite of monitoring indicators should provide surrogate measures of land use activities representative of stress on ecosystems as well as measures of ecosystem functioning (Contant and Wiggins 1992). As noted by the Crombie Royal Commission (1992:125):

> Coordinated, comprehensive research, modelling, and monitoring programs would help to ensure that pathways in the ecosystem are explored, that cumulative effects are assessed, that remedial programs can be evaluated, and that indicators of ecosystem health can be developed and applied.

Sharing knowledge and exchanging information through effective information networks is critical An information management system should be capable of integrating diverse data sets, evaluating data collected for specific geographic areas over long periods of time, and facilitate comparisons of historical data and present conditions within defined boundaries. The type of information collected should be extensive, or ecosystem-wide, supplemented with more intensive, site-specific, information where available. The information management system should facilitate testing of assumptions, methods and techniques to achieve ecosystem objectives and foster informed discussion among core actor groups.

Adaptable

A key principle is being responsive to new information, changing needs, and evolving conditions. The dynamic nature of ecosystems, limited information, and imperfect understanding casts a "veil of uncertainty" over environmental planning and management (Young 1994:98). Dovers and Handmer (1992:274) refer to it as "... a problem of managing change in complex, poorly understood systems". The complex and dynamic nature of ecosystems demands that institutions "expect the unexpected" to happen. It demands a precautionary approach that ensures future options are not precluded by a failure to act where uncertainty exists. Institutions need to move forward in the absence of comprehensive information and understanding. As Ringold et al. (1996:745) note:

> The adaptive approach acknowledges that action is necessary or appropriate with imperfect knowledge ... and that initial actions can be refined as more information becomes available.

The adaptive principle also affirms the reality of regional contingencies and differing capacities to take action to protect healthy ecosystems. Policies should provide for adaptation to variable conditions rather than requiring conformity to uniform prescriptions (Christiansen 1985:71). Pre-determined or programmed solutions are replaced with innovative and flexible approaches that recognize the uncertainty in predicting outcomes. Scientific understanding, and its predictive tools of the trade are acknowledged to be limited, and institutions should support innovation and encourage experimentation (Bardwell 1991:611). This means allowing for reformulating goals, standards and requirements on the basis of information provided by ecosystem monitoring and research. It requires a commitment to ongoing evaluation of objectives, measures and outcomes both internally as well as through external means.

Integrated

The integration principle seeks to replace a patchwork of regulatory controls with preventative strategies that apply an integrated mix of regulatory, economic, and voluntary instruments. It provides a counter-weight to reliance on regulatory controls by emphasising instruments that anticipate and prevent environmental degradation. It endorses multiple-means to achieve collective goals and to institutionalize collective action (Gerlach and Bengston 1994). Direct regulation takes on a supportive role by providing the authority and motivation for implementing preventative strategies. It is motivated by awareness that the fragmented approach characterizing traditional planning and management have failed to address environmental problems holistically (Rinquist 1993). The emphasis on prevention also reflects the need for precaution, given the lack of information and uncertainty over management strategies. It acknowledges the enormous costs and technical difficulties of restoring degraded ecosystems. As Kuusinen, Lesperance and Bilyard (1994:24) note:

> Both environmental quality and international economic competition will drive future natural resource policies toward reorienting economic activity to reduce waste and pollution from resource extraction, refining, manufacturing, distribution, and product use, through product reuse and recycling.

Successful integration balances diverse and conflicting interests, often within a set of relatively fixed institutional structures. Integration should be viewed in a strategic sense, rather than as a mandate for total restructuring of institutional structures and organizational mandates. Critical linkages need to be identified and strengthened among key policies and programs that hold the most promise for addressing inconsistent goals and fragmented decision making. As noted by Rabe (1986:xv):

> Such innovation must be sufficiently far-reaching to transcend existing medium boundaries and establish new organizations and procedures explicitly devoted to greater integration. At the same time it must nor be so far-reaching as to defy common

> comprehension, prevent a manageable transition from past practices, or ride roughshod over political realities.

The choice of instruments and tools for directing and managing human activity systems in a particular context will be affected by a number of factors, including how broadly problems are defined, the specific goals and objectives agreed upon, and the resources available (Fiorino 1995).The movement toward fully integrated strategies should begin with the most feasible steps toward integrated planning and management. Over time, the level of effective integration and coordination should increase as the benefits of this approach are demonstrated and embraced by core actors.

Coordinated

The principle of coordination involves securing the participation and accountability of core actors for defining and achieving collective outcomes.Past approaches which have relied on centralized public authorities to define problems and dictate solutions has been seriously questioned (cf. Gibbs and Bromely 1989; Bocking 1994; Creer-Wotten 1994; Nelson and Serafin 1994). Criticisms stem from the preponderance of reactive versus pro-active strategies, its regulatory orientation, the slow pace of change, and the increasing difficulty in fulfilling self-defined mandates (Creer-Wotten 1994). Gerlach and Bengston (1994:30) note:

> Central control to achieve ecological and economic sustainability will not be socially or politically sustainable. The answer, many seem to agree, is a new form of governance which actively includes the public in planning, decision and implementation processes. (Gerlach and Bengston 1994:35)

The ecosystem approach places increased responsibility and accountability on individuals and communities to interpret and apply ecosystem principles in their activities (Nelson and Serafin 1994, Bocking 1994, Francis 1990). All actors must be accountable for the contribution they make to long term goals. The coordinative function of planning is a relatively neglected area of planning thought (Alexander 1992) Antecedents to the concept are found in planning literature that argues for citizen participation and mutual learning (cf. Arnstein 1969; Friedmann 1987, 1973; Chevalier and Burns 1978). For example, Ventriss (1987) argues for planning processes which link citizen knowledge to action, in a continuous process. It is, in his words: "... a process of constantly putting knowledge to use in building the capacity of citizens to involve themselves in all aspects of community affairs" (Ventriss 1987:286).

Underlying this principle is acknowledgement of the right of the governed to participate as fully as possible in decision making processes that affect them. It also is based on the practical necessity of involving a wide range of actor groups whose support and resources are critical for successful outcomes. As such, the coordination principle can be seen as a response to the undesirable outcomes generated by different interests acting independently on the basis of different information, priorities and courses of action. Interdependencies among actors generate policy outcomes which are a function of the activities and interactions of numerous and diverse organizations (Warner 1972:22, Hanf 1978). Different actor groups need to be engaged to contribute their knowledge and information, and to participate in the task of generating policy options and solutions (Mulvihill and Keith 1992:409).

Coordination implies intervention to facilitate cooperation among independent organizations. Structures are needed that can foster the selection and implementation of a coherent strategy and set of instruments (OECD 1989; MacNeil 1971). Coordinating strategies deploy the collective capabilities of relevant organizations to achieve desired outcomes, taking into account existing constraints, interests and opportunities. It requires collaborative approaches that facilitate agreement on desired future conditions, including the type, mix and distribution of activities that can be sustained in a particular ecological system, and the distribution of responsibilities (GAO 1994). Coordinating mechanisms are important bridges that act as referent organizations for participating actor groups. These mechanisms facilitate exchange of information, discussion of common interests, and cooperative decision making in the interests of system-wide goals. Environmental partnerships also are critical at all stages of the policy process, from problem definition and agenda setting, developing options to address specific issues, and undertaking specific actions to implement solutions (Long and Arnold 1995). Successful environmental partnerships include core actor groups, define a vision that encompasses the participants' goals, and maintains relationships among participants and decision makers from the outset. They also respect actors' needs and interests, steward the partnering process, and translate findings into tangible actions.

Catalytic

The catalytic principle reinforces the need to develop the institutional capacity to sustain implementation. While recognizing the limits of centralized control, the catalytic principle does not dismiss the instrumental value of various forms of hierarchical organization to promote successful implementation. In practice, hierarchical forms of decision making and decentralized patterns of mutual adjustment co-exist. Each policy field has its unique history and characteristics, with its own set of dominant organizations, rule structure, interdependencies (Wamsley 1985; Rhodes 1986).

There are a wide variety of factors affecting achievement of public policy objectives (cf. Mazmanian and Sabatier 1983; Mann 1982). Rinquist (1993:97-99) identifies four types of factors positively related to successful outcomes. Internal statutory factors include: a statutory basis providing clear goals and standards for implementation, adequate technical resources and policy tools, and sanctions for non-compliance. Internal political factors include: support for program goals within participating organizations and affected interests, and adequate resources to carry out program responsibilities. Administrative outputs include adequate inspection and enforcement activities. External environmental factors refer to economic conditions influencing public and private perceptions of the relative importance of environmental policy goals.

The catalytic principle suggests that the primary role of central authorities are to: promote an ecosystem perspective, motivate and strengthen capacity and accountability for action at the community level, and develop long term indicators. These roles can be accomplished by encouraging, recognizing and supporting responsible action by all actor groups. Some specific roles for central authorities include: enacting statutory requirements and policies to provide a framework for protecting ecosystems, providing incentives to promote ecosystem scale perspectives, and providing information and resources to facilitate action (cf. Manning 1994, Yaffee 1996).

3.8 Barriers to an Ecosystem Approach

The barriers to implementing elements of an ecosystem approach are numerous. Common barriers that inhibit implementation of an ecosystem approach can be summarized as follows:

- information and data incomplete, dispersed, in-accessible;
- limited understanding and theory to translate loose ideas and concepts into recommended action;
- fragmented system of rules;
- inflexible rules and/or conflicting requirements;

- competing goals and objectives;
- unclear roles and responsibilities;
- limited resources and capacity; and
- lack of accountability for collective outcomes.

Some of the barriers to integrating environmental considerations in public policy include lack of clear sectoral objectives that translate ecosystem principles, segregation of environmental responsibilities in separate management units, limited accountability of line managers for the environmental implications of government policies, inadequate information sharing, and extant scientific and methodological issues related to the adequacy of available data, quantification of environmental risks and cause-effect relations (Bregha et al. 1990:13-27).

Many of the obstacles facing implementation illustrate the continuing and powerful influence of short term, ecologically destructive decision making. In his discussion of water management institutions, Wengert (1972) concludes that the most important determinants of water management behaviour were economic interests having no direct or primary relationship with water, but which influence patterns of growth and the demand for water supplies and waste management services. In his analysis of water quality management and protection in an urbanized watershed in Ontario, Sproule-Jones (1994:213) found that the rules related to water quality functioned as "... a set of marginal rules in use that affect but do not determine the decision situations facing at least half a million watershed residents."

The goal of integrated resource and environmental management has been likened to a chimera or an elusive grail (Fiorino 1995; Rabe 1986; Rinquist 1993). Lang (1986) identifies a long list of challenges facing integrated resource management, including: insufficient knowledge, lack of consensus on how resources should be used and managed, no clear policy context in which to plan, lack of clarity or agreement of the means to achieve desired ends; indeterminate outcomes and consequences of alternate courses of action, problems and solutions that cut across organizational boundaries, multiple stakeholders wishing to be part of the decision making process, and demands to accomplish planning within time, staff and budgetary constraints (Lang 1986:28-29).

Rabe (1986:115) lists three enduring impediments to integrated environmental management including: absence of clear ideas to be readily translated into policy reform, few political constituencies for integrated management, and dependence on crisis to generate support for integrated approaches. Other barriers, noted include: continuing acceptance of the divisibility of the ecosystem into single media, difficulty of measuring threats posed by cross-media pollution, inadequate data for cross-media analysis, little cross-fertilization among specialists and practitioners, resource constraints forcing action on short term priorities, and the tendency to focus on efficiency-oriented reforms.

The obstacles facing interorganizational cooperation are numerous, including: threats to organizational autonomy, few perceived benefits to cooperation, disagreement over goals and the means to achieve them, lack of consensus on respective roles and responsibilities, disagreement over technical issues, poor communication, and structural and operational dissimilarity (Halpert 1982). Overlapping jurisdictions, media-specific environmental regulation, fragmented responsibility and accountability, and ineffective coordination has characterized environmental management practice (Born and Remery 1989; Royal Commission 1992; Rinquist 1993; Caldwell 1994). As Fiorino (1995) notes, technical advances in the ability to detect contaminants has not been matched by increased institutional capacity for integrated environmental management.

> We are able to detect environmental contaminants at the level of parts per billion, or better, but we are unable even to begin to unify the many pieces of law that define the goals and framework for our strategies. ... Without institutions that are able to connect across problems and set priorities on the basis of some logical premise, policy will be disjointed and resources squandered. (Fiorino 1995:225)

There are numerous institutional obstacles to implementing environmental management systems based on pollution prevention and eco-efficiency:

- price and tax subsidies for water, wastewater, and energy promote inefficient use of resources
- traditional regulation requires end-of pipe remedial technology rather than prevention technologies
- tax regimes lack fiscal incentives for investment in eco-efficiency, innovation research
- lack of full-cost pricing reflecting life cycle costs
- limited scientific understanding of global and local ecosystem interrelationships and impacts
- reduced capacity of key scientific organizations and public agencies to provide environmental information to business
- business financial horizons that preclude viable options that could produce economic benefits over the life cycle of the technologies, in favour of short term economic performance (NRTEE 1996:7-10)

The ecological land use planning literature identifies numerous barriers to implementation. Twenty years ago, Magazine (1977) identified major obstacles to local environmental management that persist. Inadequate funding and competition for scarce resources is a pervasive obstacle to environmental management. Environmental programs are often given low priority in local budgets, leading to chronic lack of funds for capital improvements, for complying with senior government mandates, and for developing required expertise. Also, confusion over distribution of environmental responsibilities among separate authorities and levels of government spawn overlap, duplication and conflict. Magazine (1977) found a lack of staff expertise at the local level, insufficient technical support from senior levels of government as well as lack of information with respect to new management techniques, and evaluation methods. Absence of proven management strategies forced reliance on outdated tools.

More recently, Domon, Gabriepy, and Bouchard (1989) found that ecological approaches were often not implemented in planning practice. Some of the barriers they cite include the difficulty of processing large amounts of data, limited reliability of indicators and interpretation keys used to characterize impacted ecosystems, site-specific management decisions, lack of ecological understanding, and a failure to understand the policy context and interests of affected parties.

In his review of land use planning practice in Canada, Richardson (1989) lists a number of barriers to achieving environmental sustainability, including short-term socio-economic goals, economic incentives encouraging decisions contrary to sound ecological planning, fragmentation of planning processes and administrative structures, and limited ecological knowledge among planners. He concludes that reforms at the macro level of governance are required, including changes in public and business attitudes, policy processes, economic planning and institutional structures (Richardson 1989:79).

In her analysis of several Canadian communities, Grant (1994) found formal environmental policies but few changes in planning practice. Major barriers include lack of provincial leadership, limited local authority to require protection of natural processes and landscape functions, dependence on property tax for revenue generation, and few financial resources for identifying, mapping and protecting valued resources. Other barriers identified include rigid development standards preventing innovation, and values that reinforced conventional development practice and that viewed environment and economy as competing interests.

Lee (1993:80) observes that there are few places where the key concepts related to adaptive environmental management could be said to have gained "... even an initial foothold". Both technical and institutional barriers exist. He identifies a number of technical/scientificobstacles especially relating to the experimental aspects of adaptive management, including sparse data, limited theory, and the difficulty of addressing the unpredictable dynamics of ecosystem functioning (Lee 1993: 58). Too little is known about the range of functions supported by a particular ecosystem, there are few models to identify sensitivities of these functions, and a lack of baseline data to identify attributes or demonstrate ecological values Manning (1994:374).

The ability to address technical issues is confronted with mission-oriented science that has emerged as the product of adversarial decision processes. Gunderson, Holling and Light (1995:526) observe that modes of inquiry and mission-oriented research, whose goal is to validate existing theory rather than invalidate hypothesis, hinder the development of alternative views. The demand that science function in a defensive posture to provide enough data to withstand challenges in court or quasi-judicial hearings works against requirements for long term experimentation and hypothesis testing. Related barriers include: vulnerability to changing levels of political support, policy changes, lack of stable, long term funding, avoidance of the experimental model of management due to the perceived risk of failure, and the risk of revealing the need for disruptive (i.e. controversial) policy changes (Lee 1993).

A fundamental obstacle is the ability of institutional structures to resist change (Gunderson, Holling and Light 1995; Paelkhe and Torgerson 1990). Dovers and Handmers (1992) contrast the ideal of institutional openness and adaptability with three levels of societal resistance to change: attempts to preserve the status quo, failure to act until irrefutable evidence is provided, and incremental change that fails to re-assess fundamental assumptions. Even with their positivist model of institutional renewal, Gunderson, Holling and Light (1995:497) acknowledge the persistent ability of institutions to resist change in the face of ecological crises and external pressures. They found that while institutions have adaptive potential they also can become locked into a rigid command-and-control approach. Organizations rarely provide an integrative perspective because none are accountable for maintaining or protecting ecosystem integrity. The referent organizations that emerge to deal with system-wide concerns rarely receive the support and decision making authority required to influence policy decisions of participating members (Donahue 1987).

3.9 Summary

The ecosystem approach is characterized by eight key principles: boundaries, objectives, functions, cumulative effects, integrated, adaptable, coordinated, and catalytic. These principles have implications for how problems and opportunities are bounded. They expand the scope and scale of past approaches by planning for and managing human activities in the context of a hierarchy of nested ecosystems having different physical and temporal scales. An ecosystem approach also seeks to bridge societal and ecosystem needs by integrating human uses and values with objectives related to healthy ecosystems. Whereas past approaches target consumption of resources and protecting public health, the ecosystem approach is based on a vision that integrates sustainable human uses and benefits with ecosystem integrity.

The ecosystem approach informs decisions through analysis of ecosystem functions. It integrates environmental information on components of the ecosystem with the processes such as those related to the cycling of water, energy and nutrients as well as the provision of direct benefits to humans, such as a continuous supply of clean drinking water. The ecosystem approach is distinguished by its acknowledgement of limited tolerance of ecosystems to stress. While conventional approaches assess potential threats discretely at the site level, the ecosystem approach is concerned with the potential cumulative effects of multiple stressors and land use change on ecosystem functioning. This approach has implications for the scale and scope of analysis by considering effects at multiple levels of ecosystem organization, from the local to the bio-regional.

An ecosystem approach accommodates diverse and uncertain conditions and is responsive to new information and dynamic conditions. Whereas conventional approaches often impose uniform and rigid rules, the ecosystem approach supports rules and instruments that are flexible. The approach should be functional in different environments and should continue to improve and evolve as new information and understanding emerges of ecosystem functioning and effective management of human activities.

Similarly the adaptive principle is reflected in an emphasis on various forms of monitoring and long term research. It involves tracking ecosystem response to land use change and management strategies to better understand long-term ecosystem dynamics and the means to achieve agreed-to objectives. The ecosystem approach is future-oriented and preventative rather than short-term and reactive. It replaces a system of fragmented and disjointed controls on individual sources with an integrated set of regulatory and non-regulatory instruments. Similarly, the ecosystem approach links actors across separate jurisdictions to collaborate in achieving collective goals.

It involves new environmental partnerships that secure the participation and accountability of core actors for defining a common vision and working towards it.

Finally, the ecosystem approach recognizes the critical task of developing the institutional capacity to sustain implementation. Whereas earlier approaches sought to strengthen the powers of the centre, the ecosystem approach seeks to empower individuals and groups at the community level. The centre becomes a catalyst by providing a framework for action and applying its resources and influence in the interests of healthy ecosystems of which humans are an integral part. Fiorino (1995) provides a concise interpretation of what is needed:

> The goal should be institutions that can adapt, integrate, and preserve democratic values, analyses that provide a factual and politically acceptable basis for decision making, a view of problems that recognizes their complexity and interrelationships, and hard choices intelligently made (Fiorino 1995:225).

The barriers to adopting an ecosystem approach present a continuing challenge to and rationale for finding practical solutions. Prevailing information-related barriers include incomplete data and knowledge of ecosystem structures and functions. This is coupled with limited theoretical understanding of the dynamics of human activities interacting with complex ecosystems. The uncertainty that prevails can create stumbling blocks to translating general principles and ideas into workable solutions that all actors can agree to. Fragmented and inflexible rule systems also inhibit ecosystem approaches. Diverse human activities and stresses are not addressed coherently. Also, conflicting requirements of different rules and instruments mitigate efforts to plan for ecosystems more comprehensively. These problems are compounded where core actors have competing interests, limited capacities, and unclear roles and responsibilities.

The ecosystem approach is not yet a fully articulated paradigm. Given the continuing obstacles, its effective implementation will not be assured in the short term. Caldwell (1994:31) notes:

> The process of jurisdictional change is likely to resemble the punctuated evolution theory in palaeontology, where periods of radical change are believed to occur between long periods of gradual development.

The next chapter reviews emerging strategies for protecting groundwater. The principles outlined above provide guide-posts to renewed planning for groundwater consistent with an ecosystem approach. Attention to each of the principles will highlight shortcomings and suggest options for addressing continuing challenges.

CHAPTER 4
STRATEGIES FOR GROUNDWATER PROTECTION: A REVIEW OF THE AMERICAN EXPERIENCE

> *The contrast between the lack of effort in Canada and the major effort in the United States has become so large that it would not be inappropriate for the United States to accuse Canada of purposefully deriving economic advantage in its industrial sector through lack of expenditures on cleanup and protection of groundwater.*
>
> *...Federal and provincial legislation results in much less protection of groundwater than federal and state legislation accomplishes in the United States*
>
> (Cherry 1989:18).

4.1 Introduction

This chapter addresses one of the central questions of this inquiry, namely: *What strategies have emerged to address deficiencies in planning for groundwater protection?* Groundwater protection activities outside of North America are not well documented. Available evidence suggests that progress is being made to increase the level of protection of valued groundwater resources in western Europe. In 1989 the United Nations Economic Commission for Europe adopted a charter on groundwater management. The charter advocated long term policies to protect groundwater by preventing pollution and over-use. It called for comprehensive strategies to be implemented at all appropriate levels (UNECC 1989:1). Individual countries, such as Britain, Germany, France and Sweden also have pursued strategies for protecting groundwater supplies, particularly through restrictive zoning around wellfields (cf. NRA 1992; Headworth 1986; Brommssen 1991). However, available literature is not of sufficient scope or depth to provide more than a general account of these institutional arrangements.

In contrast, there is substantial documentation of leading strategies for groundwater protection in the United States. The dependence of fully one-half of the U.S. population on groundwater as a source of drinking water, and continuing threats to its quality, have prompted pursuit of new and innovative approaches to groundwater protection. Substantial policy and program development have taken place all levels of governance to control access to and use of groundwater, and to influence human activities which might degrade groundwater functions. There is a wealth of information and analysis of strategies which have evolved to address deficiencies of past practice. These institutional responses provide a solid basis for considering progress toward an ecosystem approach (Neufeld and Mulamoottil 1991).

The positive influence of American environmental policy on the evolution of Canadian policy is well known. Despite different regulatory frameworks and styles, American policy has often been emulated and adapted to fit the Canadian institutional context. For example, American environmental policy has had a direct influence on Canadian and provincial laws and programs, such as environmental assessment, the regulation of hazardous contaminants, and development of water quality standards (cf. Hoberg 1991; Harrison and Hoberg 1994).[18] The case study described in Chapters Seven and Eight also finds evidence of the positive influence of the United States on groundwater protection policy in Ontario.

This chapter is organized around sections corresponding to three levels of governance in the United States: federal, state and local. The purpose is to review actions taken, consider progress toward comprehensive and integrated approaches, and identify continuing challenges from the perspective of an ecosystem approach.

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18 The United States can also stimulate Canadian public policy through negative externalities such as cross-border air pollution (Hoberg 1991:110).

4.2 Federal Groundwater Protection

4.2.1 Regulatory Framework

The United States Environmental Protection Agency (EPA), is the lead federal agency charged with implementing environmental legislation and policy. National legislation has provided the regulatory framework, technical standards, and basis for federal policies and grant programs which, in turn, have mandated state and local government action (Henderson 1987). Prior to the 1970's there was little or no federal regulatory activity addressing groundwater. However, the legacy created after of decades of improper disposal of hazardous wastes gave rise to significant public concern and subsequent federal regulatory action.

In 1972 the Clean Water Act was adopted to protect the declining health of the nation's surface waters. It included, among other things, regulation of discharges of pollutants and establishment of ambient standards for surface waters.[19] The Act also encouraged states to develop plans to protect water from non-point sources of pollution (CWA s.208). While the focus was primarily on surface water, federal funds were provided to develop plans for protecting groundwater.

In 1974 the Safe Drinking Water Act was adopted. It required the development of primary and secondary drinking water standards to protect human health, and imposed controls on underground injection of waste into deep aquifers. This Act also authorized the EPA to designate aquifers serving as the principal drinking water supply for an area. It provided for the withholding of federal funds for projects deemed to pose a threat to sole source aquifers. Under the Act state, local and regional authorities could petition for designation, and federal funds were provided to develop comprehensive plans in areas meeting specific criteria.

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19 For a review of federal legislation see Tripp 1984; EPA 1984; Henderson 1987.

In 1986, amendments to the *Safe Drinking Water Act* expanded the scope of drinking water standards and imposed strict time tables for their development. It also directed that states develop *Wellhead Protection Programs.* The purpose is to protect public groundwater supplies from contamination and prevent the need for costly treatment to meet drinking water objectives. Each state Wellhead Protection Program is required by law to: specify duties of public agencies and water suppliers, delineate wellhead protection areas based on available hydrogeologic information, identify all potential sources of contamination within these areas, develop management strategies to protect groundwater from contaminants, describe contingency plans, outline procedures for establishing and protecting new wells, and make provision for public participation in a wellhead program (SDWA s.1428(a)).

Major legislation was enacted to address the threats posed by hazardous contaminants. In 1976 the *Toxic Substances Control Act* was adopted to regulate the manufacture, processing, distribution, consumption and disposal of hazardous substances. In the same year the *Resource Conservation and Recovery Act* was adopted to regulate management of hazardous waste. Four years later the *Comprehensive Environmental Response Compensation and Liability Act* authorized the EPA to initiate or otherwise require the removal and cleanup of hazardous waste sites as well as to regulate spills of hazardous substances. By 1987 the EPA had 270 programs and activities that addressed sources of groundwater contamination, with waste management issues continuing to occupy the greatest amount of attention, including: abandoned waste sites, landfills, land application, injection wells, surface impoundments, underground storage tanks, waste piles (EPA 1987a).

4.2.2 EPA's First Groundwater Protection Strategy

None of early legislative initiatives set out a national strategy for comprehensive groundwater protection (Tripp 1984:132). Despite significant regulatory action and expenditures on pollution control and remediation, the EPA was faced with "... increasingly unmanageable problems of groundwater contamination" (Pye, Patrick and Quarles 1983:190). In 1979, the Agency initiated development of a groundwater protection strategy to compliment its regulatory programs. The intent was to provide a framework for accomplishing a number of broad goals: build institutional capacity at federal and state levels, promote consistent groundwater policies and priorities, expedite information and data gathering, focus attention on high priority problems, promote long range planning and more comprehensive approaches (Pye, Patrick and Quarles 1983:190-191).

The U.S. Groundwater Protection Strategy was released in 1984. Core elements of the Strategy refined the goals identified at the outset of the process: increase support for the development of groundwater protection programs at the state and local level, assess contamination threats to groundwater, classify groundwater to guide development of regulations and identification of priority areas, and consolidate scattered federal groundwater responsibilities in a single Office of Groundwater Protection (EPA 1984).

The 1984 Strategy acknowledged the principal role of state and local governments in groundwater management and protection. States were expected to assume primary responsibility for implementing environmental programs including groundwater protection. The federal role was defined in terms of exercising national leadership in the development of general program frameworks, establishing standards required by legislation, conducting research and information collection, and providing various forms of assistance to support state efforts (EPA 1984:20).

In a departure from past practice of issuing new regulations related to control pollution sources, the Strategy used incentives and rewards to encourage action at the state level. States were encouraged to use existing federal grant programs to develop groundwater protection strategies. Between 1984 and 1990 over $80 million was spent under provisions of the *Clean Water Act* to build groundwater protection capacity at the state level (EPA 1992:1-25). EPA also committed to provide technical assistance covering scientific issues, program development and implementation, data management and training (EPA 1984:35). Federal research efforts were to be based on identified state priorities and on threats to groundwater that were not addressed adequately. This included issues such as underground storage tanks, septic systems, and pesticides (EPA 1984:37).

A three-class system of groundwater classification was proposed in the Strategy. The purpose of classification was to provide guidance for defining protection goals for different groundwater aquifers and for determining the controls needed to achieve these goals (Pye, Patrick and Quarles 1983:205). The first category included groundwater deemed highly vulnerable to contamination because of hydrogeologic characteristics and that was an irreplaceable source of drinking water, or groundwater considered *ecologically vital* (EPA 1984:43). Ecologically vital groundwater was defined as groundwater providing base flow to surface waters which would suffer loss of unique habitat as a result of contaminated groundwater discharge. The second category applied to other groundwater that was as an existing or potential source of drinking water, or served some other beneficial human use (EPA 1984:45). The third category included groundwater that was not a potential source of drinking water, of limited beneficial use, and not hydrologically connected to other groundwater or surface water such that contaminants could enter these waters and cause adverse health or environmental effects.

Groundwater classified in the first category was to be protected through siting restrictions on potentially contaminating land uses or activities. Groundwater classified in the second category was to be protected largely through design and operating controls. While no specific controls were unique to the third category of groundwater, the same standards of protection for hazardous waste facilities were to apply to all three classes (EPA 1984:46).

4.2.3 EPA's Second Groundwater Protection Strategy

Ten years after it initiated its first planning process to develop a Groundwater Protection Strategy, the EPA established a task force to make recommendations for addressing persistent deficiencies in groundwater protection. The task force expressed concern with the disproportionate emphasis on groundwater clean-up activities across the country, and called for a "better balance" between remediation activities and prevention activities (EPA 1991). Another major concern identified was continued preoccupation with individual sources of contamination in most jurisdictions and a corresponding failure to consider groundwater as a resource to be protected and managed. The need for improved integration and coordination of federal, state, and local activities also was identified. The "patchwork" of federal, state and local control efforts was criticized, as was the failure to address dispersed contamination sources (EPA 1991:10).

The goal of the 1991 Groundwater Strategy is: "... to prevent adverse effects to human health and the environment and to protect the environmental integrity of the nation's groundwater resources" (EPA 1991:6). Groundwater protection principles are enumerated in three areas:

prevention, remediation, and intergovernmental responsibilities. With respect to prevention it calls for protection of groundwater through a variety of means including pollution prevention programs, source controls, siting controls, designation of wellhead protection areas and future water supply areas, as well as protection of aquifer recharge areas (EPA 1991:6).

Source controls should be augmented with a resource-based approach to protection that takes into account "... the total impact of all sources of contamination as well as the unique hydrogeologic features of the resource" (EPA 1991:11). The use, value and vulnerability of groundwater resources as well as social and economic values also are to be considered in developing protection programs. Remedial activities are to be prioritized on the basis of limiting the risk of adverse effects to human health, restoring current and potential drinking water sources, and finally, remediating groundwater closely connected to surface waters (EPA 1991:7).

The 1991 Strategy emphasizes greater flexibility and deferral to state and local policies, priorities and regulatory activities for those jurisdictions that have adopted protection programs deemed satisfactory by the EPA (EPA 1991:14). The federal government should promote state and local action in a way that takes into account the unique characteristics of each state, their different stages of strategy development, identified gaps and current levels of federal assistance (EPA 1991:14). The Strategy calls for state and local governments to take the lead regulatory role where activities of concern are numerous or localized, when the principle instruments are land use controls, and where technologies are readily available to apply to a problem. The federal regulatory role is to be limited to situations with significant impacts on interstate commerce, technically complex problems needing federal research, actions that would otherwise create unwarranted and in-efficient duplication, such as product bans, and issues of national security (EPA 1991:12).

The Strategy commits the federal government to provide state governments with financial, technical and management tools to help states develop comprehensive, integrated programs to protect groundwater. This includes conducting scientific and economic research on various aspects of groundwater protection and providing standard-setting information to states , such as criteria for ecological protection, risk assessment, fate and transport data, economic values and trade-offs (EPA 1991:12). The federal government also committed to coordinating multiple federal programs and activities and to make optimum use of federal grants to promote intergovernmental coordination (EPA 1991:10).

4.3 State Groundwater Protection

4.3.1 Regulatory Framework

State governments have been developing groundwater policy and legislation for over a decade. The state role in groundwater management and protection is based on their legal and statutory authority, their administrative and technical capacity, and the fact that many groundwater systems fall within state boundaries (Liner, Morely and Stanger 1994:1-4). State governments have been delegated complete or partial authority for enforcement of federal laws, such as control of hazardous waste facilities, underground injection wells, and pesticide use. Most also have general environmental statutes which provide authority to protect groundwater and to regulate major emission sources. The majority of states use general water quality standards to supplement federal standards for drinking water. Many states have established clean-up funds to deal with contaminated sites and the majority monitor groundwater around major contaminated sites as well as monitoring general trends in groundwater quality and quantity.

Some also have established groundwater classification systems as part of their protection strategy (EPA 1984:21-23).

Most legislative action has been taken in response to specific groundwater concerns. For example, between 1985 and 1987, states enacted legislation that addressed underground storage tanks (27), agricultural chemicals (25), land use planning (6), standard setting (5), groundwater classification (3), groundwater funding (3), and water use management (3) (EPA 1988b). This trend continued between 1987 and 1992, when 44 states enacted legislation dealing with underground storage tanks, largely as a result of federal legislative requirements. The next largest category was legislation dealing with pesticide registration (23 states) (Morandi 1994).[20]

Between 1985 and 1987, twelve states enacted legislation to promote state-wide protection strategies (EPA 1988b:viii). A further nine states adopted comprehensive groundwater protection planning legislation between 1987 and 1992 (Morandi 1994:3). While the specific provisions of each bill varies, the legislation generally directs one of more agencies to prepare a comprehensive plan to protect groundwater quality from contaminant sources. Regulatory and non-regulatory elements are incorporated, including groundwater classification systems, designation of critical groundwater areas, groundwater quality standards, permits for discharges to groundwater, land use controls, groundwater mapping, monitoring, data collection, and special studies (cf. EPA 1988b:viii; Morandi 1994:6).

From 1986 to the present, the EPA developed a comprehensive set of guidance documents to

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20 While not the focus of this inquiry, rules for allocating groundwater usage has been a significant policy concern in arid regions of the United States, and elsewhere such as the Middle East, where irrigation agriculture and rapidly growing urban centres compete for limited supplies (cf. Ostrom 1990; Tuinhof 1992).

help states implement wellhead protection. States are encouraged to use existing authority and organizational structures wherever possible as the basis for assigning responsibilities (EPA 1988:3). In addition, integration of wellhead protection with related environmental programs is encouraged, along with establishment of formal coordinating mechanisms between and within levels of government.

Land use measures and other controls on activities around public wells are recommended for implementing wellhead protection. This includes zoning ordinances, subdivision and site plan review, design standards such as secondary containment for hazardous waste storage, best management operating standards, and prohibitions on the manufacture, storage, sale or use of hazardous materials. Other identified measures include purchase of property or development rights in sensitive areas, public education, groundwater monitoring, household hazardous waste collection, and water conservation (EPA 1989a).

States are afforded considerable flexibility in delineating protection zones around public water supplies (EPA 1988:11). They are encouraged to develop clear criteria and methods for preliminary delineation of protection zones and to increase their accuracy and precision over time. Multiple zones should match the type of management actions and the potential risk to groundwater from direct introduction of biological and chemical contaminants. Grouping of contaminant sources by location or degree of risk is encouraged to prioritize inventory efforts. Drinking water source protection areas should be given priority when conducting inventories of potential contamination activities (EPA 1988:19).

Despite the absence of direct appropriations under the Safe Drinking Water Act for wellhead protection, 26 states had approved programs by 1992. Three years later 40 states had approved wellhead protection programs (EPA nda; Morandi 1994:vi). Wellhead protection statutes emphasize the role of local governments in developing programs through land use controls, and generally limit the state role to identifying geographic areas for program development, and providing technical and financial assistance to local government (Morandi 1994:8).

4.3.2 Groundwater Protection Strategies

Many states have initiated groundwater protection strategies without creating new state legislation. Prior to 1985 only eleven had a state-wide protection strategy in place. By 1987 all states had participated in the groundwater strategy grant program under the *Clean Water Act* (EPA 1987:2).). State groundwater protection strategies provide a coordinated and integrated framework for groundwater protection policy at the state and local level. As noted by the EPA in its review of state use of federal groundwater strategy funds:

> Most strategies clearly reflect an attempt to develop a comprehensive, long range framework for groundwater protection, not just a temporary series of mitigation measures or sampling activities. They seek, in other words, to institutionalize groundwater protection at the state and local levels. (EPA 1987:3)

Often federal grants provide "seed money" for developing a state policy framework or strategy for groundwater protection. Most states use federal grants to institute task forces to oversee the development of protection strategy and implementation of recommended measures (EPA 1987:3). Many states used the grants to assess the adequacy of their regulatory programs and to undertake various technical activities such as characterizing groundwater resources, upgrading their data management systems, developing groundwater classification systems, and sponsoring technical workshops (EPA 1987:4). States with existing protection strategies use federal strategy funds to expand and increase the scope of their protection activities.

Consistent with its commitment to be a catalyst for state and local action, the EPA held a series of regional round tables in 1991 with state directors of environmental agencies and groundwater program directors across the United States. The purpose of these discussions was to develop a consensus on the requirements for comprehensive state groundwater protection programs that would be relevant to states with differing priorities, resources and concerns. The product of these discussions was a federal guidance document that defines elements of a comprehensive state groundwater protection program and describes the basis for improving these programs over time (EPA 1992). Comprehensive protection programs are to be guided by three objectives: to prevent groundwater contamination whenever possible, to protect groundwater at a level commensurate with its relative vulnerability, use and value, and to pursue remediation when prevention fails, or where contamination already exists. Remediation priorities are to be guided by the relative use and value of the resource.[21]

A comprehensive state groundwater protection program includes six strategic activities:

- develop a core set of resource-based goals to guide relevant programs;
- set priorities based on characterization of the resource, sources of contamination, and improved integration of related programs;
- define legal authority, roles, responsibilities, resources and coordinating mechanisms across relevant federal, state, local programs;
- implement all necessary prevention, remediation and enforcement actions to accomplish goals consistent with state priorities and schedules;
- coordinate information collection, monitoring, reporting and information management to measure progress, re-evaluate priorities; and

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21 Vulnerability is defined as "... the relative ease with which a contaminant introduced into the environment can migrate to an aquifer under a given set of management practices, contaminant characteristics, and aquifer sensitivity conditions" (EPA 1992:1-1).

- undertake public education and participation in all aspects of groundwater protection to define and achieve support for protection goals and program priorities.

  (EPA 1992:2-1-17)

Once in place, a comprehensive state groundwater protection program provides the framework for coordinating and focusing federal, state, and local groundwater-related activities on geographic priorities established by the state (EPA ndb). Federal endorsement of state comprehensive protection programs is based on general criteria rather than conformity to a specific list of requirements. Phrases such as "consistent with" and "an adequate level" describe a minimum core program. The core program is distinguished from a fully integrated program on the basis of the scope of activities, the degree of sophistication and the degree of influence the protection program has on related public activities and programs (EPA 1992:2-2). Full integration is attained when the strategic activities "... fundamentally influence and are supported by the day-to-day operations of all groundwater-related programs within the State, including those of EPA and, where relevant, other federal programs" (EPA 1992:2-1).

Following endorsement of a groundwater protection program by the EPA, written multi-year program agreements are prepared and signed by federal and state authorities. These agreements identify milestones for implementation, ways to further integrate groundwater protection activities, and ways to promote cross-program decision making to protect the resource. It also details specific actions EPA will take to support state protection efforts. These agreements guide annual planning efforts of both federal and state levels to develop their groundwater protection programs in a coordinated manner (EPA nd).

4.4 Local and Area-Wide Groundwater Protection

Some municipal groundwater protection programs in the United States, such as Cape Cod, Massachusetts and Long Island, New York, were initiated in the 1970's, prior to significant federal action. Others, such as Dade County, Florida and Dayton, Ohio, developed protection programs a decade later. In most cases, these initiatives were galvanized by contamination events that ranged from pervasive degradation of groundwater to permanent loss of a communal source of drinking water. Most of these communities are dependent on groundwater as their primary source of drinking water and faced unanticipated expenditures to drill replacement wells, to access alternative supplies, and to attempt to clean-up contaminated groundwater (cf. Page 1987; Liner, Morley and Stanger 1994; Jaffe and DiNovo 1987).

In 1989 a study was released of forty state groundwater protection strategies, including eight in-depth case studies (Liner et al. 1989). The cases were selected in consultation with an advisory panel of state and local groundwater officials. They were chosen to reflect different groundwater problems, different approaches, different levels of policy development and practice, and geographic dispersion. Interviews were conducted with state and local officials, representatives of industry, and environmental organizations. Liner et al. (1989:85) identify a trend toward increased local involvement in groundwater protection but considerable variation in the degree and nature of that involvement. Where well closures and loss of water supplies are involved, local protection programs often develop independently of state direction (Liner et al. 1989:95). Routine delegation of certain responsibilities to local governments is found in most states. This includes regulation of public water supply, septic systems, underground storage tanks, and wellhead protection through land use controls. State authority is delegated or transferred under state regulation, by formal contract, memorandum-of-understanding, and case-by-case agreements. State governments are reluctant to delegate additional authority to local authorities unless the latter demonstrates both a willingness and capacity to assume additional responsibilities. Some identified constraints include competing local pressures/interests on government decision makers, limited authority at the community level, and inadequate resources (Liner et al. 1989:87).

Where groundwater concerns are shared by neighbouring jurisdictions, various forms of cooperative planning and management have emerged (Page 1987; Liner, Morely and Stanger 1994). Across most of the United States, regional institutions have limited authority (Page 1987:377). In a few states, such as Massachusetts and Washington, special purpose bodies have been created for designated groundwater districts. These special purpose agencies have a range of authority over activities occurring within designated districts, ranging from advisory roles to limited taxing and regulatory powers over local development (Liner et al. 1989). In other states, such as Ohio and Florida, county governments or other regional agencies have taken a lead role in groundwater protection planning. Some enjoy authority over water supply decisions and land use planning. In most jurisdictions regional agencies act as centralized information sources, undertake education and outreach activities, provide technical analysis, consult on issues of common interest, and coordinate action among participating agencies (Liner, Morely and Stanger 1994:1-27).

Liner, Morely and Stanger (1994) examine local groundwater protection programs in six locations across the United States. The cases represent different situations with respect to groundwater supply, protection strategies, and local conditions. They found local groundwater protection programs were "... much stronger and broader than could have been anticipated" (Liner, Morley and Stanger 1994: I-19). The scope of protection efforts and the combination of protection measures that are used, varies significantly. The fewest number of protection tools were used by a small rural county in Virginia. The largest number of protection tools were used in the Cape Cod region in Massachusetts which is an area encompassing a dozen municipalities that have faced decades of development pressure and public concern over groundwater degradation. Most of the cases reviewed had undertaken an extensive study the region's groundwater resources and prepared inventories of potential threats. The more densely settled areas had their own monitoring systems, while others relied on senior government monitoring. Each case example made use of a geographic information system to support groundwater protection planning. These systems varied in terms of their level of sophistication and data entry level. (Liner, Morely and Stanger 1994:I-29). Zoning controls were found to provide a "first line of defence" against pollution threats. At the same time, zoning had little impact on existing uses or ongoing management activities. Additional recommended protection tools include education and outreach, resource assessment and threat identification, monitoring, inspections, emergency response capacity, and information management.

LOCAL AND REGIONAL PROTECTION MEASURES

Regulatory	**Non-Regulatory**
- zoning ordinances	- resource assessment & threat identification
- subdivision regulations	- land acquisition/easements
- site plan reviews	- regional development policies
- design standards	- servicing improvements
- operating standards	- public education and outreach
- wellhead protection ordinances	- groundwater monitoring
- discharge permits	- information management
- inspections	- household hazardous waste collection
	- water conservation
	- emergency response capacity

Adapted from Liner, Morely and Stanger (1994:1-11)

Local and area-wide protection programs depend on state support, including: enabling legislation that provides local authority for management and protection activities, various forms technical assistance, information, and financial assistance. In their review of local protection activities in 25 states, Morely, Hatry and Liner (1992) found that state financial incentives include grants for preparing plans and regulations, development of technical materials, mapping exercises, acquisition of sensitive areas, local monitoring, coordination activities, and for cost-sharing personnel and demonstration projects. Direct technical assistance takes the form of best management practice manuals and model ordinances, training on protection techniques, delineation of protection areas, monitoring, technical reviews, and individualized assistance through direct consultation with communities (Morley, Hatry and Liner 1992:36).

4.5 Voluntary Approaches

In addition to government-sponsored initiatives, voluntary implementation of groundwater protection activities has been actively promoted by non-government organizations. The most ambitious effort to engage the public at the community level has been led by the Groundwater Foundation, based in Lincoln, Nebraska. It is a non-profit foundation that grew out of the Nebraska Groundwater Foundation, formed in 1985 "... to create factually informed and motivated citizenry caring about and for its groundwater" (GF 1993:1). The Foundation's educational mandate to promote conservation and management of groundwater is realized through a number of means. In 1989 the first annual Groundwater Festival for a small group of elementary level school children was held in Nebraska. Its popularity grew steadily, and in 1993, 8,000 children registered for the Nebraska children's festival. Groundwater festivals have since been sponsored throughout the United States.[22]

In 1992, with start-up funding from the Kellogg Foundation, the Groundwater Foundation launched the *Groundwater Guardian Program*. Its purpose is to help communities in their groundwater protection efforts by promoting and recognizing community-level education and advocacy related to groundwater protection. To be recognized as a *Groundwater Guardian* community the Foundation requires that communities follow a structured process and report on activities annually. The first step is forming a Groundwater Guardian Team, with representation from citizen organizations, business, agriculture, education and government. The teams are responsible to work with community leaders to develop and implement local goals, objectives and long term plans for protecting groundwater through a set of *results-oriented* activities (GF 1995b:5). These activities include public awareness (e.g. local groundwater festivals), conservation (e.g. encouraging water-saving devices), pollution prevention (e.g. wellhead protection program), public policy (e.g. land use protection measures) and best management practices (e.g. fertilizer use) (Groundwater Foundation 1995b: 9-10). Each activity must include measurable objectives, implementation timetables and methods for evaluating results. To support its Groundwater Guardian program, the Foundation has developed guidelines for communities, various other publications, a telephone hot-line, local recognition ceremonies, and an annual national Groundwater Guardian conference. In 1995 there were 55 North American communities entered the Groundwater Guardian program (GF 1995a:1).[23]

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22 The concept of children's groundwater festival's has taken root in parts of southern Ontario, including Waterloo Region, Halton and Peel Region.

23 The two Canadian communities to receive a Groundwater Guardian designation are Wilmot Township and Woolwich Township in Waterloo Region.

4.6 Toward Comprehensive Strategies

In 1984 the U.S. National Research Council established a Committee on Groundwater Quality Protection at the request of the EPA. The Council reviewed ten state and three local programs, representing a range of critical contaminant sources, hydrogeologic characteristics, and types of protection strategies. The analysis was guided by a "total resource management approach". For the Council this meant addressing a variety of interrelated issues, such as economics, public health, ecological protection, resource conservation and priorities for resource use (NRC 1986:viii). Through interviews, literature reviews and discussions with officials, technical and institutional features were identified that showed promise in protecting groundwater quality.

The Council found that no single program addressed all aspects of groundwater protection comprehensively. Also it found the level of investment in preventative actions was consistently and disproportionately low in comparison to the level of investment in corrective and remedial activities. It concludes that a comprehensive groundwater protection program requires the following components:

- clearly defined goals and objectives;
- adequate information collection and information management to provide a quantitative understanding of the occurrence, quality and dynamics of the groundwater resource, together with information on potential sources of contamination;
- adequate technical basis using appropriate scientific technical principles and assumptions;
- reduced or eliminated threats to groundwater by prohibiting certain activities or products, by siting activates away from sensitive areas, and applying incentives for environmentally-friendly products, technologies and waste recycling;

- coordinating and linking local, state and federal activities;
- adequate legal authority to take action;
- long term funding, and trained personnel;
- assessing the feasibility and costs of control, and potential effects on public health and environment; and
- securing public involvement and political support by balancing expeditious exercise of authority with consulting affected parties (NRC 1986:5-7).

One year later the U.S. Conservation Foundation released a major report on groundwater protection (CF 1987). It conducted a major review of groundwater protection practices in the U.S. and held a series of national forums on groundwater policy. Participation in these forums included government officials, industry representatives and environmental organizations. Four principles are advanced for improving groundwater protection: actively manage groundwater as a resource rather than subjecting it to ad hoc decision making, prevent groundwater contamination, prevent degradation of the most valuable aquifers and critical water supplies, recognize the inherent variation in the nature, vulnerability, and use of groundwater, and accommodate variable capacity among state and local governments to manage it (Conservation Foundation 1987:13-14).

The Foundation calls for comprehensive management of the resource that is based on better understanding of the groundwater resource, increased control over uses of groundwater and threats, protection of well fields and recharge areas, and coordination with other environmental protection and resource management programs (CF 1987:7). It recommends a set of components for state comprehensive groundwater protection that reflect many of the elements recommended by the Research Council (Table 3).

TABLE 3: GROUNDWATER PROTECTION STRATEGIES: RECOMMENDED ELEMENTS

CONSERVATION FOUNDATION (1987)	NATIONAL RESEARCH COUNCIL (1986)
INFORMATION BASE	INFORMATION BASE
Comprehensive mapping of aquifer systems and associated recharge and discharge areas	Collect physical and chemical data on occurrence and quality of groundwater throughout each region. Conduct inventories of potentially contaminating activities. Develop accessible information management systems facilitating analysis of problems and long term trends.
CLASSIFICATION	CLASSIFICATION
Classify all potentially useable groundwater.	Classify groundwater that identifies critical areas and resources for special protection.
GROUNDWATER QUALITY STANDARDS	GROUNDWATER QUALITY STANDARDS
Establish numeric limits for contaminants using multi-tiered approach.	Develop an expanded list of groundwater quality standards using multi-tiered approach.
SOURCE CONTROLS	SOURCE CONTROLS
Control Sources of contamination through discharge controls, land use controls, waste reduction/recycling	Develop incentives for waste minimization and recycling as part of integrated system of source controls, monitoring requirements and standards. Restrict land use activities in designated sensitive areas through planning controls. Require clean-up of contaminated sites before property can be sold.
COORDINATION	IMPLEMENTATION
Coordinate Withdrawals and Quality Management Coordinate surface water and groundwater programs Coordinate groundwater protection with related environmental/resource protection programs	Ensure open decision making with active participation of all affected interests. Share and exchange information with all affected interests. Develop political leadership. Provide federal financial support, criteria, standards, research.
MONITORING/DATA COLLECTION	
Develop groundwater monitoring program and data collection strategy.	
ENFORCEMENT	
Establish enforcement program using full range of tools available	

The question of appropriate roles for government and non-government actor groups is addressed by both the Research Council and the Conservation Foundation. The Foundation advocates a *new environmental partnership* involving "... maximum participation and creativity from local governments, private industry and public interest groups" (CF 1987:14). It charges state governments with primary responsibility for groundwater protection and management, including providing technical assistance, financial support and legal authority to local governments to carry out their responsibilities under comprehensive groundwater protection and management. The NRC describe the state role in terms of enforcing federal and state standards, setting standards in the absence of national standards, maintaining records of groundwater quality and quantity, chemical usage, and land use, state-wide planning, helping regional and local agencies preparing groundwater management plans, providing information and education, and opportunities for public dialogue on goals, standards, and control strategies (NRC 1986:22-23).

The Conservation Foundation argues that the key roles of the federal government are to stimulate state and local action by providing financial and technical support for state program development, ensure consistency and equity among states, and provide oversight of state programs. Other specific roles are to establish national standards and provide the technical and scientific basis for state standards, provide water quality and other data on resource conditions, support state enforcement of standards, and provide a national focus for scientific and public dialogue. Both state and local governments should be given "substantial flexibility" to design and apply measures that reflect geographic differences as well as different capabilities. Also it suggests that states should exercise discretion in delegating responsibilities to local government on the basis of their demonstrated capacity (CF 1987:15-16).

The roles identified for regional authorities include: preparing groundwater basin management plans, accepting state delegation for enforcement as appropriate, and providing a focus for public processes including citizens committees, working groups, information gathering and dissemination. The roles for local government include: responsibility for protecting drinking water supplies, controlling sources of contamination under its jurisdiction, and utilizing land use controls consistent with state groundwater programs. Specific tasks of local government centre around preparing and implementing local groundwater plans, enforcing standards, providing basic information to users and acting as the primary contact for individual citizens.

The Foundation also identifies important roles for business and industry. This includes: responsibility to reduce use of toxic substances and waste generation through equipment and process modifications, new product development standards, environmental audits, and research into improved technologies. Voluntary action by the private sector action is advocated to prevent the need for "... unnecessarily burdensome and costly regulation" (CF 1987:17). Public interest groups were to educate the public, assist in identifying priority protection areas, and advocate for responsive action by appropriate parties (CF 1987:6, 17-18).

4.7 Continuing Challenges

This review of the literature on groundwater protection suggests that significant and innovative approaches have evolved in the United States over the past 20 years. Notwithstanding, the literature also points to a number of recurring challenges confronting efforts to improve the management and protection of groundwater. It reveals a number of concerns that have continued to frustrate the process of developing and implementing comprehensive strategies, since the EPA embarked on its first national protection strategy in 1979. The review of continuing challenges is organized with reference to the guiding principles of an ecosystem approach enumerated in Chapter Three.

Boundaries

A continuing challenge is getting communities to plan for groundwater systems before they have experienced significant degradation or impairment of groundwater. In many cases it continues to be driven by a need to solve specific problems rather than to work towards long term goals (Harris et al. 1988:339). At the local level, communities have initiated protection efforts in reaction to visible and immediate threats. In some jurisdictions pervasive growth pressures prompted concern among officials and the public. In others, highly visible contamination incidents galvanized concern about potential adverse health effects and provided the impetus to take action (Page 1987:378).

Planning on the basis of groundwater systems requires an approach that transcends the confines of local jurisdictions. As Page (1987:178) notes, it places reverse onus on affected jurisdictions to look beyond the confines of their own immediate territory:

> Effective planning must be based on the natural boundaries of the groundwater regime with management responsibilities assigned according to the specific needs rather than the converse. In short, jurisdictional assignments - local, county and state - should reflect the hydrogeological system .... Page (1987:178)

Protection efforts in the U.S. are focused in three geographic areas (Jaffe and DiNovo 1987:75). The smallest area of interest is that immediately surrounding a public well. Wellhead protection, which is mandated by the federal government, developed at a program level by state governments, and implemented by local governments, is the best example of this. Because it contributes water directly to the well, contaminants that are discharged in this area can be quickly drawn into public water supplies.

A larger geographic focus of some protection efforts encompasses groundwater recharge areas that extend beyond the confines of a well field. These are areas where groundwater systems are replenished by infiltrating precipitation. Because of the strong downward flow of water, groundwater is vulnerable to contaminants discharged to the surface or sub-surface. These areas can be very extensive, particularly for surficial or unconfined aquifers. The broadest geographic area is defined by the area overlying an entire major aquifer. Some jurisdictions have classified aquifers based on susceptibility to contamination, quality, yield, existing and potential use. In some cases management plans have been developed for aquifers that cross local and state boundaries.

Objectives

Agreement among core actor groups on a common vision for protecting valued groundwater functions is critical. A groundwater strategy should be framed by long term objectives and measurable outcomes to guide decisions and actions of private, non-profit and government actors. However, the literature suggests that minimal attention has been given to defining clear goals and measurable outcomes for groundwater protection. In most cases, general goals are expressed in terms of protecting human uses of groundwater. Despite increasing awareness of groundwater's important role in the hydrologic cycle, the predominant focus has been on community drinking water. The two stated goals of the EPA are to ensure protection of drinking water supplies and to maintain the environmental integrity of ecosystems associated with groundwater. However, much less attention has been given to groundwater's ecological values, functions and sensitivities (Hodge and Roman 1990).

Most local and state jurisdictions are guided by groundwater standards that are based on maximum allowable concentrations to protect human health. A few jurisdictions have set targets below the maximum allowable level, which trigger preventative actions where contaminants are detected at concentrations approaching these pre-defined targets.[24] The purpose is to avoid the need to take costly and aggressive regulatory or remedial action after groundwater has been degraded to maximum allowable levels. The focus on human health may neglect equally vital ecological functions provided by groundwater, such as its role in sustaining terrestrial and aquatic habitat. As noted by Henderson (1987:65), "Will natural systems depending on groundwater supplies be destroyed if our regulations extend solely to groundwater supplies that serve human needs?" A comprehensive vision for groundwater protection is needed that integrates sustainable human uses with agreed-to objectives and measurable outcomes for protecting ecosystem functions.

Functions

An adequate characterization of the functioning of groundwater ecosystems is a prerequisite for groundwater protection planning. Characterizing groundwater systems involves collecting, analyzing, and mapping information its occurrence, quality, dynamics, linkages and potential vulnerability to stresses. Specific information may include the areal extent of groundwater systems and aquifer units, hydraulic properties, flows, recharge and discharge areas, groundwater storage, quality and functional linkages to surface water (NRC 1986; Jaffe 1987).

In the United States, large sums of money and expertise have been invested in groundwater

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24 For example, Cape Cod adopted a target of one-half the maximum contaminant level (set by senior governments) based on nitrogen loading concerns (Liner, Morely and Stanger 1994:I-26).

investigationsat relatively few contaminated sites. As LeGrand and Rosen (1992:867) note, this has occurred without the benefit of a planning framework to guide decisions on the best means of protecting vulnerable and valued groundwater aquifers.

> For such investment, very detailed knowledge will be obtained at a small percentage of the total sites in the nation that can case groundwater contamination, but very little of the nation's groundwater will be protected or improved.

Modest levels of funding have been available under the *Clean Water Act* since the 1970's, to state and local governments to collect surface water and groundwater data on a watershed or aquifer scale. In many cases this information provided the first and most valuable source of information for the development of groundwater protection plans (Page 1987:377).

Information-gathering activities should reflect the inherent uncertainties and variety of situations under which groundwater is found (LeGrand and Rosen 1992:867).These conditions affect groundwater chemistry, its recharge and movement through the subsurface, its linkages to surface water, and its susceptibility to contamination. However, available and reliable data is often scarce. Incomplete hydrogeologic data makes it difficult to provide meaningful input to planning exercises without expensive and detailed investigations.

Cumulative Effects

There is a need to assess the total impact of all stresses on groundwater systems. Assessing potential threats involves identifying, evaluating and monitoring land use stresses and groundwater vulnerability to these stresses. By far the largest investment of financial resources for assessment activities have been directed at large and visible sources of contamination, namely hazardous waste sites. There continues to be disproportionate expenditures on investigation and clean-up of contaminated groundwater sites (LeGrand and Rosen 1992:867).

Most of the groundwater-related activities of the U.S. Environmental Protection Agency are directed at control of contaminant sources and remediation of waste sites. Approximately 95% percent of its groundwater budget is spent on remedial action and clean-up activities (Mlay 1991). There has been a formal commitment to redirect more federal resources from remediation to prevention activities, given the high costs of well replacement and groundwater clean-up, as compared with the cost of implementing a protection program. (EPA 1992:1-10).

Assessment activities involve identifying, evaluating and monitoring groundwater uses and other potential land use stresses that may impair groundwater functions. However, there are many unknowns in defining the magnitude of potential threats posed by various land uses. It arises in part from the difficult task of estimating the movement and fate of contaminants in unsaturated and saturated zones, and predicting likely health effects and ecosystem impacts arising from groundwater contamination (Libby and Kovan 1987:356; National Research Council 1986; Anderson 1987; Leusink 1992; Page 1987:370).

The wide range of possible contaminants and divergent management practices across jurisdictions preclude uniform approaches to information gathering and decision making (EPA 1992; Page 1987). There remain unresolved issues concerning the level of detail required to support planning and decision making (LeGrand and Rosen 1992:870; Economic Commission 1989:1). An incremental approach to data collection and analysis may be warranted. This requires making use of existing data, providing the means for making this information widely available, and carefully targeting additional data collection over time (Page 1987:155). Initial assessment of groundwater conditions, uses and threats can be complimented over time with more detailed information for an entire groundwater system (Jaffe 1987:155).

With regard to data management, monitoring and research Liner et al. (1989) found fragmented data systems among agencies, data management problems such as staff turnover and quality control, inadequate information on health risks of pollutants, and lack of resources for monitoring and enforcement. They recommended establishment of ambient monitoring, special studies targeting high risk areas, adoption of common data sets, development of geographic information system capability, quality controls on self-monitoring by contaminant sources, full-cost permit fees to fund compliance monitoring, and increased federal technical assistance and training.

Monitoring systems should help answer the fundamental question of whether progress is being made in the direction of desired outcomes. It involves developing a system for measuring baseline conditions, establishing trends in environmental quality, and assessing the significance of environmental effects over time. Specific tasks include developing a framework for collecting, integrating, managing and transferring information and data to measure progress, facilitate analysis of long term trends, and to support decision making.

Integrated

The groundwater literature suggests the need to adopt a mix of rules and instruments that protect, prevent, control and remediate valued groundwater systems. Protection activities are defined as the rules and instruments used to guide the location, type and intensity of land uses and activities so as to protect valued groundwater resources and functions. Prevention activities are those rules and instruments to encourage or require processes, practices, materials, products or energy that avoid or minimize the creation of pollutants and wastes, at the source. Control activities limit by permit, license, approval, or other means, the use of groundwater and the release of pollutants and waste to the environment that may enter and/or degrade groundwater. Remediation activities include procedures and practices to restore groundwater-ecosystemsthat have been damaged by human uses and activities.

Until recently control through direct regulation, and remediation of major contaminant sources have been the instruments of choice by governments. Most regulatory action has targeted specific sources of contamination, such as hazardous waste sites and underground storage tanks. The ability of this approach to achieve long term environmental objectives is in question. Direct regulation of all sources, facilities and activities that can degrade groundwater faces economic, technical and practical limits. The varied and diverse threats to groundwater are clearly beyond the ability of central authorities to control (Mills 1992:22).

Significant gaps exist in the sources included in these regulatory efforts, particularly non-point and dispersed sources, and the inability to regulate thousands of new substances created and discharged annually (EPA 1992). Also, a strategy of regulating individual sources on a site-by-site basis will not address the combined or cumulative impacts of numerous activities on a regionally-defined groundwater system. In many jurisdictions the majority of public and private expenditures related to groundwater continue to be replacement, clean-up and remediation. Remedial activities are often expensive, not always effective, and are ultimately avoidable if preventative measures are implemented (Hariss et al. 1988:331; Page 1987:155). Clean-up operations face major technical obstacles when seeking to remove or treat different types of contaminants under complex hydrogeologic conditions (Hall 1991).

In response there have been calls to shift the emphasis from ad hoc control of contaminant sources to comprehensive strategies that apply a mix of regulatory and non-regulatory tools to preventing contamination of groundwater (Economic Commission 1989; Mills 1992). Early protection efforts used overlay zoning restrictions in the vicinity of areas deemed sensitive to contamination. Some locales have added new protection measures over time, such as groundwater-related subdivision regulations density restrictions and servicing requirements, design standards and expanded prohibitions on use of hazardous substances, monitoring, land acquisition in sensitive areas, as well as education and outreach programs to promote voluntary prevention by households, business and industries (EPA 1989a).

Adaptable

Groundwater protection planning requires application of flexible tools that can accommodate variable circumstances and the exigencies of time and place. It also requires continuous evaluation and improvement to adapt to changing conditions and priorities. Tools which influence the location, design and density of development provide the greatest opportunity for preventing degradation groundwater (Butler 1987:281; (NRC 1987:18; Harris et al. 1988; Buresh 1987). These include innovative measures for managing growth in critical groundwater areas through land use policy, alternative development standards, easements, land acquisition, and private voluntary stewardship. As noted by Libby and Kovan (1987: 358), "The essential task is to create incentives that guide private land use decisions in ways that protect vital recharge areas."

The way ongoing land uses are managed over time is as important as managing new development (Liner, Morley and Stanger (1994:I-15). Innovative engineering and best management practices as well as various pollution prevention measures are playing an increasingly important role along-side traditional regulatory measures (Miller 1992). Whereas direct controls tend to focus on direct discharges, pollution prevention promotes structural and process changes to prevent the need to manage contaminants in the waste stream. The latter pre-empts the need to impose additional, often costly, end-of-pipe pollution control measures through adoption of processes, practices, materials, products or energy that minimize the creation of pollutants and wastes, at the source. Pollution prevention can be mandated by law or promoted through incentives to influence behaviour that may impact groundwater. It has been suggested that, as a minimum, regulatory measures be complimented with incentives wherever possible, which are matched to the cost of taking action (Allee 1986).

Most groundwater programs lack criteria or data to measure effectiveness (NRC 1986). This is partly due to the relatively short time that many protection activities have been in place. Also, typically more information is collected on protection activities than on measurements of results and outcomes of protection efforts (Hatry, Liner, Morely 1992:5). Liner et al. (1989) found little documentation of options and trade-offs between prevention and control or remediation activities and few action plans for identifying responsibilities, tasks and expected results. They recommended systematic analysis of alternatives, ongoing evaluation and updating of protection strategies, and regular reporting on groundwater conditions and progress.

Protection strategies require specific objectives and measurable criteria to form the basis upon which to consider alternative strategies and to examine potential effects (Leusink 1992:100). The EPA has done some work on developing indicators to measure progress in groundwater protection (EPA 1989b). It has developed general indicators for public water supplies, hazardous and industrial waste sites, and for area-wide sources of contamination. As noted by

Jaffe (1987:155), one of the best measures of effective protection strategy is one that protects desired uses and functions by minimizing and eliminating threats to groundwater:

> The long term success of establishing a local groundwater protection program can best be evaluated by a lack of pollution threats to public and private water supplies; in a preventative program, the absence of problems is, in some ways, a more accurate measure of success than merely identifying pollution through groundwater monitoring and responding to it by stringent regulatory measures.

Coordinated

Fragmentation of authority and responsibility is a continuing barrier to effective groundwater protection (Page 1987). Over time a patchwork of policies and programs affecting groundwater have emerged, administered by separate organizations and different levels of government. These policies and programs often do not share the same approach, objectives, or priorities (EPA 1992:1-11). Disparate control efforts among different levels of government has led to calls for improving coordination of programs and activities among government and non-government actor groups (Leusink 1992, Kenski 1990).

Of all the federal environmental programs in the U.S., groundwater protection activities are among those which afford affected jurisdictions the most discretion in translating federal requirements (Fiorino 1995:85). There has been a consistent emphasis on reduced federal involvement and increased state authority and local responsibility for implementing environmental programs including groundwater protection (EPA 1984). It has been expressed in terms of a flexible partnership among three levels of government, with increased accountability and responsibility at state and local levels for groundwater protection.

Liner et al. (1989) found a common failure to include all relevant agencies and sectors in the strategy development process, and lack of integration with other state-wide plans. They recommend increased stakeholder involvement in strategy development as well as creation of inter-agency committees and advisory groups to improve coordination. They also recommend that clear lines of communication between field staff and central offices be established, and a case management approach taken to coordinate efforts where overlapping problems were found in the same location.

While groundwater strategies are generally sponsored by one level of government or set of agencies, the activities associated with it are dependent on the participation of a range of actors, both public and private. Strategies build on existing institutional arrangements wherever possible, but also act as catalysts for changing the way protection activities are planned and implemented across all levels of government and among all organizations (EPA 1992:1-20).

Planning for groundwater protection requires the ability to coordinate decision making among local jurisdictions whose boundaries encompass a particular groundwater system. As noted by Morely et al. (1992:69):

> ...inter-local cooperation ... is an important mechanism for dealing with groundwater protection issues that transcend the boundaries of individual local governments, and for encouraging greater involvement of local governments in groundwater protection.

The limited authority of county and regional agencies in most states preclude consistent interpretation and implementation of groundwater protection policies and guidelines. In some states, new administrative structures and special districts have been created, whose boundaries are based on the groundwater system of concern. In other states, existing regional authorities and other coordinating mechanisms have been used to facilitate inter-local and intergovernmental cooperation. However, regional authorities in the U.S. rarely have decision making authority for matters such as water supply, public health and land use planning. Their success depends on an ability to build consensus for action. Responsibilities often include facilitating exchange of information and coordinating the actions of local agencies and government departments.

Morley et al. (1992) suggest that a process for instituting cooperation among affected agencies and local governments should consider the following: identifying jurisdictions encompassing the groundwater resource and whose responsibilities fit with the type of cooperative effort to be undertaken, selecting a lead agency and coordinating mechanism, choosing activities to be undertaken on a cooperative basis and ones to be undertaken independently, establishing a mechanism to formalize cooperation, identifying sources of funding and other resources where new activities are envisioned, and obtaining input from affected or interested organizations in order to promote understanding and build support. The active involvement of all interests and sectors is required, including groundwater users, private industry, non-government organizations and the general public (NRC 1986; CF 1987; EPA 1992).

The ability to engage multiple jurisdictions and levels of government in a coherent and coordinated plan of action is central to the task of enhancing the scope and functioning of protection programs (Liner, Morley and Stanger 1994:I-28; EPA 1991:7; Page 1987:375). Strategies are needed that promote collaboration and link activities of core actors, based on common goals and priorities (Page 1987:374; Leusink 1992:99; EPA 1991:7). However, considerable developmental work remains on defining appropriate roles and responsibilities of all relevant organizations and stakeholders (Canter, Knox and Fairchild 1988:529). Some specific institutional coordination issues to be addressed include: cooperative management of groundwater systems that underlie multiple jurisdictions, selecting priorities for action among overlapping organizations, institutional mechanisms for sharing information and pooling resources, and coordinated decision making for public and private lands (Canter 1986).

Catalytic

Capacity-building includes the distribution of authority, roles and responsibilities, knowledge, technical and financial resources. It also includes use of coordinating mechanisms, and other actions to ensure the continued support of core actors and decision makers to sustain strategy implementation.

The community-based approach to groundwater management and protection has been widely endorsed because of the strategic role local authorities play in achieving national and state goals for groundwater management and protection (Leusink 1992:101; EPA 1991). As noted by Libby and Kovan (1987:358): "The instruments for effective supportable policy [to protect groundwater] are at the city, township, county and multi-county regional level." The responsibility of local and regional authorities for providing water to meet community needs gives them a direct and ongoing stake in maintaining long term supply of good quality groundwater. In addition local responsibility for guiding land use decisions gives them a pivotal role in achieving protection objectives.

Support for community-based protection not only suggests a strong local role in implementing mandated or delegated responsibilities. A local protection strategy involves establishing local goals and objectives, deciding on the level of protection to be afforded sensitive areas, as well as selecting the specific protection tools that best suit local circumstances (Jaffe 1987). It also implies providing scope for translating broad protection policies in terms that are relevant to a specific community's needs, abilities and priorities (Libby and Kovan 1987; Liner, Morely and Stanger 1994). Groundwater protection strategies will reflect a community's capacity to manage and protect groundwater (Liner et al. 1989; Jaffe and DiNovo 1987:168). There are a number of factors that impact capacity and willingness to take action, including sufficient recognition of the problem, support from formal decision makers, technical and administrative staff, a legal or policy mandate for action, consensus and support of key interest groups, and sufficient resources (Leusink 1992:99; Canter, Knox and Fairchild 1988:529; Jaffe and DiNovo 1987:168).. Liner, Morely and Stanger (1994:I-26) recommend that programs be tailored to specific threats or problems facing a community in order to reduce implementation costs and more easily gain the support of citizens, public officials and the business community (Liner, Morely and Stanger 1994:I-26).

The majority of communities who have acted to protect groundwater have done so with limited technical and financial support from senior levels of government. Although many state groundwater protection strategies acknowledge the importance of providing assistance to local governments and regional authorities to encourage their participation in implementing groundwater protection measures there remains a strong un-met need for financial support and other forms of incentives, such as technical assistance, and training (Morely et al. 1992; Liner, Morely, and Stanger 1994). Liner et al. (1989) found insufficient funding for implementation, legislative inadequacies, requests for increased federal research, training, technical assistance and standards development, as well as flexibility over the use of federal funds, an absence of action plans identifying tasks, responsibilities and expected results Local expenditures often far exceed the combined outlays of federal and state governments.

> Despite the existence of some strong local programs, it is clear that in most cases local government cannot act to protect groundwater without backing from the state. Most local governments lack the incentive or expertise to take on most groundwater

> protection responsibilities. Sufficient resources to finance protection and regulatory backing from the state are needed at the local level. Liner et al. (1989:87)

Building institutional capacity requires an institutional framework that enables communities to effectively protect groundwater resources over the long term. It includes addressing roles and responsibilities, legal authority, resource commitments, technical capacity, and actor support for implementation. While building on existing institutional arrangements wherever possible, strategies also act as catalysts for changing the way protection activities are planned and implemented across all levels of government and among all organizations.

Planning for groundwater protection requires the guidance and assistance of senior governments to stimulate community interest and commitment to taking responsibility for groundwater protection (Tuinhof 1992:121; Liner et al. 1989; EPA 1992). State governments have prime responsibility for developing management and protection programs while the local government has significant responsibility for implementation activities. It has emerged as an antidote to the institutional rigidity and inconsistency of past federal actions in groundwater protection and inefficient expenditures from a resource-based perspective. The new federal government role is defined in terms of ensuring consistency and equity among states, providing technical support, while reducing over-sight activities and financial support (Fiorino 1995:86). There has been a concomitant shift in emphasis from adherence to rigid criteria to flexible interpretation and adaptation of federal requirements to state priorities. The need for more flexibility in determining and addressing state and local priorities has been supported on the basis of differing capabilities, needs and understanding of the resource (EPA 1992:1-11).

Liner et al. (1989) recommend that state governments increase their support for local actions by ensuring that enabling legislation is in place to support local protection activities, delegate responsibilities where local communities demonstrate a willingness and a capacity, state oversight of implementation, adequate funding, or fund-raising authority, to local governments, improved information sharing, and increased technical assistance and training. Additional revenue sources recommended for funding groundwater protection included increased permit fees, taxes on polluters, dedicated fines and general revenue sources to establish trust funds for groundwater-related activities. Increased delegation of responsibilities to capable and willing localities also was recommended to reduce costs (Liner et al. 1989:16-21).

While an informed and supportive citizenry has been found to be critical for implementing protection measures, education and outreach activities were limited in most states. There was a lack of educational material, minimal technical assistance regarding best management practice for industry, and a failure to tap into university-based programs. Liner et al. (1989) recommend increased technical assistance and training to business and industry, working with higher education institutions to develop educational materials, training and curriculum development for elementary and secondary schools, and training materials for government and non-government organizations.

4.8 Summary

The groundwater literature confirms that protection strategies provide a comprehensive framework for integrating programs and activities related to groundwater protection and for coordinating the actions of core public and private actor groups to achieve long term goals. Groundwater strategies also confront practical implementation issues such as adequate information, resources, technical and political support. The literature reflects a growing consensus that strategies for protecting groundwater should include the following critical elements: developing a vision, characterizing groundwater resources, assessing and monitoring threats to groundwater, instituting a system of rules and instruments to manage human activities, and building capacity to sustain implementation efforts. All of these elements reflect a trend toward an ecosystem approach.

The literature also points to a number of recurring challenges confronting efforts to improve the management and protection of groundwater, that can be summarized as follows:

- moving from the site-specific to a groundwater system focus;
- integrating goals of human health and ecosystem integrity;
- improved characterization of groundwater systems and potential threats;
- transforming reactive controls to preventative planning;
- coordinating activities of different actor groups; and
- addressing limited institutional capacity for implementation.

Planning for groundwater systems requires defining measurable objectives to protect human uses and ecological integrity over the long term. Improved characterization of groundwater systems is needed, combined with assessment of the interactions of multiple stresses and uses of groundwater. Regulatory controls should be integrated with a broad set of instruments directed toward long term goals. Better coordination of programs and activities of government and non-government actor groups is paramount, with a focus on strengthening community capacity for action. Various forms of support from senior levels of government are critical, including enabling legislation which provides authority required to implement protection measures, transfer of responsibilities downward where communities and individuals have demonstrated a willingness and a capacity to protect groundwater, ensuring means are available to finance protection activities at the community level, providing base-line standards, information and mapping, technical assistance and training where needed.

Graduated approaches to groundwater protection are needed that accommodate variable conditions and circumstances while, over time, achieving increasing scope and integration. This requires a commitment to strengthen and expand protection initiatives beyond priority threats and concerns to protect groundwater's ecological functions and its human use values over the long term. These critical activities, together with the guiding principles of an ecosystem approach provide an organizing framework for addressing the continuing challenges facing groundwater protection. The next chapter discusses this framework in some detail.

CHAPTER 5
CONCEPTUALIZING AN ECOSYSTEM APPROACH TO GROUNDWATER PROTECTION

5.1 Introduction

The purpose of this chapter is to outline a conceptual framework for an ecosystem approach to groundwater protection. The framework integrates the guiding principles of an ecosystem approach with strategic elements of groundwater protection. It advances conceptual understanding of an ecosystem approach by defining working components and principle elements which provide a normative framework for critically analyzing real-life examples.

The *Ecosystem Approach Framework* consists of four components: *activities, principles, questions, and attributes* (Table 4). *Activities* are defined as a set of actions that broadly constitute a comprehensive and integrated strategy for protecting groundwater. Major activities include: defining outcomes, characterizing groundwater ecosystems, assessing and monitoring change, influencing decisions and actions, and building institutional capacity to sustain implementation. *Principles* are defined as generalizations that form the basis for reflecting upon and applying an ecosystem approach. The *principles* component of the framework incorporates the guiding concepts that define an ecosystem approach. They are grouped into the following categories: ecosystem boundaries, objectives, functions, cumulative effects, integrated, adaptable, coordinated and catalytic. The *questions* component of the framework transforms the guiding principles into a set of key questions. These questions focus the investigation on prime considerations. *Attributes* are properties belonging to, or characteristic of, an ecosystem approach to groundwater protection. They are reference points against which to evaluate the consistency of a groundwater strategy with the principles of an ecosystem approach.

TABLE 4: ECOSYSTEM APPROACH FRAMEWORK

ACTIVITIES	PRINCIPLES	QUESTIONS	ATTRIBUTES
Defining Outcomes	Boundaries	*Do the planning boundaries encompass connections among different ecosystem levels?*	well fields regional systems watersheds & groundwater basins
	Objectives	*Is decision-making guided by a full range of ecosystem objectives?*	hydrogeological processes biodiversity support sustainable use
Characterizing Groundwater-Ecosystems	Functions	*How are groundwater-ecosystem processes, functions and linkages characterized?*	local & regional hydrogeology surface water-groundwater relationships aquatic and terrestrial habitat linkages
Assessing & Monitoring Change	Effects	*How are the stresses associated with diverse land uses and groundwater-ecosystem responses being assessed and monitored?*	stress-response framework - land use stresses - ecosystem response
Influencing Human Activities	Integrated	*Do an integrated set of rules and instruments provide a complete range of protection functions?*	regulation, economic incentives, voluntary instruments protection, prevention, control, remediation
	Adaptable	*Is there an emphasis on flexible tools and ongoing evaluation to adapt to new information and diverse conditions?*	flexible tools internal/external review
Building Capacity	Coordinated	*How does the strategy link decisions and actions among core actors and across jurisdictions?*	coordinating mechanisms protection partnerships
	Catalytic	*What measures are taken to strengthen institutional capacity?*	authority & policy framework resources information management technical support recognition

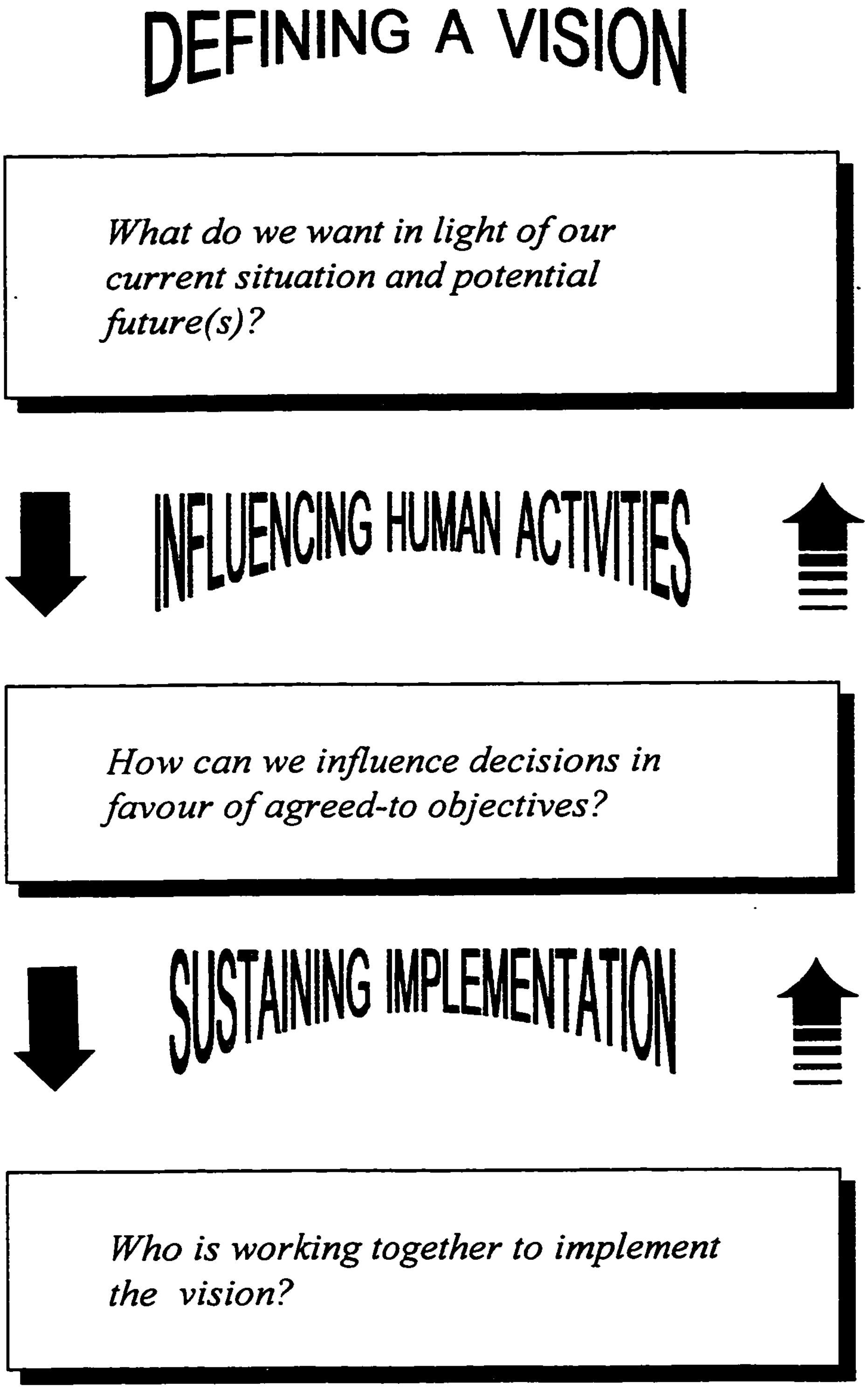
There is a dynamic and inter-dependent quality to the relationship among the elements of the framework. Three broad features of an ecosystem approach are depicted in Figure 3. The first is defined by the planning, analysis and monitoring activities which are directed at maintaining healthy ecosystems and the human uses that are compatible with a self-sustaining system. It might be summarized as "*What do we want in light of our current situation and potential future(s)?*" The second is represented by the rules and instruments that structure human behaviour toward desired outcomes. It might be summarized *as "How can we influence decisions in favour of agreed-to objectives?"* The third feature is defined by the roles, responsibilities and interactions among actor groups. It might be summarized as "*Who is working together to implement the vision?*" All three components must be addressed in an ecosystem approach, and function iteratively through feedback mechanisms. For example, the assessment and monitoring activities provide benchmarks for developing the rules and instruments to protect groundwater systems. Similarly, the ability to influence human activities is dependent upon coordinating the activities of core actor groups and building capacity for implementation. The next sections describe in more detail the principles and attributes of an ecosystem approach to planning for groundwater protection.

5.2 Defining Outcomes

Key Questions:

- *Do planning boundaries encompass connections among different ecosystem levels?*
- *Is decision making guided by a full range of ecosystem objectives?*

FIGURE 3: GENERALIZED FEATURES OF AN ECOSYSTEM APPROACH



Principle 1: Ecosystem Boundaries

The ecosystem approach depends on building a shared vision for the ecosystem, of which humans are an integral part. This has direct implications for the *boundaries* chosen for planning and management. The ecosystem approach expands the boundaries to include whole systems, defined by critical processes and valued groundwater functions, as well as the major stresses impacting those functions. The boundaries should account for a continuum, or hierarchy, of ecosystems corresponding to the scales at which planning and decision making occurs. This principle broadens the scope of conventional groundwater management from a decision making framework preoccupied with site-specific conditions to include a broader framework provided by the groundwater systems and watersheds that form the context for addressing human needs as well as the relationship to ecosystem health. While there are no strict rules for their application, each boundary provides an opportunity to plan for groundwater processes and functions at a number of different spatial and temporal scales.

Key Attributes

The specific attributes related to the boundaries principle reflect multiple scales for groundwater protection planning, including well fields, regional systems, watersheds and groundwater basins.Of these, the first boundary is tied most directly to human use or consumption of groundwater. It takes into consideration the areas and features that supply groundwater recharge to wells and well fields. The focus is on the subsurface and surface area surrounding wells wherein contaminants or other land use stresses could impact existing and potential water wells in the present or future.

The intermediate ecosystem boundary for planning purposes is not tied to particular wells or extractive use. It encompasses aquifers and aquifer complexes in a given area, consisting of multiple groundwater lenses of variable extent and thickness, but all related to a similar geologic environment of deposition. This would include areas recharging local and regional groundwater flow systems as well as areas of groundwater discharge to wetlands, streams, lakes and rivers.

The largest ecosystem boundary is defined by groundwater systems and processes found within an entire catchment area of a watershed as well as the major groundwater basins extending across watershed divides. It would take into consideration factors such as the size, thickness and depth of surficial deposits and bedrock formations as well as the flows between these formations.

Principle 2: Ecosystem Objectives

An ecosystem approach is guided by clearly defined outcomes. This involves both narrative descriptions of long term goals as well as measurable objectives. Goals are broad statements that reflect a collective vision for the future. Objectives are necessary to explicate the goals of a strategy. Objectives are more circumscribed statements of intent that lend themselves to specific description and measurement. They include biological, physical and chemical indicators and targets for groundwater-ecosystem functions. Indicators provide substitute measures for these functions and benefits, which help substantiate whether goals and objectives are being achieved. For example the presence of a sensitive species, such as brook trout, in a stream receiving direct discharge from a groundwater source may be used to indicate the continuing health of that system. Targets are quantitative and qualitative criteria that help define the significance of measured indicators. Chosen indicators and targets become the benchmark against which progress and performance are measured.

The use of ecosystem objectives has a number of practical implications. First, the consumptive benefits of groundwater for drinking water, agriculture, industry and other uses should be pursued within the limits and ability of the groundwater-ecosystem to renew itself. Present and projected rates of resource use and other stresses must not reduce or destroy the prospects for their use over the long term. This translates into quality and quantity targets for achieving sustainable use[25].

The ecosystem objective principle affirms the need to broaden the conventional focus on human use considerations to include ecological health considerations, recognizing that human health and welfare ultimately rely on processes and services provided by dynamic and healthy ecosystems. Ecosystem objectives flow from a common understanding of desirable outcomes that relate to valued groundwater-ecosystem functions. The process for determining these objectives requires combining technical-scientific analysis with discussion among core actor groups of human values and preferences. Given incomplete understanding of ecosystem functions and processes, some combination of descriptive or qualitative targets and quantitative measures are acceptable. Also, the dynamic nature of ecosystems suggests that goals and objectives be re-visited as conditions and priorities change.

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25 Concepts such as *optimal yield* and *maximum stable basin yield* recognize upper limits to rates of groundwater extraction (Freeze and Cherry 1979:364-66).

Key Attributes

The key attributes of ecosystem objectives include essential hydrogeological processes, biodiversity support, and sustainable use. Essential hydrogeological processes are those relating to the recharge of groundwater, its movement and storage in the saturated zone, the chemical evolution that accompanies groundwater flow, as well as its discharge. Biodiversity support functions relate to groundwater's role in maintaining the integrity of ecosystems associated with it. This includes contributing to the health and diversity of aquatic and terrestrial ecosystems (e.g. streams, lakes and rivers, wetlands, bogs and marshes). Sustainable use refers to maintaining the ability of aquifers to continue to provide water of adequate quality and quantity for human benefit without producing undesirable impacts, such as depleting groundwater storage or reducing its ability to meet targets for biodiversity support.

5.3 Characterizing Groundwater-Ecosystems

Key Question:

- *How are groundwater-ecosystem processes, functions and linkages characterized?*

Principle 3: Ecosystem Functions

Groundwater characterization activities broadly include the tasks of defining groundwater systems to be protected. More specifically this includes collecting, analysing, and mapping the hydrogeology of subsurface water-bearing units. From an ecosystem perspective the key principle associated with characterization activities is considering groundwater-ecosystem *functions*, including the dynamic and interacting processes that link physical, chemical and biological components of the system.

Examining ecosystem functions represents an evolution from conventional analyses that define groundwater solely in terms of quality and quantity at the site-specific level. These factors must be understood within the wider context of interconnected processes linking groundwater flow systems at a number of scales. It also requires examination of interactions among groundwater and surface water systems.

Key Attributes

A key attribute associated with characterizing groundwater ecosystem functions is collecting information that is sufficient to adequately characterize the hydrogeology and functioning of local and regional groundwater systems. It involves description and analysis of the chemical and physical properties of groundwater formations, flows within and between formations, groundwater recharge and groundwater discharge.

The interaction of groundwater and surface water systems also should be characterized. Natural seasonal fluctuations as well as the effects of water withdrawals on flows in both directions, from groundwater to surface water and vice versa, should be accounted for. Direct linkages that support aquatic and terrestrial ecosystems also should be quantified.

5.4 Assessing and Monitoring Change

Key Question:

- *How are the stresses associated with diverse land uses and groundwater-ecosystem responses being assessed and monitored?*

Principle 4: Cumulative Environmental Effects

From an ecosystem perspective it is critical to assess potential *cumulative effects* of human activities, or stressors, over time. This involves analysis of diverse land use activities and the potential pathways through which groundwater functions may be degraded or otherwise altered over time. It includes consideration of impacts on hydrogeological processes, sustainable use and biodoversity support. Cumulative effects assessment should be undertaken to support the development of a long term vision and to inform discussion of the means for achieving desired outcomes. While traditional impact assessment fails to provide a framework for considering how past, present and future human activities may be linked to the functioning of ecosystems, the ecosystem approach seeks to understand the complex cause-effect relationships which lead to ecosystem change.

Monitoring is an important component of a groundwater protection strategy, since it answers the basic question regarding progress toward desired outcomes. It should support planning and decision making by providing evidence on the effectiveness of groundwater protection measures, document why and how ecosystems are changing, and support related research activities. Monitoring activities include the collection, management and transfer of information and data. An ecosystem approach seeks to understand relationships among land use change and ecosystem change. Monitoring should provide information on critical relevant human activities that may stimulate changes in ecosystem conditions.

In contrast to conventional monitoring that typically focuses on a narrow range of chemical parameters at the site level, a monitoring system should use a suite of indicators and targets that provide surrogate measures of stress on ecosystems as well as changes in ecosystem functioning. This requires adoption of an integrative framework linking the type and intensity of land use activities at a landscape or regional level with short and long term changes in groundwater-ecosystem functioning. The type of information collected should be extensive, or ecosystem-wide, supplemented with more intensive, site-specific, information where available.

Key Attributes

A key attribute associated with assessing and monitoring cumulative effects is application of an integrative framework that links multiple stresses with potential changes to groundwater functioning as a result of those stresses. It requires description and analysis of the location, type and nature of existing and proposed groundwater uses, land use activities and sources of contamination at scales consistent with the chosen ecosystem planning boundaries: well fields, regional groundwater systems and watersheds/groundwater basins. The potential effects of multiple stresses should be assessed using a stress-response framework or equivalent set of analytical techniques.

5.5 Influencing Decisions and Actions

Key questions:

- *How are the rules and instruments integrated to provide a complete range of protection functions?*
- *Is there an emphasis on flexible tools and ongoing evaluation to adapt to new information and diverse conditions?*

Principle 5: Integrated

Decisions regarding the system of rules and instruments applied to influence human activities should be consistent with the vision for groundwater protection and should be informed by analysis of groundwater characterization, assessment and monitoring. Rules and instruments come in various forms along a continuum from encouraging or permitting some behaviours whilst requiring or prohibiting others. The three most common instruments are direct regulation, economic instruments, and voluntary agreements. As issues, priorities, perceptions, attitudes and values change, so will the mix of preferred rules and instruments.

Direct regulation gives rules the force of law through formal statutes and regulations. Compliance is mandatory and negative sanctions are prescribed if rules are not followed. Economic instruments provide fiscal incentives for individuals and groups to comply with rules. This can take many forms, such as tax measures, user charges, grants and loans. In these cases certain behaviours are rewarded while others may be penalized financially. Voluntary instruments rely on information and good will to persuade individuals and groups to take action. These can take various forms, such as operating guidelines, codes of practice, and non-binding agreements. Compliance is voluntary and no formal sanctions are applied for failure to cooperate.

The principle of *integration* highlights the importance of developing a coherent set of rules and instruments that work together to achieve a long term vision. This principle is in direct response to traditional reliance on a limited set of regulatory instruments that focus on reactive control measures to the exclusion of preventative strategies. Rather than relying on one type of instrument at the expense of another, an integrated approach would take advantage of the strengths of each. For example, regulatory measures should provide the incentives for and the boundaries within which voluntary activities can flourish. A combination of economic measures, voluntary instruments and regulatory controls should provide a clear mandate for action without limiting actions to some prescribed minimums.

An integrated strategy should encompass four major functions - protection, prevention, control and remediation. Protection activities are defined as the rules governing the location, type and intensity of land uses in order to protect valued groundwater resources and functions. For example, land use policy influences patterns of growth and development through designating land uses, defining infrastructure requirements and prescribing assessment activities. Development control measures are another example, in which specific uses of land are controlled by regulation, criteria for reviewing proposed development is established and standards for permitting development in a given area applied. Non-regulatory measures may include stewardship agreements or land acquisition, in which control over the use of sensitive areas is acquired through purchase, donation or conservation easement.

Prevention activities are rules that seek to reduce or eliminate the use or creation of potential contaminants and that promote the efficient use of energy and other resources. Examples of basic prevention activities include waste reduction, adoption of best management practices and preventative maintenance of equipment and facilities. More intensive prevention activities are directed at re-engineering how facilities and businesses operate. It can include adoption of advanced environmental management systems, substitution of raw feedstocks, use of clean production processes, and in-process recycling to prevent the creation of harmful by-products or hazardous waste streams.

Control activities include rules that govern resource use and that control the use or release of contaminants that may alter or otherwise degrade ecosystem functioning. They are commonly associated with regulatory instruments such as permits, licenses and approvals. Control instruments also govern waste storage, handling, transportation, treatment, and disposal. Other controls take the form of health and environmental standards, and bans and use restrictions for designated products or contaminants. Remediation activities which govern mitigation and clean-up of contaminated groundwater include emergency response procedures for contamination events, containment and treatment of contaminated groundwater, and contingency planning for future emergencies, such as the loss of a water supply.

Key Attributes

A key attribute of an integrated approach is applying a mix of instruments that elicit actions which are consistent with achieving identified outcomes. It should include some combination of regulation, economic incentives and voluntary measures that stimulate positive behaviour by landowners and land users. Together they should reinforce desired outcomes and encourage decisions and activities that support those ends.

Another key attribute of integration is a set of rules and instruments that encompass prevention, protection, control and remediation of groundwater systems. An emphasis on prevention should lead to rules and instruments which guide the location, type and intensity of land uses and activities so as to protect valued groundwater resources and functions. In addition, processes, practices, and material use should be directed in such a way that undesirable stresses to groundwater are prevented. Measures must also be in place which specifically control the release of pollutants and waste to the environment that may enter and/or degrade groundwater, to respond to contamination events and to require restoration of groundwater and related ecosystems that have been damaged by human uses and activities.

Principle 6: Adaptable

The *adaptive* principle supports a precautionary approach that applies protection and prevention measures to avoid loss or impairment of groundwater processes and functions. It explicitly recognizes that technical understanding and predictive capability is often severely limited, and suggests policies which make use of the best available information while at the same time reversing the onus on potential stressors to prevent actions that could seriously impair groundwater functions. This principle highlights the need to develop and apply rules under conditions of uncertainty, and to adjust approaches on the basis of new understanding and dynamic conditions. Uncertainty inherent in planning for groundwater protection has implications for the role played by technical information in the decision making process as well as the way in which rules and instruments are applied. Also required are flexible instruments and tools that can be adapted to variable and diverse conditions.

The adaptive principle also promotes continuous review, evaluation and improvement. Rules and instruments should be functional in different environments and should continue to evolve as new information and understanding of ecosystem functioning and human activities emerge. Without ongoing evaluation of how rules and instruments are being implemented, there is no ability to learn from or improve upon past practice. Conventional approaches are characterized by the use of cumbersome instruments applied indiscriminately. Most lack mechanisms for regular review of the purposes for which rules were developed, or for testing the results of implementation.

Key Attributes

A key attribute of an adaptive approach is application of instruments and measures that are flexible enough to adjust to diverse and changing conditions. They should be based on the principle of taking precautionary measures while rewarding innovation and increasing the capacity for creative problem solving. This would reduce reliance on tools that apply uniform and standardized prescriptions based on legislated minimum requirements. Some flexible instruments include alternative development standards and mandated performance criteria, development permit systems, conservation easements, stewardship agreements, tax incentives, and pollution prevention planning.

Another key attribute of an adaptive approach is providing mechanisms or processes that facilitate continuous review and improvement. In addition to internal review this requires that opportunities be provided for external evaluation at regular intervals to ensure that groundwater protection activities are consistent with identified objectives and that they are evolving to reflect new information and understanding.

5.6 Building Capacity

Key questions:

- *How does the strategy link decisions and actions linked among core actors and across jurisdictions?*
- *What measures are taken to strengthen institutional capacity?*

Principle 7: Coordinated

A critical feature of an ecosystem approach is building and releasing the capacity of core actor groups to sustain implementation. These include mechanisms for developing a collective vision as well as for coordinating the activities of core actor groups. Also required is the institutional framework that supports and encourages positive action.

The two key ecosystem principles are *coordinated* and *catalytic*. The principle of coordination addresses the need for core actors to work together to achieve individual and collective goals. It recognizes that interdependencies exist which require the design of cooperative solutions and replaces traditional reliance on single agencies or authorities for implementation with shared accountability across all sectors of a community for achieving collective goals. An important attribute is use of coordinating mechanisms that provide appreciation, resource-sharing and decision-support functions. In some cases these mechanisms will play an external advisory or quasi-judicial role by offering judgements of what action is required and how it should be carried out. In other cases it will simply provide a forum for core actor groups to seek agreement on pursuing common purposes. In both cases, adequate representation of affected interests on these mechanisms is critical.

Of equal importance is the establishment of protection partnerships among core actors that translate discussion into concerted action. These partnerships should link different sectors of the community and relevant authorities at each stage in the process of developing and implementing a strategy. Three broad stages include include defining the agenda, developing specific solutions and implementing actions.

Key Attributes

An important means of securing the participation and accountability of core actors for defining and achieving collective outcomes is through interorganizational coordinating mechanisms. These mechanisms should perform a range of functions: increasing awareness and appreciation for the different perspectives among core actor groups, coordinating resource and communication flows among actor groups, and providing a decision-support function in the development and implementation of a Strategy.

Another critical attribute is developing protection partnerships with core actor groups from key sectors: business, government, and non-profit. To be successful, partnerships are critical during the formative agenda-setting stage, during the development of solutions and approaches, and for carrying out implementation activities.

Principle 8: Catalytic

The catalytic principle sharpens the focus of capacity-building at the community-level. It reverses the onus for both defining and implementing solutions from the centre to the periphery. Whereas in the past, centralized approaches relied on remote controls and top down authority, the ecosystem approach calls for strengthening the ability of a community to apply solutions, and make use of local knowledge of and appreciation for the ecosystems in which groups and individuals live and work. The former emphasis on power and control at the centre is replaced with an emphasis on mobilizing and recognizing responsible action by all actor groups. To achieve this requires adequate authority and policy support, resource commitments to sustain implementation, shared knowledge and information, technical support, and ways to recognize and encourage responsible action.

Key Attributes

A critical attribute of developing the institutional capacity to sustain implementation is having the authority and policy framework to mandate action, clarify roles and responsibilities, and support community-based activities. Financial and related resources also must be adequate to support activities associated with implementing the Strategy.

Another important attribute is establishing a means for sharing knowledge and information through effective information networks managing information and making it available to core actor groups and decision makers. An information management system should be capable of integrating diverse data sets, evaluating data collected over long periods of time, and facilitate comparisons of historical data and present conditions at multiple scales. The information management system should facilitate testing of assumptions, methods and techniques to achieve ecosystem objectives and foster informed discussion among core actor groups.

Support for community-based action also includes information transfer in the form of guidelines, standards, policies and technical advice. Another attribute is recognizing and encouraging actions by core actors to implement the Strategy. It could include public recognition programs as well as support networks within and among key sectors to encourage responsible action.

5.7 Summary

The conceptual framework provides a coherent basis for describing and analyzing an ecosystem approach to groundwater protection. Strategic activities include: defining outcomes, characterizing groundwater-ecosystems,assessing and monitoring change, influencing human decisions, and building institutional capacity. The ecosystem approach paradigm is characterized by eight key principles: boundaries, objectives, functions, cumulative effects, integrated, adaptable, coordinated, and catalytic. Each of the guiding principles has associated attributes that define an ecosystem approach to groundwater protection:

- planning boundaries defined by well fields, regional systems, watersheds & groundwater basins;
- ecosystem objectives consistent with sustainable use, maintaining essential hydrogeological processes and biodiversity support functions;
- characterization of groundwater-ecosystem functions by addressing local & regional hydrogeology and surface water-groundwater relationships;
- assessment of cumulative environmental effects of multiple land use stresses on groundwater-ecosystem functions by means of a stress-response framework;
- integrated use of regulation, economic and voluntary instruments to protect, prevent, control, and remediate groundwater;
- emphasis on precautionary and adaptive tools and continuous review;

- use of coordinating mechanisms and protection partnerships; and
- capacity-building through authority & policy frameworks, resource flows, technical support, and public recognition.

The next chapter provides a description of the institutional context for ground water protection in Ontario. Policies and programs, corresponding to federal, provincial and municipal levels, that control access to and use of ground water, and that regulate or otherwise influence human activities which might degrade ground water functions over are reviewed. Continuing challenges facing ground water protection in Ontario are enumerated from the perspective of an ecosystem approach.

CHAPTER 6
GROUNDWATER MANAGEMENT AND PROTECTION IN ONTARIO

6.1 Introduction

The starting point for considering progress toward an ecosystem approach to groundwater protection in Ontario are the existing laws, policies and programs that control access to and use of groundwater, and that regulate or otherwise influence human activities which might degrade groundwater functions over time. This chapter reviews those institutional arrangements. It is organized around sections corresponding to three levels of governance: federal; provincial and municipal. Progress at all levels is reviewed and critical issues facing groundwater protection from the perspective of an ecosystem approach are enumerated.

While the focus of this inquiry is on regional groundwater strategies, an understanding of the larger set of institutional arrangements is critical, for two reasons. First, the rules governing human activities and the relations among actor groups are nested in a hierarchy of rule systems. These rule systems constrain the capacity for action at lower levels and circumscribe the alternatives available (cf. Sproule-Jones 1993; Ostrom 1994). Second, the complexity and scope of groundwater systems and the impacts of policy decisions extend beyond the confines of any single jurisdiction. The ability to develop and implement an ecosystem approach to groundwater protection will necessarily involve multiple levels of governance.

6.2 Federal Groundwater Protection

6.2.1 Regulatory Framework

The Canadian Constitution establishes a form of cooperative federalism whereby proprietary interests and legislative authority are distributed between two orders of government - federal and provincial. The authority for environmental protection is not clearly vested in either the federal government or provincial governments (Skogstad and Kopas 1992). Both have used various powers set out in the Constitution to establish some measure of responsibility for the environment. In contrast to the United States, federal and provincial governments in Canada rely on different powers so that areas falling within the domain of one level of government are excluded from the other level.[26] This has created a system of joint dependency over the environment, where neither level of government is assured sufficient authority to enact comprehensive environmental regulation (Northey 1991:152).

The federal government has jurisdiction over federal lands and water in the territories, national parks, Indian lands, seacoasts, inland and ocean fisheries, commercial navigation and shipping. It shares responsibility for agriculture with the provinces (DOE 1987:43). The federal government also can exert regulatory leverage where federal responsibility is implicated (Kennett 1990:34). For example federal responsibility over fisheries under section 91(10) of the *Constitution Act* supports federal regulation of water quality. However it is limited to fisheries conservation and the courts have interpreted it narrowly so that it is consistent with provincial control over natural resource development (Kennett 1991:27). Another source of federal authority directly relevant to environmental matters are its general powers related to "peace, order and good government". However, the federal government's actions are constrained in that it cannot group provincial matters together to create a national concern; it cannot overly prejudice provincial interests, and its actions must be necessary for the interests of Canada as a whole (Northey 1991:142).

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26 In the United States while the federal government has virtually unlimited regulatory ability, both federal and state levels of government are capable of entering a regulatory field and passing comprehensive legislation. This is known as "joint autonomy" (Northey 1991:150).

To the present, the federal government has had limited involvement in groundwater issues. While some of its legislative authority impinges on groundwater management and protection, the federal government has displayed significant reluctance and indecisiveness about its role in this area. Traditionally the federal government perceived itself as having no major role in addressing groundwater concerns. A number of explanations have been provided for this: the fact that groundwater lying beneath lands, other than federally controlled lands, falls under the regulatory control of provincial governments; groundwater does not fall entirely within the mandate of a single federal department or directorate; groundwater is used by a minority of Canadians; and a pervasive myth of abundance precludes considering the possibility that limits to the use and abuse of the resource exist (Morgan 1993: 1-4). Environment Canada has suggested that the limited involvement of the federal government in groundwater issues arises from its orientation to surface water concerns, a weaker mandate for groundwater, a shortage of qualified staff, competition with traditional programs for resources, and a lack of external lobbying for action by the federal government on groundwater issues (DOE 1990b:11).

Various federal statutes and processes are directed at controlling activities that could directly or indirectly impact groundwater functions and quality . The *Fisheries Act* impinges on groundwater by virtue of the fact that it prohibits certain activities, without authorization, that result in the harmful alteration or destruction of fish habitat (*Fisheries Act* s. 35). This includes altering base flow conditions in rivers and streams, which are often a function of groundwater discharge. However, federal policy for the management of fish habitat does not address related groundwater concerns (DFO 1986).In the early part of this century, the provinces were granted administrative jurisdiction over inland fisheries, including the *Fisheries Act*.

In 1975 the federal parliament passed the *Environmental Contaminants Act*. It empowered the federal government to take certain steps to control or regulate the use of substances deemed to pose health or environmental risks. In 1988 the *Canadian Environmental Protection Act* was passed. It is the federal government's principal legislation governing toxic substances. This Act provides controls over the production, use, release and disposal of substances defined as toxic under the Act. To date a number of regulations have been passed covering matters such as ozone-depleting substances, polychlorinated biphenyls, ocean dumping, and pulp and paper mill discharges (Environment Canada 1995a). Groundwater impact assessments are mandated for some projects involving certain types of chemicals (Morgan 1993:3).

In June 1995 a House of Commons Committee recommended legislative amendments and additional measures for supporting pollution prevention, a new process and additional criteria for designating toxic substances, control of nutrients, biotechnology products, fuels and other substances. (House of Commons 1995).[27] The Committee argued strongly for shifting the emphasis of the Act from managing pollution to an approach based on the following principles: pollution prevention, the ecosystem approach, biodiversity, the precautionary principle, and user responsibility. The federal government endorsed many of the Committee's recommendations in principle, and a number of changes to the Act were contemplated (Environment Canada 1995a). However, the Act has not been amended.

In 1992 the federal Parliament passed the *Canadian Environmental Assessment Act* replacing an earlier non-statutory process initially established in 1974. The Act requires that environmental assessments be conducted for physical works or activities that are: proposed by a federal agency, require specified federal licenses or approvals, receive federal financial

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27 Additional areas include: ocean dumping, environmental emergencies, international commitments, federal activities, federal and aboriginal lands, public participation, enforcement and administration.

assistance, or take place on federal lands (CEEA nd). Projects with the recognized potential of causing significant adverse environmental effects require a more detailed assessment of environmental effects. This includes works such as large oil and natural gas developments, mining projects and industrial plants (CEAA nd).

An environmental assessment is required to consider any change that the project may cause to the environment, including any cumulative environmental effects that are likely to result from the project in combination with other projects or activities that have been or will be carried out (Canadian Environmental Assessment Act s.16(1)). The environment includes air, land and water, organic and inorganic matters, living organisms and the interacting natural systems that include these components (Canadian Environmental Assessment Act. s.2(2)). No technical guidelines regarding water have been prepared to guide assessments. The closest reference to groundwater is found in a reference guide concerning cumulative effects assessment (FEARO 1994). It identifies criteria for setting aquatic boundaries for undertaking these assessments that includes drainage basins and existing "hydrogeological discontinuities". No explanation of the latter term is provided.

6.2.2 Non-regulatory Measures

Various non-regulatory instruments or approaches have been used to promote improved environmental decision making. Four types reviewed in this section include water quality objectives, groundwater research, financial incentives, and voluntary pollution prevention.

6.2.2.1 Water Quality Objectives

There are no legally mandated national drinking water standards mandated. Instead the federal government has worked cooperatively with its provincial counterparts to develop criteria that define safe drinking water.[28] 1968 the federal Department of Health published water quality guidelines for use by public health and water utility personnel (Hickman and Winthrop 1984:3). Ten years later these guidelines were substantially revised by a federal-provincial Working Group on Drinking Water (National Health and Welfare 1978). Intergovernmental working groups continue to develop water quality guidelines that are generally adopted, in whole or in part, by Provincial agencies (Hickman and Withrop 1984:3).

6.2.2.2 Research

The *Canada Water Act* (1970) provides for cooperative agreements between the federal government and one or more provinces for research and planning related to the conservation, development and use of water resources. It also empowered the federal government to enter into cooperative agreements with provincial governments to address water quality issues jointly. Major studies of large river basins have been undertaken. However, water quality issues, transboundary water pollution and groundwater issues have not been addressed through this mechanism (Kennett 1990:36).[29]

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28 The exception is direct federal control over drinking water on ships and related vessels plying international or interprovincial boundaries and control over activities on federal lands.

29 Major studies undertaken under the *Canada Water Act* have been described as overly detailed, product-oriented and lacking strategic focus (Shrubsole 1990). In terms of agreements developed under the Act, Provinces enjoy complete autonomy to comply with the terms of an agreement in their own way and there are few incentives for one provincial jurisdiction to include consideration of the consequences of its actions on another provincial jurisdiction or to

Most federal groundwater activities consist of in-house research, through Environment Canada and its research agencies. In 1990, over 60 percent of the department's spending on groundwater was devoted to research and development activities (DOE 1990:51). Currently the National Water Research Institute in Burlington, Ontario, has a Groundwater Remediation Project. The primary emphasis of this project is determining processes of contaminant transport and transformation in a variety of groundwater environments and the role played by groundwater in regional water budgets. In addition the NWRI is developing new technologies for isolating and restoring existing groundwater contamination (CCIW 1996). However, there are no apparent mechanisms to draw on results of research to develop guidelines and strategies (DOE 1990b:52-53).

Some federal agencies have special purpose programs related to groundwater. For example, Agriculture Canada monitors pesticides in drinking water in Ontario (MacRitchie 1994:67). A federal agency that has had extensive involvements in mapping soils and geology is the Geological Survey of Canada. In 1993 it began a unique project examining the regional hydrogeology of the Oak Ridges moraine area in southern Ontario (Sharpe, Dyke and Pullan 1994). The primary objective of this multi-year study is to understand the moraine's interior structure enough to detail identify the physical elements which control groundwater flow. The rationale given for the project is to address the current difficulty of directing land use activities and of increasing groundwater use because of poor understanding of the extent of water bearing

voluntarily give up autonomy to achieve joint management (Kennett 1991:89-100). One example of a significant effort to address transboundary water concerns was the establishment of the Prairie Provinces Water Board to oversee the management of surface waters crossing boundaries of the prairie provinces. The Board has been confined to administering a formula concerning water flows that has been agreed to by all participants, but has no independent authority or control over the behaviour of the parties. Further, the more contentious issue of water quality management has not been addressed.

sediments and distribution of recharge areas in the Moraine.

6.2.2.3 Economic Measures

As noted previously, economic instruments have been limited primarily to capital cost allowances on purchase of air and water pollution control equipment, taxes on certain products (tires and fuel), user charges for water use and waste disposal, deposit-refund systems for beverage containers, and local sewer use charges for industrial sources (MOEE 1995e). The federal government has supported the use of groundwater for drinking water indirectly, through loans and grants towards the development of water supply systems for new residential areas under various programs, such as the *National Housing Act* under various economic development programs (Hickman and Winthrop 1984).

It also has used tax incentives to promote conservation of certain environmentally significant lands. In 1995 it removed the 20% cap on income tax credits on donation of ecologically significant lands to municipalities and non-profit organizations. A credit of 100% of the donor's net income can be used for donation of recognized environmental lands, including conservation easements (Attridge and Eising 1995:4). However, these provisions have not been applied to sensitive groundwater areas.

6.2.2.4 Pollution Prevention

The federal government released its pollution prevention strategy in 1995 (Environment Canada 1995b). That strategy argued that goals for environmental protection could best be achieved through some combination of legislation, regulation, voluntary prevention initiatives and economic instruments. While the strategy committed the federal government to instituting pollution prevention across its operations, to work with other orders of government and with business to achieve a climate where pollution prevention becomes a major consideration in decision making, it is not clear how, or whether, this strategy will have any material impact on federal activities related to groundwater. Pollution prevention has been promoted through instruments that rely on persuasion to achieve compliance. Actions include education, public recognition programs, voluntary agreements with targeted sectors, and various forms of technical guidance (Environment Canada 1992; MOEE 1994a). Two specific examples are the national Accelerated Reduction/Elimination of Toxics Program, the Voluntary Challenge Registration for greenhouse gas reductions. The *Canada-Ontario Agreement Respecting the Great Lakes* (COA) is a recent example where a federal-provincial program has evolved moved from a strategy based on point source controls into one that integrates prevention. In 1971, the COA focussed on controlling phosphorous discharges by sewage treatment plants. Subsequent agreements broaden the focus to toxic chemical pollution and runoff from agricultural and urban lands, and shifted the emphasis to pollution prevention and voluntary approaches to protect the Great Lakes ecosystem.[30]

> Without precluding the use of regulations, further voluntary and cooperative initiatives by responsible parties will be the primary mechanism to achieve real and measurable reductions in the use, generation or release of both persistent bio-accumulative and toxic substances, and other substances impairing the Great Lakes Basin Ecosystem.
> (COA 1994:2)

A recent survey of environmental management in Canadian companies and institutions found that many respondents considered pollution prevention to be an important emerging issue

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30 It is noteworthy, however, that the primary commitment to groundwater in COA is focussed on investigating measures for cleaning up groundwater contamination at priority sites (COA 1994:4) The Agreement makes no commitment to develop and implement preventative groundwater strategies.

(KPMG 1996) A voluntary approach to prevention has been endorsed by industry. A leading example is the *Responsible Care* initiative of the Canadian Chemical Producers (CCPA 1994). There is also increased emphasis on reporting environmental performance as an essential component of pollution prevention. For example, recent work for the Canadian Institute of Chartered Accountants developed a framework for environmental reporting in accordance with standards and expectations relating to environmental conduct and responsibility (CICA 1994). At the same time, industry has acknowledged the need for a supportive regulatory context.

> We did not suggest that existing regulations be eliminated. They are a valuable base on which to build new, industry and goal-specific, initiatives. We also recognize that a mechanism must be in place for those organizations that fail to meet their commitments - for the sake of the environment, for companies that do not meet their targets, and for the government in terms of public accountability. (Rauter 1996:5).

The aforementioned survey found that the top motivating factors influencing environmental management decisions were compliance with regulations (93%) (KPMG 1996:8).[31]

6.2.3 Toward a Federal Groundwater Strategy

In 1984, the federal government appointed a three-person advisory committee to conduct a wide-ranging inquiry into federal water policy. One of the background papers commissioned for the inquiry was an overview of groundwater issues (Vonhof 1985). It identified a number of general deficiencies in groundwater management and protection including limited monitoring of the quality of groundwater resources, poor definition of the extent and degree of contamination and variable levels of protection provided to groundwater depending on its use and the availability of alternate supplies (Vonhof 1985:85-86). Recommendations for federal

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31 Other influencing factors identified in the survey included Board of Director liability (73%), the influence of employees (62%), and cost savings (53%).

action included initiating a groundwater quality monitoring program in cooperation with the provinces, development of a national groundwater strategy patterned after the strategy adopted by the United States Environmental Protection Agency in 1984, and development of a national data bank on groundwater contamination (Vonhof 1985:85-87).

In 1987 the Federal Water Policy was released. It acknowledged that insufficient attention had been paid to groundwater in Canada, and undertook to increase government action in this area (DOE 1987). It stated, "The federal government is committed to the preservation and enhancement of the groundwater resource for the beneficial uses of present and future generations" (DOE 1987:19). A commitment was made to take action in five areas:

- develop strategies, national guidelines and activities for groundwater assessment and protection;
- conduct research, technological development and demonstration projects in response to groundwater problems;
- develop exemplary federal groundwater management practices;
- adopt measures to achieve appropriate groundwater quality in transboundary waters; and
- provide information and advice on groundwater issues of federal and national interest.

However, no funding was earmarked to implement these policies, and federal expenditures on groundwater issues declined following release of the Water Policy (Cherry 1989:5).

In 1990, the Department of the Environment (DOE) proposed a federal groundwater strategy, based on the commitments made in the Federal Water Policy (DOE 1990a). Significant deficiencies in groundwater management are identified in resource evaluation (aquifer identification and assessment), aquifer management (planning and operations), groundwater allocation (licensing and regulating withdrawals), and conjunctive use of surface water and groundwater (DOE 1990b:18). Three major impediments to improved groundwater management are identified: absence of coherent and consistent groundwater management strategies and policies at all levels of government, lack of organized framework of knowledge of the groundwater resource in all jurisdictions across the country, and few groundwater data bases focussing on groundwater management needs (DOE 1990b:27-28).

The proposed federal strategy acknowledges the need to address groundwater contamination issues within the framework of an ecosystem approach:

> Groundwater contamination cannot be addressed separately from the larger issue of groundwater management; groundwater concerns cannot be dealt with outside the context of the hydrologic cycle as a whole; the hydrologic cycle cannot be considered separately from the other physical, chemical and biological systems, which together comprise the ecosystem in which we live. (DOE 1990a:4)

Similarly it stresses the need for coordination among different jurisdictions and levels of government. Specifically, the proposed strategy advocated that the federal and provincial governments work together to address groundwater issues.

> ... jurisdictional issues - such as what is 'federal' and what is 'provincial' - have become less relevant as we have begun to realize that the consequences of any action taken by any level of government or any segment, group or even individual members of society manifest themselves across all sectors and do not respect political boundaries.
> (DOE 1990a:4)

The draft strategy acknowledges the primary role of the provinces and local governments in developing and implementing legislative and regulative mechanisms for protecting groundwater (DOE 1990b:16). It also recommends that the federal government approach the provinces on a cooperative, cost-shared, basis, for guideline development, creation of data banks, and development of management strategies, including the use of economic incentives and other management tools (DOE 1990a:12). It called for improved coordination of federal groundwater-related activities, significant upgrading of the capability of the federal government to undertake groundwater programs and projects, and improved access to high quality groundwater expertise (DOE 1990a:11, 12).[32]

The proposed federal groundwater strategy was intended to be used as a basis for discussions with other federal departments, following approval by the federal Cabinet, and was to form the basis for negotiations with provincial governments on cost-shared agreements for implementation (DOE 1990a:10). The strategy did not receive Cabinet approval and funds were not appropriated for its implementation.[33]

Since the aborted federal groundwater strategy of 1990, and continuing reductions in federal groundwater activities, concern has persisted about lack of federal involvement and leadership in groundwater issues. A report prepared by some of Canada's leading groundwater specialists in 1993 identifies significant deficiencies.

> At present the ability of government and industry in Canada to manage and protect groundwater resources is limited by deficiencies in information on many aspects of the resource, and lack of governmental organization, linkages and partnerships suitable for recognizing and solving groundwater problems before they reach exceptionally difficult and expensive proportions (Morgan 1993:3)

Three broad actions are recommended to address federal deficiencies: develop a framework of partnerships within which groundwater problems can be identified and actions taken; create new

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32 An "enriched" program was envisioned that would have entailed a return to the level of hydrogeological research activities in 1980, which were twice 1990 levels (DOE 1990a:9).

33 While the draft groundwater strategy was under development, a major funding initiative for investigating and managing groundwater problems was included in an early draft of the Canada Green Plan. However, this did not survive final revisions, leaving the Green Plan without strong commitments for groundwater (Morgan 1993:1).

mechanisms for implementing programs, for groundwater inventories, management and protection, and identify priorities for federally sponsored research (Morgan 1993:3). More than 20 specific recommendations are made, among them: produce a federal groundwater strategy encompassing all pertinent federal ministries, establish an office for groundwater protection to provide education and disseminate information, negotiate federal-provincial agreements to inventory and characterize groundwater resources, develop national standards for storage, retrieval and display of groundwater information, and strengthen research capability (Morgan 1993:4-12).

In 1995 the Royal Society of Canada and the Canadian Water Resources Association, under the sponsorship of Environment Canada, held a series of regional workshops across Canada to discuss major water issues facing Canadians (Bruce and Mitchell 1995). It found widespread confusion over roles and responsibilities in the federal government for water issues, concerns about insufficient capacity in the federal system to understand and address pressing water issues, and the potential loss of institutional capacity to address major water issues (Bruce and Mitchell 1995:vi). While the topic of groundwater was not addressed exhaustively, it notes: "Groundwater has been seriously neglected in this country, both regarding its quantity and quality" (Bruce and Mitchell 1995:11).

The report expresses support for the development of national guidelines for water quality, national standards for data collection and management, maintenance of a national system of water quality and quantity data, federal public awareness programs, involvement in large inter-jurisdictional basins and coastal areas, development of public awareness programs, and increased federal capacity to analyze critical issues (Bruce and Mitchell 1995: vi - vii). It concludes that appropriate functions for the federal government related to fresh water should be: policy development, data collection and dissemination, research, information and awareness, inter-jurisdictional planning, and conflict resolution (Bruce and Mitchell 1995:6).

6.3 Provincial Groundwater Protection

6.3.1 Regulatory Framework

In practice provincial governments have assumed primary responsibility for environmental protection, including groundwater. Even in areas where the federal government has a strong mandate, such as under the federal *Fisheries Act*, responsibility for its administration has been delegated to the provinces through agreement of both jurisdictions. Provincial governments have extensive authority to manage natural resources and to protect the environment. This arises from ownership of public lands and rights in the water on those lands, authority over property and civil rights (CA s.92(13)), natural resources (CA s.92(a); s.109), and over all matters of a local or private matter (CA s.(91(10)).

In Ontario, the Ministry of Environment and Energy (MOEE) is the lead provincial agency responsible for overseeing the use and protection of groundwater. When it was created in 1972 it inherited responsibility for the supervision of groundwater resources in Ontario from its predecessor, the Ontario Water Resources Commission. The Ministry relies on general laws, regulations and policies to control sources of contaminants. The *Ontario Water Resources Act* (OWRA) and the *Environmental Protection Act* (EPA) are the two major statutes in Ontario that provide general prohibitions against the deposit of contaminants to the natural environment, including groundwater that may cause the impairment of its quality for any use that can be made of it. Emissions to air, land and water are controlled on a site-by-site basis through issuance of permits or certificates of approval. Each year the MOEE issues thousands of approvals for point sources of emissions. For example, in 1995 the MOEE issued over 7,500 approvals (MOEE 1996a). The number of approvals issued by the Ministry has increased steadily. For example, between 1993 and 1995, the years for which data is available, the number of approvals issued by the Ministry has risen by approximately 10% per year (MOEE 1996a).

In addition to the EPA and OWRA, there are other laws that govern certain activities. Table 5 lists major regulated undertakings in Ontario, the relevant statute and responsible Ministry. The major statutes are reviewed below.

6.3.1.1 *Ontario Water Resources Act*

The MOEE has the authority to regulate and control the location, drilling, construction, use and abandonment of water wells under the OWRA and a companion regulation (O. Reg.903). In addition, withdrawal groundwater is controlled through a requirement for a *permit to take water* for any proposal to take more than a total of 50,000 litres of water per day (OWRA s. 34). The requirement does not apply for taking water for household purposes, fire-fighting, or for the watering of livestock. Approximately 800 *permits to take water* are issued by the Ministry per year (MOEE 1996a). The Act provides broad discretion to an approving Director when issuing, refusing to issue, or impose terms and conditions on a water taking permit, as s/he considers proper (OWRA s.34(6). Issuance of permits are guided by a set of general objectives (MOEE 1984). Most of the rules related to water withdrawals concern problems of interference. This includes interference with prior groundwater users as well as maintenance of stream flow to protect downstream uses. Restoration of water supplies or reduced takings may be required to protect existing uses. Monitoring groundwater levels by the owner of large volume wells is often made a condition of providing a *permit to take water*.

TABLE 5 : REGULATED ACTIVITIES

Undertakings	Legislation	Ministry
Water works[1]	*Ontario Water Resources Act*	Environment and Energy
Water takings (in excess of 50,000 litres/day)	*Ontario Water Resources Act*	Environment and Energy
Drinking water supplies	*Health Promotion and Protection Act*	Ministry of Health/Local Health Units
Sewage works[2]	*Ontario Water Resources Act*	Environment and Energy
Septic systems	*Environmental Protection Act*	Environment and Energy
Waste disposal sites, waste management systems[3]	*Environmental Protection Act*	Environment and Energy
Activities that alter/destroy fish habitat	*Fisheries Act*	Natural Resources/Fisheries and Oceans Canada
Underground storage tanks	*Gasoline Handling Act*	Consumer and Commercial Relations
Pits and quarries	*Aggregate Resources Act*	Natural Resources
Brine disposal	*Petroleum Resources Act*	Natural Resources
Zoning and subdivision of land, and related development Development permit system	*Planning Act* *Niagara Escarpment Planning and Development Act*	Municipal Affairs and Housing Niagara Escarpment Commission/Natural Resources
Activities or undertakings by the Province, municipalities, or by a public body, and private undertakings designated by regulation	*Environmental Assessment Act*	Environment and Energy

[1] Water works means any works for the collection, production, treatment, storage, supply and distribution of water (OWRA 1(u).

[2] Sewage works includes works for the collection, transmission, treatment and disposal of sewage, including drainage, storm water, commercial wastes and industrial wastes (OWRA 1(r, s).

[3] Waste includes ashes, garbage, refuse, domestic waste, industrial waste, or municipal waste, or other wastes as designated by regulation (EPA 24(d).

All water works capable of supplying more than 50,000 litres per day require a *certificate of approval* from the MOEE to operate. Under section 52 (1) of the OWRA no person shall establish, alter, extend or replace new or existing water works except under and in accordance with an approval granted by a Director appointed by the Minister. The certificate stipulates what works are to be constructed, treatment levels, performance specifications, operation and maintenance schedules, and monitoring and reporting requirements. In 1995 the MOEE issued 1,322 water works approvals (MOEE 1996a). Approval is not required for water works to be used only for supplying water for agricultural, commercial or industrial purposes that is not required to be fit for human consumption, nor for water works incapable of supplying water at a rate greater than 50,000 litres per day, or for privately owned water works supplying five or fewer residences (OWRA s. 52(8).

The authority for municipal and industrial sewage works approval is contained in section 53(1) of the OWRA. It requires that no person shall establish, alter, extend or replace new or existing sewage works except under and in accordance with an approval granted by a Director appointed by the Minister. It does not apply to privately owned sewage works serving only five or fewer residences, to agricultural drains, or to sewage works that discharge to the subsurface, the latter which are subject to provisions of the EPA. In 1995 the MOEE issued 1,834 municipal waste water approvals and 325 industrial waste water approvals.

The Minister of Environment and Energy has broad legislative authority to investigate, control, and require clean up of groundwater contamination and prosecute for failure to comply. It can issue control orders to owners, requiring remedial action to alleviate the effects of impairment of water quality. Under the OWRA, the Director may by order prohibit or regulate the discharge of domestic and industrial sewage or waste into a watercourse (s.31). Where the Director determines it is in the public interest s/he can require that preventative, mitigative, or other actions be taken by an emission source which may be discharging material into water that may impair its quality (OWRA s.32).[34]

Issues of concern may be identified through routine inspections, through review of reports submitted to the Ministry, by citizen complaints, and as a result of investigations. The Ministry's Regional offices have prime responsibility for abatement and related functions. The abatement function involves developing and implementing actions to rectify an identified problem or to ensure compliance. This is achieved through abatement plans, issuance of various control documents and direction of clean-up efforts. The effectiveness of abatement and restoration measures is determined through field investigations and review of technical reports.

The assessment function involves assessing environmental conditions and determining compliance with approvals issued. This is achieved through inspections, monitoring, data collection and review and analysis. The response function involves responding to spills, complaints or other emergencies as they arise. The enforcement function involves taking legal action against persons contravening Ministry statutes, regulations or approvals. It is achieved through investigations, preparation of case reports and court appearances.

With regard to groundwater, the MOEE has a case-by-case approach to dealing with

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34 Under the EPA an appointed Director may issue a control order to the responsible party where it is determined that an emission contravenes the Act or exceeds prescribed standards (EPA s.6). A stop order may be issued it there is an immediate danger to human health, life or property (EPA s.7). A Director can issue an order requiring preventative measures and specify the equipment, facilities and procedures to be put in place to prevent or reduce the risk of discharge of a contaminant to the natural environment (EPA s.18, OWRA s.32). The Ministry also has other specific powers such as ordering the removal of waste (EPA s.43).

quality/quantity problems. Where there are groundwater quantity or quality concerns, regional and district offices of the MOEE will investigate.[35] Groundwater-related abatement activities include investigating water quality and quantity complaints, conducting waste management impact assessments, auditing annual monitoring reports, assessing the extent and magnitude of groundwater contamination from various sources, and identifying alternatives to manage contamination (Singer 1994).

The OWRA also gives authority to a Director appointed under that Act to define a public water supply area (s. 33). In an area defined as a public water supply no material of any kind that may impair the quality of water can be placed, discharged or allowed to remain, nor can actions be taken to unduly diminish the amount of water available in an area. However, it does not apply to actions or takings of water commenced before notice of the area was given. These provisions are similar to general prohibitions in the Act against discharges that may impair the natural environment.

6.3.1.2 *Environmental Protection Act*

Waste sites and systems are regulated under Part 5 of the Environmental Protection Act (EPA). It specifies that no waste management system or disposal site may be used, operated, established, altered or enlarged unless the Director under the EPA has issued a certificate of approval. The approval addresses a wide range of matters such as the types and quantities of waste acceptable at the site, site engineering, operating procedures, and monitoring.[36] It covers

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35 If septic systems are the source of complaint, the delegated authority under part 8 of the EPA will investigate.

36 Prior to issuing the requisite approvals under the EPA and OWRA, an approval may be required under the Environmental Assessment Act (see EA section below).

landfills, transfer stations, processing sites, incinerators and waste transportation systems. In 1995 the MOEE issued 1,692 waste sites and systems approvals (MOEE 1996a).

Regulation 347 of the EPA contains listings of substances and concentrations that are defined as hazardous waste. General standards for waste disposal sites and waste management systems are outlined. The regulation requires waste generators to evaluate their wastes and to register them with the MOEE if found to be hazardous or liquid industrial waste (MOE 1993). The information requirements include a description of the waste and the generating process, an estimate of the quantity generated and its major characteristics. It covers hazardous wastes discharged to on site treatment facilities, discharged into sanitary sewers, and transported to water pollution control plants or approved disposal sites. There are also certification and registration requirements for haulers of hazardous waste in Ontario.

Sewage systems discharging to the subsurface are regulated under Part 8 of the EPA and a companion regulation (O.Reg. 358/90). Administration of this regulatory function has been delegated to Local Health Units in the Province (see the municipal section below). The Province retains responsibility for legislative and regulatory amendments, issuing directives, developing guidelines, as well as providing advisory services on request.

6.3.1.3 Policies under OWRA and EPA

A wide range of policies and guidelines relate to ground water management and protection. Most have been produced by the MOEE alone or in partnership with other Ministries. Table 6 lists the major groundwater-related policies and guidelines emanating from the Provincial

TABLE 6: GROUND WATER-RELATED POLICIES AND GUIDELINES

- Water Management - Policies, Guidelines, Provincial Water Quality Objectives Of The Ministry Of Environment And Energy (MOEE: B-1-1)
- Revised Tables Of Objectives For The Ministry Of Environment And Energy's Publication "Water Management" (MOEE: B-1-2)
- Resolution Of Well Water Quality Problems Resulting From Winter Road Maintenance (MOEE: B-3)
- Drinking Water Quality - Ontario Drinking Water Objectives (MOEE: B-5)
- Incorporation Of The Reasonable Use Concept Into MOEE Ground Water Management Activities (MOEE: B-7)
- Resolution Of Ground Water Interference Problems (MOEE: B-9)
- Treatment Requirements For Municipal And Communal Water Works Using Ground Water Resources (MOEE: B-14)
- Manual Of Policy, Procedures And Guidelines For On-site Sewage Systems (MOEE).
- Individual On-site Sewage Systems: Water Quality Impact Risk Assessment (MOEE: D-5-4)
- Private Wells: Water Supply Assessment (MOEE: D-5-5)
- Guideline For Preparing Environmental Assessments: Mandated Technical And Information Requirements (MOEE).
- Fish Habitat Protection Guidelines For Developing Areas (MNR).
- Guide To Agricultural Land Use (OMAFRA & MOEE)
- Stormwater Management Practices Planning And Design Manual (MOEE)
- Guidelines On The Land Application Of Residual Sewage Sludge (OMAFRA, MOEE, MOH)

government. The Ministry of Environment and Energy has a large number of policies and guidelines which provide guidance to proponents of undertakings subject to EPA or OWRA approvals. These guidelines address a broad range of matters, such as required environmental impact information facility design information, plans and descriptions of proposed works, specifications, treatment requirements, sampling and analysis requirements, receiving water criteria and water quality objectives. Discharge limits and treatment requirements are determined on a case-by-case basis, in consultation with the applicant. Those guidelines most related to groundwater protection are reviewed below.

In 1986 the MOEE released its policy for applying the concept of reasonable use to landfill sites, ex-filtration lagoons and large subsurface sewage disposal systems (MOEE 1986a). The policy describes the basis for limiting contaminant levels in groundwater on properties adjacent to landfill sites. Decisions are made for each case individually, using three major considerations: present use, potential use and quantity and quality of groundwater available. As a general policy, human consumption is considered the most important use of water to be protected. Agricultural use and protection of aquatic life are also considerations (MOE 1984:7). Failure to achieve water quality objectives may be permitted under a number of circumstances. They may be considered unattainable because of natural background quality, because of irreversible contamination, lack of suitable treatment techniques, or where meeting the objectives would have "... substantial and widespread adverse economic or social impact" (MOE 1984:16). The reasonable use policy outlines procedures for determining acceptable levels of degradation. For example, where the designated reasonable use of groundwater is drinking water and background water quality is above Provincial Drinking Water Objectives, a reduction in quality by 25 percent of the difference between background levels and the provincial objectives is considered acceptable (MOE 1986:17). Where groundwater units contain water of naturally poor quality, have yields that are too low for practical use, or have been previously contaminated, it may be deemed to be suitable for use as a contaminant attenuation zone. In these defined zones dilution, dispersion, assimilation or other biological, physical and chemical processes are relied upon to reduce contaminant levels to acceptable levels.

Since the release of the reasonable use policy, the MOEE has produced a series of internal guidelines for hydrogeological assessments of proposed landfills. In 1992 the MOEE released a guide for applying for a certificate of approval for a waste disposal site (MOE 1992b). It provided general instructions to applicants as well as outlining information requirements and other approval requirements for specific types of waste disposal sites and facilities. However, no objectives for groundwater protection are identified.

The MOEE developed its guidelines for use of on-site sewage systems in 1982. *The Manual of Policy, Procedures and Guidelines for Private Sewage Disposal Systems* covers matters related to certificates of approval and fees, soil classification, technical data requirements, and the design, construction and operation of all classes of sewage system. Since that time the Ministry has issued periodic updates and revisions to the manual. In addition, due to increasing concern regarding increasing development in un-serviced areas, the MOEE released a set of interim planning guidelines in 1992, that address, among other matters, methods for assessing the potential groundwater impact of proposed development utilizing on-site sewage systems, and hydrogeological study requirements for proposals involving individual well water supplies.

For works with sewage effluent disposal on land that may have any impact on groundwater, a groundwater impact assessment is required. Although the requirements for such an impact assessment are determined on a site-by-site basis by the MOEE Regional office, in general the following information must be reported: expected discharge rate of contaminants to groundwater, background levels of contaminants in groundwater, estimated allowable amount of degradation based on current and potential future uses, measures taken to reduce and prevent groundwater contamination, and appropriate monitoring program to assess proposed control measures (MOE 1992c:33).

In 1992 the MOEE and OMAFRA released updated guidelines on the land application of residual sewage sludge (OMAFRA 1992). It sets out recommended application rates and other conditions relating to the spreading of sewage sludge as a soil conditioning agent. Various measures are recommended to prevent groundwater degradation, such as through minimum separation distances to wells and minimum below grade groundwater levels that are acceptable.

In 1994 the MOEE released its Stormwater Management Practices Planning and Design Manual. The issue of groundwater protection and its relationship to stormwater infiltration is discussed throughout. Related topics include technical and practical aspects of stormwater infiltration techniques as well as circumstances where this activity could potentially degrade groundwater resources.

6.3.1.4 Other Source Control Legislation

The storage, distribution, sale and use of federally registered pesticides is regulated by the MOEE under the authority of the *Pesticides Act*. It is an offense under that Act to deposit or discharge a pesticide into the environment that causes or is likely to cause impairment of the quality of the environment for any use that can be made of it. Pesticides are placed in one of 6 schedules, each of which has attached to it a requirement or an exemption for a license to apply the product. Licenses for pesticide application are issued by the MOEE.

Underground storage tanks are regulated under the *Gasoline Handling Act*, by the Ministry of Consumer and Commercial Relations. Under that Act all gasoline handling equipment, including underground storage tanks in service stations, consumer outlets, marinas and bulk storage facilities require approval from MCCR. Regulations under this Act require that all steel underground storage tanks are installed, protected against corrosion, and monitored by the owner. Further the Act, as amended in 1988 requires that any owner of an underground storage tank used for gasoline or other motor fuels provide evidence to MCCR that the tank and associated piping are adequately protected from external corrosion. Revisions to the Act and related Code (O.Reg 521) in 1993 imposed additional safety requirements on tanks installed after that date, such as double wall containment.

The operation of pits and quarries is regulated under the *Aggregate Resources Act*, by the Ministry of Natural Resources. No person may operate a pit or a quarry without first acquiring a licence to do so. A site plan must accompany the application and must include, among other matters, groundwater-related information such as the location of nearby wells and proposed depth of excavation. Potential environmental impacts must be described as well as proposed remedial measures, including possible effects on water resources. Over 2,500 pits or quarry licences are issued each year (Province of Ontario 1991). In addition, the MNR regulated deep well disposal of oilfield brine under the *Petroleum Resources Act* and a companion regulation (O.Reg. 915).[37]

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37 Deep well disposal of liquid waste other than oil field brine is regulated under the EPA and a companion regulation (O. Reg. 303).

6.3.1.5 *Fisheries Act*

The Ministry of Natural Resources administers section 35 of the *Fisheries Act* under agreement with the federal government. MNR's responsibilities include, among others, producing guidelines on protecting fish habitat, participating in fish habitat rehabilitation, laying charges under the *Fisheries Act*, and reviewing and commenting on development proposals (MNR 1994). Projects for which harmful alteration or destruction on fish habitat cannot be mitigated are referred to the federal Department of Fisheries and Oceans for authorization pursuant to section 35 of the Act (MNR 1994:20).

Until recently the MNR has actively reviewed development projects likely to affect fish habitat through its participation in land use planning. Since 1988 the MNR have been requesting that stormwater management for proposed developments address the protection and maintenance of base flows, in keeping with their responsibilities under the *Fisheries Act*.

Under its *Strategic Plan for Ontario Fisheries*, the goal of the Ministry of Natural Resources is to protect healthy aquatic ecosystems, rehabilitate degraded systems and improve benefits from fisheries (MNR 1994:22). In 1994 the MNR released a document entitled Fish Habitat Protection Guidelines for Developing Areas (MNR 1994). The habitat protection guideline identifies potential impacts on fish habitat from changes to groundwater conditions and base flows associated with development activities (MNR 1994:9-10). Also the guideline outlines general standards and guidelines for proposed groundwater extraction activities so as to protect fish habitat. For example it discusses, briefly, potential changes to base flows, recharge and discharge volumes, seasonal fluctuations and groundwater temperatures (MNR 1994:51-53).

Additional work is needed to better define the relationship between groundwater and fish habitat, and to articulate planning and design criteria (cf. Blackport et al. 1995, Imhof et al. nd).

6.3.1.6 *Environmental Assessment Act*

Most public infrastructure projects in Ontario are subject to review and approval under the *Environmental Assessment Act (EA Act)*. These include undertakings such as public roads and highways, transit facilities, sewage and water works, electrical generation and transmission facilities and flood protection works (MOEE 1994a). Unless otherwise designated, most private sector undertakings are not subject to the Act; most large private sector landfill proposals have been designated.

Under the EA Act, proponents are required to prepare a document describing the proposed undertaking and its purpose as well as the following: different methods of carrying out the undertaking, alternatives to the undertaking, likely environmental effects, ways to mitigate negative environmental effects, and the advantages and disadvantages of the proposed undertaking and its alternatives (EAA s. 5(3)).

The environmental assessment documents are circulated for comment to various government ministries and agencies, municipalities, First Nations and the general public. Technical deficiencies are highlighted through the review process, after which time a public comment period is provided. Projects may be approved by the Minister of Environment and Energy or referred to the Environmental Assessment Board for a hearing and approval.

In 1994 the MOEE outlined its technical and information requirements for environmental assessments (MOEE 1994b). The guideline recommends that water-related matters be considered within the context of watershed management plans and goals, existing and committed land and water uses, surface water and hydrogeological conditions. Where an undertaking may impact groundwater, hydrogeological investigations are recommended. The studies are to define subsurface conditions in sufficient detail to enable prediction of main contaminant migration pathways, potential receptors, future boundary impacts, and expected contaminant attenuation capacities (MOEE 1994b:9).

6.3.1.7 *Niagara Escarpment Planning and Development Act*

The Niagara Escarpment Planning and Development Act was adopted in 1973 to protect the Niagara Escarpment as a continuous natural environment, and to ensure that development be compatible with this primary goal. The purpose and objectives have been translated into a planning and regulatory framework known as the Niagara Escarpment Plan, which covers 1,830 square kilometres and 37 local municipalities. The Niagara Escarpment Plan includes 7 land use designations, from Escarpment Protection to Urban Centre and Mineral Resource Aggregate Extraction Areas. It also includes a system of parks and open spaces. For each land use designation in the Plan there are criteria for designation, objectives, permitted uses, new lots policies, and development criteria that define how a permitted use should be carried out. The criteria establish performance standards for permitted uses, and are the basis on which the Niagara Escarpment Commission administers a system of development permits.[38]

The Plan includes policies to protect water resources. It contains development criteria to protect water quality and quantity, including groundwater resources. The criteria address matters such

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38 The development permit system replaces zoning as a means of regulating land uses.

as set-backs from water courses and wetlands, alteration of natural grade and drainage, sediment and erosion control, water takings, wetlands, and fisheries (ss. 2.6.1 - 2.6.26). Two general criteria allow permitted uses, subject to the following:

> The long term capacity of the site can support the use without a substantial negative impact on Escarpment environmental features such as contours, water quality, water quantity, natural vegetation, soil, wildlife, populations, visual attractiveness and cultural heritage features (ss. 2.2.1a), and
>
> The cumulative impact of development will not have serious detrimental effects on the Escarpment environment... (ss. 2.2.1b)

A cumulative effects monitoring framework for Niagara Escarpment Plan also has been developed that is based explicitly on an ecosystem approach. It is designed to monitor a suite of indicators of land use stress and ecosystem response, in the context of the objectives of the Niagara Escarpment Planning and Development Act (Whitelaw, Neufeld and Carty 1995).

6.3.1.8 *Planning Act*

The *Planning Act* is the primary statute governing the use and subdivision of lands, other than Crown land, in Ontario. In response to growing concerns that the land use planning process was not adequately addressing environmental matters, and concerns about the efficiency and effectiveness of the process, the provincial government appointed a Commission on Planning and Development Reform in 1991.[39] As a result of this inquiry, the Province made substantial revisions to the *Planning Act* and its administration. In 1995 a purpose section was added to the Planning Act:

- to promote sustainable economic development in a healthy natural environment;

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39 The Commission described the potential impact of septic systems on groundwater and public health as being of "sleeping giant" proportions (Commission on Planning 1991).

- provide for a land use planning system led by provincial policy;
- to integrate matters of provincial interest in provincial and municipal planning decisions;
- to provide for planning processes that are fair by making them open, accessible, timely and efficient;
- to encourage cooperation and coordination among various interests;
- to recognize the decision making authority and accountability of municipal councils in planning. (PA s. 1(1)).

The Act enumerates matters of provincial interest, for example: the protection of ecological systems including natural areas, features and functions, the supply, efficient use and conservation of energy and water, adequate provision and efficient use of sewage and water services and waste management systems, and protection of public health and safety (PA s.2(a, e, f, o)). Matters of provincial interest are described in Provincial policy statements released by the Minister of Municipal Affairs and Housing (PA s.3(1)). In January 1995 a comprehensive set of policy statements was released by the Province (MMA 1994). It incorporated four previous policy statements (mineral aggregates, floodplains, housing, and wetlands) as well as policies in additional areas, including water. The water policy stated:

> Development may be permitted only if the quantity and quality of groundwater and surface water are protected. Development that will impact on groundwater recharge areas, head-waters and aquifers which have been identified as sensitive areas will not be permitted. (MMA 1994:1)

Following a change in government, the Ministry of Municipal Affairs and Housing released a revised and shortened statement intended to "re-balance" the emphasis away from environmental issues towards economic development priorities. As noted by Longo and Williams (1996:18): "These [1994] policy statements and the accompanying implementation guidelines were perceived as creating a restrictive, centralized, and prohibitive land use system that was unduly slanted toward environmental protection". The revised water policy states:

> The quality and quantity of groundwater and surface water and the function of sensitive

> groundwater recharge/ discharge areas, aquifers and headwaters will be maintained or enhanced. (MMAH 1995).

The news release accompanying the revised policy statement emphasized "... giving municipalities increased flexibility to make local planning decisions that reflect local needs ..." (MMAH 1996a). Amendments to the Planning Act in 1996 replaced the requirement that municipal decisions *be consistent with* provincial policy statements, with the requirement that municipalities *have regard for* provincial policy.

The two traditional Provincial roles in municipal land use planning, namely policy review and approval functions, have been significantly diminished over time. Provincial approval of local official plans has been delegated to regional governments with approved official plans since the mid-1970's. Since that time, the authority to approve severances and plans of subdivision has been delegated to regional municipalities, certain counties, and cities separated from county government The 1995 *Planning Act* formally assigned Regional Councils approval authority over local official plans (PA s. 17(2). The 1995 *Planning Act* also gave Regional Councils and separated cities approval authority over plans of subdivision (PA s.51(5), s.51(6).

The exempting provisions of the 1996 *Planning Act* provide the authority to remove the upper tier policy review function completely. The provisions give the Minister and delegated approval authorities, the ability to exempt local official plans and plan amendments from their review and approval, following adoption by a local municipal council (PAS 17(9, 10). Approval authority for plans of subdivision can also be delegated to a local municipality (PA 51.2(2,3). The Province is seeking to remove itself entirely from the approval process by 1998 and will negotiate exemptions for local official plans and amendments with all upper tier municipalities

(MMAH 1996b).[40]

Under the 1996 *Planning Act* all ministries, except the Ministry of Municipal Affairs and Housing, are specifically excluded from the notice and circulation provisions. Prior to 1996, municipalities were required by regulation to circulate proposed planning policies and development approvals to provincial Ministries, such as the Ministry of the Environment and Energy (MOEE) and the Ministry of Natural Resources (MNR) for their comments. As noted by Longo and Williams (1996:18): "Now, not only the process, but substantive decision making and policy formulation, is (sic) transferred to municipalities." Municipal Affairs and Housing may circulate planning documents to other ministries at its discretion and has the right to appeal a municipal decision to the Ontario Municipal Board (OMB). However, the right of the Province to declare a provincial interest in planning matters appealed to the Board has been removed. This means that Cabinet cannot review or overturn a planning decision rendered by the OMB.[41]

6.3.2 Non-regulatory Measures

A range of non-regulatory instruments may be used to influence activities that impair groundwater. The following are described in this section: water quality objectives, policies for un-regulated contaminant sources, financial measures, information and mapping, watershed planning, land stewardship, and pollution prevention.

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40 It is also noteworthy that the provision in the Planning Act of 1995 allowing the Province to prescribe the content of official plans by Provincial regulation was deleted from the Act in 1996.

41 Appeals to Cabinet are permitted for decisions rendered by Joint Boards under the *Consolidated Hearings Act*, where more than one provincial statute come into play.

6.3.2.1 Water Quality Objectives

The MOEE has the authority to make regulations for prescribing standards of quality for potable and other water supplies under the OWRA (s.75). However, to date it has relied on non-statutory guidelines.[42] In 1964 the Ontario Water Resources Commission released its first set of drinking water objectives. Since that time the MOEE has released a succession of expanded and revised Ontario Drinking Water Objectives, most recently in 1992 (MOE 1992a). There are three types of objectives: maximum acceptable concentrations (MAC), interim maximum acceptable concentrations (IMAC), and aesthetic objectives (AO). MACs are identified for a set of health-related parameters while IMAC are health-related objectives for which there is insufficient toxicological data to establish MAC with certainty. Aesthetic objectives are identified for major substances that may impair the taste, smell or colour of water. The presence of contaminants in excess of the specified level is considered grounds for rejecting the water unless effective treatment is provided. Ontario Drinking Water Objectives form the basis for establishing treatment levels required for water supplies serving more than five private residences or large users of water.

Water quality objectives also have been defined for the protection of aquatic life and

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[42] In 1986 the MOEE initiated a process to develop regulations covering monitoring and waste water discharge limits for nine industrial sectors and municipal sewage treatment plants. The goal of the Municipal-Industrial Strategy for Abatement (MISA) program is the virtual elimination of discharges of toxic contaminants to waterways. Monitoring regulations mandate self-monitoring activities and reporting requirements. Regulations will require discharges to meet specified effluent quality limits for selected contaminants. Performance levels are prescribed in terms of pollutant loadings as well as concentration limits. In addition, sources will be required to demonstrate compliance by monitoring effluent and reporting the results to the MOEE. Regulations have been prepared for the industrial sectors but not the municipal sector (MOEE 1994).

recreational uses as well as for agricultural use (MOE 1984). The objectives do not take into account the synergistic effects of multiple contaminants nor additional stresses such as temperature variation. Thus water containing concentrations of contaminants at or near the specified objectives may not protect aquatic life (MOEE 1984:11). Certain substances (e.g. mercury, polychlorinated biphenyls) which bio-accumulate in organisms have been given "zero tolerance" limits. This designation indicates that new releases of the substance should be prohibited and existing releases reduced "...to the lowest practicable levels" (MOE 1984:21). There are also a large number of substances with undefined tolerance limits. These are substances which have inadequate scientific data for defining an objective. The Ministry of Environment and Energy is considering adoption of a precautionary approach when developing new standards and making site-specific decisions: “Especially when there is uncertainty about the risk presented by a particular pollutant or classes of pollutants, the Ministry will exercise caution in favour of the environment” (MOEE 1996c:2).

In 1978, the MOEE published a booklet entitled: "Water Management: Goals, Policies, Objectives and Implementation Procedures of the Ministry of the Environment". The booklet replaced an earlier publication of the Ontario Water Resources Commission entitled "Policy Guidelines for Water Quality Control in the Province of Ontario" (1970). While the earlier guideline concerned itself almost exclusively with surface water quality management, the 1978 publication described goals and procedures for protecting groundwater quality and quantity in the Province. The two stated goals for groundwater are to protect it for the greatest number of beneficial uses, and to ensure fair sharing and conservation of groundwater (MOE 1984a:7, 9). Its general policy is that degradation of groundwater quality on property adjacent to sources of contaminants be controlled to protect existing and potential "reasonable uses" of water (Ontario Ministry of the Environment 1984:8). Where such measures are not "practicable" the MOEE may require replacement of the affected supplies.

6.3.2.2 Policies for Un-Regulated Sources

Policies and guidelines have been developed for a range of activities that are not regulated by statute. For example, the use of deicing salts on highways and salt storage are not regulated activities. Salt is specifically exempted as a contaminant under the EPA when used for deicing purposes on a highway by any road authority. In 1984 the MOEE issued two policies related to application of road salt. Its guideline on snow disposal and deicing operations encourages reductions in application rates, adoption of special protection measures in proximity to salt-sensitive areas, and permanent storage structures. The policy on resolving well water quality problems from winter road maintenance defines cost-sharing arrangements between the MOEE and a road authority for reimbursing homeowners whose well supplies need restoration due to the impacts of road deicing activities. Under the guideline, any homeowner whose well supply requires restoration as a result of winter road maintenance is eligible for reimbursement by the MOEE of 75% of allowable costs, with the potential to collect the remaining 25% from the participating road authority.

In 1986 the MOEE released a policy on resolving groundwater quality interference problems caused by unregulated activities (MOE 1986a). This policy outlines the position of the MOEE with regard to remediation, restoration or replacement of groundwater supplies where significant deterioration of quality has occurred from unregulated activities. Decisions on remedial action and level of clean-up required are determined on a case-by-case basis by the MOEE. A number of mechanisms are available to ensure action is taken, including voluntary actions as well as use of Ministerial orders requiring clean-up (see Remediation section below).

An approach based on a comparison of benefits and costs is recommended for determining the extent and degree of clean up or restoration required by the MOEE.

The disposal of animal wastes when undertaken in accordance with "normal farming practice" is exempted from the provisions of the *Environmental Protection Act.* Cooperation between the MOEE and the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) to address farm pollution issues was initiated with the release of the Agricultural Code of Practice in 1976. The code provided guidance on recommended farming practice in a number of areas, including: recommended manure storage methods and land application rates, as well as minimum separation distances between livestock operations and sensitive land uses. In 1995 the Code of Practice was replaced by the Guide to Agricultural Land Use. It contains general references to protecting water quality from land application of fertilizers and pesticides and wastewater disposal. However it does not provide any additional guidance beyond that contained in the earlier Code.

In 1988 the OMAFRA and the MOEE released the Protocols for Handling Farm Pollution Incidents (OMAF 1988). It is intended to provide a consistent set of procedures for staff of both ministries when responding to complaints or other problems related to farm pollution. Guidance is provided in a number of areas, including a protocol for handling well water quality incidents. Where the water is suspected of being a chemical or aesthetic problem, the MOEE is the lead agency.[43] Where the source of contamination is off-site the MOEE will recommend remedial action. A temporary water supply may be provided the owner, consistent with the MOEE guidelines for the resolution of groundwater quality interference problems. A related initiative

43 Where a quality problem is suspected of being bacterial in origin, the local Health Unit is the lead agency for addressing the problem.

is the Certificate of Compliance Program. This is a voluntary mechanism intended to ensure environmentally acceptable farm practice. In some cases a Certificate of Compliance is recommended by municipal by-law or is sometimes made a condition of lending institutions (OMAF 1988:5.1) Where OMAFRA and the MOEE concur that a Certificate should be issued, MOEE will process and issue a certificate (OMAF 1988:5.3).

6.3.2.3 Economic Measures

In 1985 the EPA was amended to require that uncontrolled releases or spills of contaminants to the natural environment be reported to the MOEE and the municipality in which it occurred. In addition the owner or person in control of the pollutant must "do everything practicable" to prevent, eliminate or mitigate potential adverse effects to the natural environment. Persons undertaking clean-up of spills are entitled to compensation from the Province (EPA, Part 10). It is Ministry policy that groundwater supplies are to be restored or replaced where significant deterioration has occurred from the release of contaminants (Ontario Ministry of the Environment 1986b, revised 1993). However, often it has not been possible to identify the responsible party to undertake clean-up activities. In response, the MOEE initiated various cleanup programs.

In 1985 the MOEE set up the Environmental Compensation Corporation under Part 10 of the EPA, to help victim of spills get compensation for damages suffered for loss or damage related to spills of pollutants. The Compensation Corporation is a payer of last resort that provides compensation to those who suffered unrecoverable losses as a result of a spill.[44] In the past it

44 Application for compensation to the ECC is made in approximately 1 in 9 spills and approximately 1 in 13 receive compensation from the ECC (Fischer, pers. comm.).

has compensated victims of spills that have contaminated individual wells. For example, in 1994-95, there were three cases in which the corporation paid for the cost of a new well or installation of water treatment for individual wells (ECC 1995). Compensation ranged from $5,000 to $8,000.

The Security Account was also established in 1985 to enable the Ministry to act quickly to resolve serious or urgent environmental problems. Funds are to be made available if a responsible party cannot be identified, or where other measures such as control orders have not met with the necessary response. Funds are directed toward projects involving remedial measures to protect against environmental damage and reduce risks to public health or safety. Over a ten year period, between 1985 and 1995, total expenditures from the security account on groundwater investigations and projects totalled over $78 million. Three projects accounted for 75 percent of total expenditures: PCB cleanup in the village of Smithville ($38.788 million), NDMA cleanup in Waterloo Region ($13.072 million), and the Hagersville tire storage fire ($6.944 million).

.The Province has invested large sums of money to help municipalities secure drinking water supplies and to treat and dispose of domestic sewage. Since 1969 the Province has provided billions of dollars of direct financial assistance to municipalities for sewage and water works. Under the current Municipal Assistance Program, base funding of fifteen percent of project costs are provided to municipalities in the form of a grant. Additional grants are provided to small municipalities, ranging from a low of 2.5% of project costs for communities with a population of 175,000, to 70% of project costs for communities with a population of 1,000 (OCWA 1994). Between 1990 and 1995 the MOEE invested $1.4 billion in construction and upgrading water and sewage infrastructure (MOEE 1995a).[45] A significant portion of this has been directed to municipalities with malfunctioning septics and/or impaired groundwater.[46] A recent example is the Town of Caledon. In 1988 a settlement area study was undertaken to examine potential growth in Caledon East. In reviewing the study, the Region of Peel retained a consultant to examine the feasibility of servicing the projected doubling of the population with a communal water supply and individual on-site sewage disposal. The consultant was also asked to investigate the cause of elevated nitrate concentrations in the existing water supply. The report identified septic systems as the primary source of elevated nitrate levels and predicted increasing levels of contamination from existing systems, as well as additional degradation down gradient of the proposed development (GEO-Environ 1988). It concluded that it would be necessary to replace the existing water supply or treat it. Subsequently the decision was made to extend sanitary sewers to service fewer than 1,000 homes, at a cost of over $16 million. The MOEE paid 80 percent of the project costs.

In 1997 the Province announced that responsibility for financing and operating water and sewage services is solely a municipal responsibility. At the same time, however, it announced provincial grants of a further $200 million to assist municipalities in addressing immediate

45 Between 1956 and 1993 the Ministry of Environment and Energy, and its predecessor, built and operated hundreds of sewer and water works in the Province, under authority of the OWRA. In 1993 the Ministry's operational responsibilities for sewer and water works were transferred to the Ontario Clean Water Agency. The mandate of the new agency was finance, build and operate water and sewage works and services on behalf of Ontario on a cost recovery basis. In addition its mandate included assisting municipalities to provide water and sewage works and services on a cost recovery basis by financing, planning, developing, building and operating such works and services. The Agency was also intended to find alternative sources of funding for water and sewage infrastructure particularly through private public partnerships. It took over ownership and operation of the water and sewer works in the Province that were previously owned or operated by the Ministry of the Environment and Energy. By 1995 OCWA owned and/or operated a total of 402 sewer and water facilities (Sanders 1996). Under the recently adopted Bill 107, all of these facilities will be transferred to municipal ownership.

46 Already in 1969, when the Ontario Water Resources Commission first announced its policy of granting financial assistance to small municipalities not able to carry the sewage and water charges to repay full costs of projects, the typical project identified was "... septic tanks not working, sewage in ditches, 1,000 people affected" (OWRC 1969).

public health and environmental concerns associated with their infrastructure. A portion of these grants will likely be directed to replace contaminated groundwater supplies with other sources of drinking water.

Another economic tool is tax rebates, which have provided an economic incentive to protect certain environmental lands in Ontario since 1987. In that year the Provincial government introduced the Conservation Land Tax Reduction Program. Under the program the province re-imburses 100% of local property taxes paid on eligible conservation lands. Eligible lands include: provincially significant wetlands, Areas of Natural and Scientific Interest (MNR), Escarpment Natural Areas in the Niagara Escarpment Plan, and certain conservation lands owned by non-profit organizations. Under proposed changes to the *Assessment Act*, this program will be replaced by directly exempting eligible lands from paying any local property tax (MNR 1997). The government is proposing to add the habitat of endangered species as an eligible criterion. It is not clear whether lands with conservation easements, or areas considered critical to protect groundwater systems would be eligible.

6.3.2.4 Information and Mapping

In addition to direct financial assistance, the MOEE, has provided various forms of technical assistance to help municipalities find and exploit usable groundwater resources for purposes of public water supply. Most of the groundwater information and mapping activities undertaken by the MOEE since its creation in 1972 were begun by the Ontario Water Resources Commission in its drive to identify new municipal groundwater supplies. As noted by the Commission in an early publication: "The [Groundwater] Branch is continually collecting groundwater and related geological data, in order to keep a constant watch on available supply"

(OWRC ndB). The Commission conducted municipal groundwater surveys to evaluate groundwater conditions for municipal water supply purposes (10 -32 per year), municipal test drilling to locate suitable water supplies (10 -55 per year), drainage basin surveys examining the availability and quality of water resources, hydrologic and hydrogeologic processes (1-10 per year), regional studies to assess the availability of groundwater and surface water resources, and special investigations of existing or potential groundwater pollution and water supply or interference problems (>250 per year) (OWRC 1972: 65-6).

Between 1969 and 1982 drainage basin reports were published for 23 watersheds in its "Water Resources Reports" series (Singer 1992). These provide detailed information on the water resources of various watersheds, including groundwater-related information such as geology, depth to bedrock, groundwater potential and chemistry. In addition the ministry produced maps illustrating the potential availability of usable groundwater in its "Groundwater Probability Map Series". Between 1969 and 1986, groundwater probability maps were produced covering 11 counties and two regional municipalities in southwestern and central Ontario (MacRitchie et al. 1994:68). These maps show probable yield of the most commonly used aquifers, depth to water-bearing formations, and groundwater quality at selected locations within the counties (OWRC 1972:73).

Between 1973 and 1978 the "Major Aquifers in Ontario" map series was produced. These 8 maps describe major aquifers in most of central and eastern Ontario in terms of their areal extent, depth to water table, geology and anticipated yields. Between 1979 and 1986 the MOEE prepared groundwater susceptibility maps for 24 areas in southwestern Ontario. These maps indicate, in a general way, the relative susceptibility of groundwater to contamination using a high-low rating system. The four major factors used to characterize susceptibility included permeability of near surface materials, groundwater movement, presence of major shallow aquifers, and use of groundwater (MOEE 1986a).

The Ontario Water Resources Commission established a network of some 229 observation wells across Ontario to monitor groundwater levels (OWRC 1972). Since 1984 responsibility for continuing to maintain the network was left to the ministry's regional offices. All but two discontinued the program (MacRitchie et al. 1994).There is no program to monitor ambient groundwater quality across the province. Approximately one-quarter of municipal drinking water supplies are monitored by the MOEE under its Drinking Water Surveillance program. In 1993 for example, 22 of the approximately 271 municipal supplies fed by groundwater were monitored for over 180 parameters (MacRitchie 1994:67). To date, the costs for analysis and for the database have been covered entirely by the Ministry. It is unlikely that the Ministry will continue routine monitoring and analysis at these levels. Municipalities may be required to monitor their water supplies under the conditions of their certificate of approval. In addition, Local Health Units monitor communal water supplies for public institutions, such as schools, that obtain groundwater from non-municipal wells.

For the past fifty years, well drillers have been required under the OWRA to submit to the MOEE and the well owner, a water well record for every new well that is drilled in the Province of Ontario. The MOEE provides a prescribed form that must be completed for each new well. The record provides information on such things as the location of the well, type of well, pump test results, recommended pumping rate, a general description of geology and intended use. No detailed information on water quality is provided. Only a general indication of water quality is provided (e.g. fresh, mineralized).

The MOEE has always assumed responsibility for plotting the location coordinates of new wells and encoding water well records. Water Resources Bulletins were published periodically in the 1970's and 1980's. By 1972 159,941 water well records were contained in an electronic data processing and storage system (OWRC 1972:64). Until 1984, the water well records were added to a computerized data base containing over 450,000 water well records (Yee, pers. comm.). Since that time, there has been a growing backlog of well records. Many of the 14,000 to 22,000 new well records received annually by the MOEE have not been entered into the data base.

Under the authority of the OWRA, the MOEE may examine any surface waters or groundwater in Ontario from time to time to determine if any pollution exists and its causes (OWRA 15(2). In addition the Ministry has the authority, under the *Environmental Protection Act*, to survey from time to time any potential source of contamination (EPA s.126). The MOEE does not have an ongoing program for groundwater characterization and mapping. Information on groundwater conditions is collected on a site-by-site basis where hydrogeology reports are required by the MOEE (Singer 1992). This may be in connection with approvals sought under various Acts. Special purpose groundwater monitoring is undertaken, or otherwise required, by the Ministry in areas where leachate from a waste site is suspected; around industrial (or agricultural) sources where violations are suspected and where impacts from farming activities are suspected. For example, special purpose monitoring has been conducted by the MOEE in targeted areas of the province where concerns exist about potential groundwater degradation by pesticide and fertilizer use (Soo Chan and Scafe 1992).

The MOEE collects information on soil and groundwater conditions in response to public complaints or where problems are suspected. Some regional offices of the Ministry have developed data bases to track complaints, investigations and approvals related to groundwater.

In addition the Ministry has inventories of some potential sources of groundwater contamination. This includes active and closed municipal landfills in the province, PCB storage sites, and old coal gasification sites.

6.3.2.5 Watershed Planning

Since their creation pursuant to the *Conservation Authorities Act* of 1946, Conservation Authorities have promoted voluntary management of water resources on a watershed basis.[47] Under that Act, Conservation Authorities have the power to study and investigate the watershed and to determine a program whereby the natural resources of the watershed may be conserved, restored, developed, and managed (s.21(a). Although not a legislated process, watershed studies and plans have provided the basis for ongoing programs of Conservation Authorities as well as providing a larger bio-regional context for land use planning. Between 1990 and 1995 87 watershed studies were initiated. Most of these studies were initiated in southern watersheds to address urban development pressures and, secondarily, to address resource protection and remediation objectives (MOEE 1997:5-6).

Some of the first watershed studies were narrowly focussed on issues of flood and erosion control and drainage. In the last decade the scope of these has studies has expanded significantly to include a broader range of resource and environmental issues, including: retention of natural watercourses, maintenance of riparian vegetation, enhanced stormwater infiltration, prevention of soil erosion, water conservation, designation of environmentally sensitive areas and consideration of cumulative impacts. Enhancement and restoration of aquatic environments is also promoted through remediation and redevelopment opportunities. In addition, linkages

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47 A watershed is defined as, "... an area drained by a river and its tributaries" (CAA s.1).

between land and water, between water quality and water quantity, and between surface and groundwater have been examined more closely (MOEE et al. 1997:3).

Whereas in the 1980's the Province played a lead role in watershed studies, its participation and support has diminished since that time. Until recently, the Province provided financial support for watershed planning through transfer payments to Conservation Authorities. In 1993 the MOEE and MNR launched a watershed promotion through the release of a series of guidance documents on watershed planning, and by funding a series of pilot projects (MOEE 1993a). A central goal was clarifying the relationship between watershed study processes and municipal planning processes. For example, one guideline assists municipalities in developing official plan policies which incorporate the goals and objectives developed through watershed. It outlines general and specific water-related policies relevant to municipal official plans studies (MOEE 1993b). Three years later, the MNR issued a news release commemorating the 50th anniversary of the *Conservation Authorities Act*, where it committed to continue to work with conservation authorities and municipalities, " ... to further define their roles and to achieve efficient service delivery, while ensuring that Ontario's tradition of watershed-based resource management is maintained and strengthened in the years to come" (MNR 1996). At the same time the Province decided to terminate all transfer payments to Conservation Authorities, starting in 1997 (MNR 1996).

6.3.2.6 Land Stewardship

Various non-regulatory instruments have been used in Ontario to influence land use activities for environmental reasons (Moull and Norris 1995). One instrument is a conservation easement. These easements represent a binding agreement, voluntarily entered into between a landowner and an authorized organization, to restrict uses or activities that might jeopardize identified conservation objectives. They can be used to protect historic buildings, open space, recreational uses, agricultural uses, to protect wildlife or other natural heritage values. The conditions of an agreement are flexible and specific to the terms agreed to by the land owner and holder of the easement. It can include agreement to limit or preclude certain activities (e.g. housing) or positive measures that promote certain activities (e.g. tree planting). Once entered into, a conservation easement is registered on land title and binding on current and subsequent land owners.

Until a few years ago, the ability to hold a conservation easement in Ontario was restricted to the Crown and its agencies. Since the early 1970s the Ontario Heritage Foundation has been empowered to hold conservation easements, pursuant to the *Ontario Heritage Act*. Most of the conservation easements held by the Foundation relate to historic buildings (Smith et al. 1992:3). It holds approximately one dozen easements for natural heritage purposes. Under amendments to the *Conservation Land Act* in 1995, municipalities, conservation authorities and non-profit organizations are authorized to hold conservation easements for the purpose of "conservation, maintenance, restoration or enhancement" of land or wildlife (s.3(2)). No more than a handful of conservation easements are held by non-government organizations in Ontario, and there is no record of their application to protect groundwater functions.

Many groups in Ontario, including conservation authorities, non-profit organizations, and the Ministry of Natural Resources have programs that promote private land stewardship through education and awareness raising activities, land owner contact programs and recognition programs. A recent survey concludes that over 125 actor groups are active in this area (Nolan et al. 1994). Land stewardship agreements are verbal or written agreements between a landowner and a third party to respect identified environmental values of privately held land. These are non-binding, but often include agreement to forewarn of future changes to management practice or decisions to sell a certain property (Moull and Norris 1995:59).

There are more than a dozen "land trusts" in Ontario, which are non-profit organizations set up specifically for the purpose of saving or managing land to protect ecological, agricultural or other social values (Hilts 1995).[48] They may seek to conserve land through fee simple ownership of special areas by purchase or donation, as well as through conservation easements. As noted by Hilts (1992), land trusts can be applied to many different priorities:

> Interests of land trust groups run the gamut from protecting farmland and farm communities, through conservation of wetlands, forests, ecological sites, and scenic areas, to provision of affordable housing. (Hilts 1992:12)

There are few programs that promote land stewardship for protecting groundwater resources. One example comes from the work of the Ontario Farm Environmental Coalition, consisting of representatives from four major farm organizations. A key activity of the coalition is promoting adoption of Environmental Farm Plans, which identify potential pollution problems on individual farms and action plans to address them (Nolan et al. 1994). One element of the farm plan relates to minimizing risks of contaminating well water through proper storage and handling of pesticides.[49] In 1994 the Ontario Soil and Crop Improvement Association initiated a 4-year *Well Steward Project*. The purpose of the project is to heighten awareness, offer

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48 One example of such an organization is the Muskoka Heritage Foundation has operated a land stewardship program since 1991 (Carlysle 1995). It provides information, advocacy and assistance to landowners to develop conservation plans and enhance natural ecological values on their property.

49 Agriculture Canada provides modest financial incentives in support of these plans (Blackie 1996).

education and demonstrate methods for protecting farm wells (OSCIA 1995). It targets older farm wells highly susceptible to groundwater contamination.[50] Simple techniques are recommended to upgrade existing wells and reduce risk of groundwater contamination, including plugging abandoned wells and upgrading dug and drilled wells.

6.3.2.7 Pollution Prevention

The MOEE established an office of pollution prevention in 1992 to promote voluntary implementation of pollution prevention with industrial, commercial, community and government sectors. In 1994 the MOEE signed partnership agreements to reduce the use, generation and release of toxic substances with 9 industry sectors.[51] Four products arising from these partnership agreements include: a pollution prevention planning model designed for each participating sector, internalizing prevention and conservation in the business planning and operating system, developing and implementing prevention plans for participating facilities, and reducing or eliminating the use, creation and release of targeted hazardous substances and wastes (MOEE 1994c:5).

The MOEE also has a recognition program for industry-led pollution prevention actions. As of December 1994, 65 facilities were enrolled in this pollution prevention pledge program (MOEE 1994c). In addition the ministry is involved in various education and training programs for

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50 These farms were identified in the Ontario Farm Groundwater Quality Survey (1991-92).

51 The sectors include industries and associations associated with motor vehicle manufacturing, metal finishing, automobile parts manufacturing, organic and inorganic chemical producers, printing and graphic arts, industrial laundries, food processing, photo-finishing mini-labs and major fast food restaurants (MOEE 1994a). A voluntary agreement also was signed with the Regional Municipality of Hamilton-Wentworth in 1993 to develop and implement a pollution prevention plan (MOEE 1994c:6).

various industry sectors as well as for government agencies and the public. These actions may have indirect benefits to groundwater through reducing release of hazardous substances and need for ultimate disposal. However, pollution prevention has not been incorporated into the Ministry's groundwater activities.

6.3.3 Toward a Provincial Groundwater Strategy

In 1990 the MOEE began a concerted effort to develop a provincial groundwater management and protection strategy. The importance of groundwater as a source of drinking water, growing demand for groundwater and increased development outside municipally serviced areas prompted Ministry concern about measures to protect groundwater quality and meet demands for secure water supplies. Other persistent concerns related to groundwater susceptibility to contamination from diverse point and non-point sources, the expense and difficulty of remediation, and groundwater interference problems in some areas of the province.

In July 1990 a MOEE working group completed a discussion paper on groundwater (GWG 1990). It identified a broad range of potential threats to groundwater quality. Some of the issues related to protecting groundwater quality included: septic systems, defining upper treatability limits for groundwater supplying rural development, site decommissioning and groundwater, groundwater protection from agriculture and transportation activities, and wellhead and aquifer protection (GWG 1990:12). Some of the general quantity issues included: implementing the well inspections program, the growing backlog of water well records, the "first come first served" approach to groundwater allocation, the need for policies for un-addressed issues such as flowing wells, addressing potential interference of drinking water wells from competing land uses, such as industry or quarry operations, and the use of predictive tools to evaluate groundwater-land use interactions (GWG 1990:4,11).

The working group also identified a number of ongoing organizational issues related to groundwater management and protection. This included the potential benefits of a central groundwater group to: focus expertise, coordinate policy development and advice to clients, and the need for improved delivery of MOEE's groundwater responsibilities, including: eliminating regional disparities in program implementation, separating resource assessment from regulatory responsibilities, and tailoring priorities to match available resources. In terms of relations with other agencies it included the need to clarify roles and responsibilities of other agencies and stakeholders with an interest in groundwater, improved communication with agencies having competing interests in groundwater, establishing a framework within which local and regional governments can manage and protect groundwater resources, forming partnerships with other agencies, stakeholders and jurisdictions on groundwater protection, and integrating a Ministry management and protection strategy with related activities and programs of other agencies and jurisdictions (GWG 1990:4).Some of the technical issues identified included the need to incorporate new technical knowledge into legislation and regulations of the ministry, assessing groundwater surface water interactions, and developing programs that manage and protect both groundwater and surface water (GWG 1990:5).

In general terms the working group outlined a possible strategy to manage and protect groundwater. The first component of the proposal was resource assessment. This included describing groundwater resources (quality, quantity, use), identifying threats to groundwater, and developing an integrated data base (GWG 1990:7). The second component was the development of a protection policy framework that would define the provincial approach, outline criteria to assess groundwater, and identify levels of protection to be afforded individual groundwater basins. The third component was the development of an enhanced regulatory framework with a set of new and up-dated protection tools to achieve management and protection goals. Some specific actions recommended included extending the Drinking Water Surveillance Program to all municipal groundwater supplies, inventorying contamination sources in critical areas of the province, developing a self-financing system to manage water well records, and establishing an accessible Groundwater Information System that integrated existing and new groundwater-related information (G.G. 1990:7-12).

In August 1990 the Provincial government announced the it would institute a groundwater protection strategy for the province (Globe and Mail 1990). The major components of the proposed strategy were public information and education, resource assessment, prevention activities, and research (Singer 1990). Enhanced public information and education on groundwater use and protection was to be achieved through establishing a toll free information line, educational materials for targeted groups, training programs for regulators and officials, and wide-spread dissemination of groundwater information. Groundwater resource evaluation activities were to be renewed, including provincial mapping of major groundwater systems in the province, cost-shared assessment of local groundwater resources aquifers with municipalities, enhanced groundwater monitoring, and an improved Water Well Information System. Prevention of contamination was to be a focus for action rather than remediation, and cooperation with MICR and municipalities to locate, assess and if necessary remove leaking underground storage tanks, add all municipalities to the Drinking Water Surveillance Program, enforce well construction requirements and work to develop point-of-use treatment devices. An enhanced research program was also envisioned to support external research in the area of groundwater issues (Singer 1990).

Following a change in government, the strategy was not adopted. However, in 1995 an application for review of the *Environmental Protection Act*, the *Ontario Water Resources Act* and the *Pesticides Act* was submitted pursuant to the new *Environmental Bill of* Rights. The application challenged the MOEE's application of these three Acts, arguing that the Ministry did not have an effective groundwater management strategy in place. A preliminary review within the MOEE concurred there was a need for a groundwater strategy and established an inter-ministry steering committee to develop a plan for implementing an integrated approach to groundwater protection. The committee has representation from the following ministries: Environment and Energy, Agriculture, Food and Rural Affairs, Natural Resources, and Municipal Affairs and Housing. The steering committee identified three areas of groundwater management needing examination: policy and regulations, data and information management, and program delivery.

In January 1996 the MOEE convened a focus group with a range of actor groups to obtain their views of on key groundwater issues of concern (MOEE 1996b). The groups in attendance included representatives from the provincial steering committee as well as non-government actor groups.[52] The focus group identified a wide range of issues related to groundwater management and protection. Four major areas of concern emerged: lack of a long term vision, information needs, roles and responsibilities, and groundwater programs (MOEE 1996b). The first area of concern was the need to develop a vision that included long term goals and guiding principles on which to establish the framework for groundwater management and protection. The second area of concern was the need to clarify roles and responsibilities of various levels

52 The non-government organizations included: Federation of Ontario Naturalists, International Association of Hydrogeologists, Ontario Society for Environmental Management, Association of Municipalities of Ontario, University of Toronto, Canadian Bottled Water Association, Ontario Farm Environmental Coalition, Ontario Groundwater Association, Conservation Council of Ontario, Waterloo Centre for Groundwater Research, and the Association of Local Health Agencies.

of government, the private sector, and public interests. The third area of concern was a lack of sufficient data, limited interpretation of available data and lack of access to existing data. This was seen to contribute to lack of technical understanding by those who manage the resource and lack of public understanding. The fourth area of concern was the need to ensure up-to-date and effective groundwater policies and programs. After the meeting, working groups were to be established to develop a vision statement and set of principles for groundwater management and also to develop options for proposing means for addressing priority concerns.

6.4 Groundwater Protection at the Municipal Level

6.4.1 Regulatory Framework

The only reference to municipal institutions in the Constitution is that they are wholly subject to provincial governments (CA s.91(10)). Local governments in Canada derive their authority through powers that are expressly delegated to them by Provinces. Each of their actions must be based on legislative provision. Municipal governments cannot delegate powers without legislative consent; they have narrowly defined means of raising revenue, and their by-laws are open to much broader legal challenge than federal and provincial governments, whose power to legislate is limited only by Constitution (L'Hereux 1985). This does not imply that local governments lack a certain measure of autonomy in exercising their responsibilities (Dupre 1967:90). However, they operate within a system that limits their ability to take actions independent of authority conferred on them by senior governments.[53]

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53 This contrasts with the situation in the United States where local governments can act as long as there is no legislation to the contrary. In some states this extends to powers of "Home Rule" where local governments have constitutionally-granted authority to legislate over local or municipal affairs to the exclusion of state legislation (Corrie 1986:146).

6.4.1.1 Source Controls

Under the *Municipal Act* and the *Public Utilities Act*, local municipalities and utility commissions have the authority to acquire, establish, maintain and operate water works. When regional municipalities were created in the early 1970's they were assigned responsibility for providing sewage and water services in the statutes that created them.[54] Local Medical Officers of Health are responsible to ensure that water provided for human consumption is potable. They are given wide-ranging authority to make judgements concerning human health under the *Health Protection and Promotion Act (HPPA)*. Under that Act municipal and other large water supplies are routinely monitored for a small number of health parameters. A medical officer of health can issue public health advisories where s/he deems water unfit to drink. S/he also has the authority to issue an order where activities pose a significant risk of contamination to a water supply (HPPA s. 15).

Starting in the mid-1970's, the MOEE entered into agreements with District Health Units of Local Boards of Health across much of the Province delegating administration of Part 8 of the *Environmental Protection Act.*[55] This section of the Act governs the treatment and disposal of domestic sewage from residential, industrial, institutional and commercial development occurring outside of municipally serviced areas. The EPA creates a duty on the part of the approving Director to issue a certificate of approval for a sewage system unless s/he is of the opinion that the proposed system will create a nuisance, will not be in the public interest, will

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54 In three regions, local municipalities retained responsibility for water distribution and sewage collection systems.

55 Where the services of a local health unit are not available (e.g. District of Muskoka, Ottawa-Carleton) the MOEE is responsible for implementation of the program.

result in a hazard to health and safety, or will result in impairment of the quality of the natural environment for any use that can be made of it (EPA s. 65(2). Regulation 358 provides additional guidance in terms of classification of sewage systems, charging of fees, and construction and operation standards for sewage systems. For septic tank systems, the regulations prohibit locating a leaching bed where the effluent from that leaching bed would cause impairment of groundwater (Reg. 358 ss.10(9)(2)). The number of septic system approvals issued annually between 1984 and 1994 ranged from a high of 34,690 in 1989 to a low of 15,270 in 1994 (MOEE 1995b).

Municipalities are responsible for regulating industrial waste discharged into sewer systems. Under the *Municipal Act* they can pass by-laws controlling or eliminating discharges, primarily to protect the effective working of the treatment plant and for purposes worker safety. The Province has a model sewer-use bylaw to guide the development of municipal by-laws. The model bylaw includes a general prohibition for any discharges to a sanitary or storm sewer which may cause the sewage works to contravene any requirement under the OWRA or EPA, or cause the sludge to fail to meet specific criteria for spreading on agricultural lands. The model bylaw requires waste survey reports by dischargers containing description of waste discharge rates, contaminant concentrations, and discharge points (MOEE 1988:15). It also defines elements to be included in a best management plan for activities associated with on-site industrial operations, for example: in-plant transfer, process and material handling areas, waste disposal areas, and policies for pollution control, safety, fire protection, protection against loss of raw materials (MOEE 1988:24).

Various municipalities are currently involved in the process of reviewing applications for certain types of water and sewage works under the OWRA and EPA. Recommendations for issuance of a certificate of approval are made to the approving Director in MOEE. The works covered in the MOEE Transfer of Review Program include works that are deemed to be environmentally in-significant, and do not include water or sewage treatment facilities, water intakes and sewage outfalls, some types of pumping stations and storage facilities, and stormwater quality works. By 1992, over 20 regional municipalities and separated cities were participating in MOEE's Transfer of Review Program (MOE 1992b). The possibility of expanding the transfer of review program to additional types of approvals is being examined by the Ministry.

A recent report commissioned by a group of municipalities in Ontario identified a number of provincial powers that municipalities may find beneficial in protecting groundwater (Willms and Shier 1996). This includes certain approval functions (water takings and waste sites), order powers (ability to order preventative actions), and powers of inspection and prosecution.[56] The report suggests that there are no legal obstacles to delegate responsibility to municipal officials and that transfer of legal powers would have to be enumerated in a memorandum of understanding regarding responsibilities, payment, training and indemnification (Willms and Shier 1996:18).

6.4.1.2 Land Use Planning

The *Planning Act* defines procedures by which municipalities adopt official plans and zoning by-laws, control the subdivision of land, administer planning, involve the public, and

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56 A variety of other powers currently or potentially available to municipalities were identified, including powers of fire marshals (Fire Marshals Act), health inspectors (Health Protection and Promotion Act) and inspectors appointed pursuant to the *Gasoline Handling Act*.

procedures for appealing planning decisions to the Ontario Municipal Board. Under the *Planning Act*, municipalities are directed to adopt official plans that contain goals, objectives and policies to manage and direct physical change and the effects on the social, economic and natural environment of the municipality (*Planning Act* s. 16(1)). Official plans designate lands for certain specified uses, outline policies to guide future development, and provide the basis for the adoption of legally enforceable zoning by-laws at the local municipal level. Environmental policies in municipal official plans vary from plan to plan. General policies regarding broad goals for environmental quality and environmental protection are often included. In addition specific sections of an official plan addressing matters may contain more specific environmental policies related to transportation, infrastructure, noise, water quality, and environmentally sensitive areas. A few communities have adopted specific official plan policies pertaining to groundwater protection (see below).

Zoning by-laws are legal instruments available solely to local municipalities to restrict the use of land, the erection, location or use of buildings or structures, and the density of development. Zoning by-laws give legal force to designations provided in the official plan. For the first time ever, the revised *Planning Act* of 1995 specifically empowered local councils to pass zoning by-laws for prohibiting land uses and buildings or structures on land that is contaminated, that is a sensitive groundwater recharge area, a head-water area, or on land that contains a sensitive aquifer (PA s. 34(1.3.1)). However, bylaws do not prevent any uses from continuing that were permitted prior to adoption of the new bylaw (PA s. 34(9)).

Municipalities control the division of land through approval of plans of subdivision. They can prescribe the information that must accompany an application, including environmental information such as soil conditions, water supplies, and sensitive natural features.

Municipalities also can influence the form of development by designating site plan control areas with reference to one or more land use designations contained in a zoning by-law. However, the range of items covered in a site plan are limited to matters such as the mass and design of proposed buildings, public access, and provision for disposal of waste water (Planning Act s.41).

The 1996 *Planning Act* authorizes the Province to adopt regulations to allow municipalities to control the use of land through a system of development permits, in lieu of zoning by-laws. No regulations or discussion papers have been drafted that explain what is intended. However, prior to these amendments only lands falling within the Niagara Escarpment Plan under the *Niagara Escarpment Planning and Development Act* were governed by a land development permit system. Development permit systems are widely used in the United States, and parts of Canada, as a flexible means of adapting development controls to individual site conditions.

6.4.2 Non-regulatory Measures

Three non-regulatory measures used by municipalities are watershed studies, groundwater information and mapping activities, and expenditures related to groundwater. As mentioned in the Provincial section above, watershed studies reflect a partnership among conservation authorities, municipal government, provincial agencies and other actor groups. Municipalities and conservation authorities are currently providing leadership in watershed planning. For example, of the 87 watershed studies initiated since 1990, 41 were led by municipalities, 38 by conservation authorities, and 2 by provincial agencies.[57] In addition, 44 of 74 studies (51%) addressed groundwater quality issues, while 39 (45%) addressed groundwater quantity issues

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57 The remaining six were led by private firms and organizations.

(MOEE 1997:7). The effectiveness of these studies relies on the goodwill of participants, the persuasive powers of participating agencies, and a willingness of local municipalities to reflect their guiding principles in planning decisions on a daily basis. The range of implementation mechanisms in use include municipal land use planning, private land stewardship activities, environmental approvals, and environmental report cards (MOEE et. al 1997).

Some municipalities in Ontario have implemented key recommendations of watershed and sub-watershed studies through municipal official plan amendments and development control policies. For example, following completion of the Laurel Creek watershed study, the municipality of Waterloo introduced official plan amendments with general and detailed policies reflecting the goals, objectives, policies and targets from the watershed study (Waterloo 1993). It addressed topics such as stormwater runoff, groundwater infiltration, and maintenance of baseflow to streams. It also outlined specific mechanisms for implementing watershed policies, and for developing watershed performance criteria through subwatershed studies, including subdivision and site plan agreements, conditions for municipal approval, design and performance guidelines, restrictive covenants, public acquisition of rights to environmental constraint areas, and environmental warnings to prospective landowners.

A few regional and local municipalities have taken initial steps to map groundwater flows around municipal well supplies and are examining the need for policy to address potential threats to groundwater in the immediate vicinity of these wells. Some municipalities have undertaken inventories of lands potentially contaminated with hazardous substances. Prime concerns relate to the potential for re-development of these sites and health hazards associated with contaminated soils.

While there is no evidence that it has been used to protect sensitive groundwater areas, the *Planning Act* permits municipalities to acquire any land, building or structure that is used for a purpose that does not conform to its bylaws (PA s. 34(8)). They may also require conveyance of land for park or other public recreation purposes (2% of land proposed for commercial and industrial use, and 5% for land proposed for all other purposes (PA s. 42(1)).

Where municipalities have few formal abatement and remediation functions related to groundwater many have been forced to make significant compensatory expenditures to address groundwater contamination problems. This has occurred most frequently where municipal groundwater supplies have been contaminated by various land use activities, and have required replacement of local groundwater supplies with other sources of drinking water.

6.4.3 Toward Municipal Groundwater Strategies

Concern at the municipal level is prompting some municipalities to examine options to increase protection of their groundwater supplies. In early 1995 a working group of municipal water managers from seven local and regional municipalities was formed to exchange information, pool resources, and to encourage supportive action by Province.[58]

An early example of action taken at the municipal level to protect groundwater is the initiative of the village of Dorchester, Ontario. In the mid- 1970's the detection of elevated nitrates in the village's wells prompted Dorchester to define a Water Supply Protection Area, based on the

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58 Members of the group include the Regional Municipality of Waterloo, Regional Municipality of Halton, Regional Municipality of Peel, Regional Municipality of Ottawa-Carleton, Wellington County, the City of Guelph, and the Paris Public Utility Commission.

results of two-year monitoring program conducted by the Ontario Environment Ministry (Novakovic and Longworth 1985). Within the designated area some activities, such as bulk storage of hazardous materials, were prohibited while others, such as livestock operations, were carefully managed. In addition, "Special Policy Areas" immediately surrounding the village wells were designated which restricted permitted uses to existing uses and open space.

Since 1985 the Regional Municipality of Waterloo has had policies in its Regional Official Policies Plan designed to protect the Artificial Water Recharge Area where surface water was being treated and pumped into the subsurface, and into the municipal water system. Within the designated area new uses and activities likely to discharge contaminants into the water table are prohibited (ROPP 1985 s.11.9). Increasing concern about wide-spread degradation of shallow groundwater systems by septic systems prompted the Region to adopt guidelines in the early 1990's, requiring hydrogeological assessments for development proposed in un-serviced areas. These guidelines are in addition to those promulgated by the Province concerning groundwater impact evaluations for development proposals. Also, the Region embarked on a multi-year Water Resources Protection Strategy (see Chapters Seven and Eight).

In 1994 the Regional Municipality of Halton adopted a new policy in its official plan that called for adoption of an aquifer management plan to protect the Region's aquifers and groundwater supply (Halton Region Official Plan 1994 s.C1c). One year later the Region released the first phase of its aquifer management plan, which provided background information and mapping of the hydrogeology of that region (Halton 1995).[59]

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59 Examples of other municipalities undertaking studies related to groundwater protection and wellhead areas include Peel Region, Paris and Guelph.

6.5 Continuing Challenges

The institutional arrangements for groundwater management and protection in Ontario present a number of significant and un-resolved issues that impact upon the development and implementation of regional groundwater protection strategies. For purposes of discussion, these issues and concerns have been organized under the guiding principles of an ecosystem approach to groundwater protection outlined in Chapter Three.

Boundaries

Unlike the United States, the scope and focus of groundwater management and protection in Ontario has changed marginally in the past two decades, and in some respects, has narrowed. Both federal and provincial governments have acknowledged the importance of adopting a resource-based approach to groundwater management and protection, based on understanding the functioning of individual groundwater systems and their sensitivities to cumulative sources of contamination. However, it has found little concrete expression in the programs and policies directed at groundwater management and protection.

The federal government has not adopted a groundwater strategy, and has not taken steps to increase policy guidance, incentives, or use alternative policy instruments to achieve groundwater protection goals. Groundwater remains a secondary and declining interest in the face of competing pressures for scarce resources. At the Provincial level, acknowledgement of deficiencies in groundwater management and protection has not been translated into a provincial groundwater strategy.

In Ontario there are very few comprehensive groundwater studies on a regional scale.[60] Watershed studies have been an important mechanism for beginning to plan for groundwater using natural boundaries. However, at a recent workshop discussing the role of groundwater in watershed studies, it was observed that these studies are often restricted to surface water boundaries rather than groundwater boundaries.

> The boundary for a watershed study are almost always defined on the basis of the boundary of a surface water drainage basin. However, because groundwater flow systems typically occur within aquifers, which do not follow surface water boundaries, the groundwater watershed may be considerably different from the surface watershed. (Crowe 1996:248).

Objectives

The objectives underlying most groundwater policies developed at the provincial level have been geared to limiting degradation of groundwater and replacing contaminated groundwater supplies. For drinking water supplies, the Ontario Drinking Water Objectives define concentrations of contaminants that are known or predicted to adversely affect human health.

The goals of "fair-sharing" of groundwater and protection of "reasonable uses", first articulated in 1978, have not been updated to reflect increased emphasis on prevention or the need to adopt a resource-based or ecosystem-based approach. The reasonable use policy aims to limit degradation of groundwater outside the boundaries of lands owned by sources of contamination in order to protect defined reasonable uses. Other ministry policies are directed at procedures for assessing responsibility for cleaning up or replacing groundwater supplies that have been

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60 Some examples include the Credit River Conservation Authority, the Grand River Conservation Authority, and Great Lakes research by Environment Canada under its Great Lakes 2000 initiative (Crowe 1996:248).

degraded or lost as a result of certain activities.

Cumulative Effects

In Ontario, the site-specific approach to assessment, monitoring and approval continues to be the preferred strategy. Activities that might impact groundwater functions, be they water takings, septic systems, or gas stations, are analyzed individually without the benefit of a framework that considers potential cumulative effects. While large contaminant sources, such as landfills, undergo detailed technical assessment, the potential impacts of most sources are assessed within the confines of the property on which they are proposed, with no regard for other stresses already impacting the same groundwater-ecosystem.

While there has been increased acknowledgement of the need to assess cumulative environmental effects in land use planning and environmental assessment, no legislative, regulatory or policy changes have translated this concern into specific requirements or actions.

Also, there is no program to monitor ambient groundwater quality or quantity in Ontario's principal aquifers. The water well records contain only generalized descriptions of water quality. The MOEE Drinking Water Surveillance program monitors a fraction of municipal supplies that use groundwater. Recent decisions to reduce routine monitoring by the Province will mean less extensive monitoring and monitoring of fewer contaminants. As noted by Singer (1992), such monitoring could help identify trends in groundwater quality deterioration and the need for prevention measures.

> Monitoring groundwater quality by establishing and maintaining a long-term network of observation wells is essential. Such a network will make it possible to observe the changes in groundwater quality over time, to arrest contamination problems at earlier

> stages, and to assure our citizens that their water supplies are safe. (Singer 1992)

There has been some discussion of the need for an independent group or agency responsible for characterizing and mapping groundwater resources of the Province. However, no action has been taken in this regard.

Functions

A recurring issue is a lack of sufficient and accessible data for planning and decision making. Until the mid-1980's the Province invested significant resources in identifying and exploiting useable groundwater sources for municipal water supplies. As many municipalities gained professional expertise and resources to investigate municipal water supplies independent of the MOEE, the initial rationale for provincial involvement disappeared. However, it is critical that groundwater conditions, use, value and vulnerability be characterized to provide adequate information base for planning and prevention. As noted by Singer (1992):

> To ensure the fair sharing and conservation of Ontario's groundwater resources, it is essential ... to expand our knowledge about Ontario's groundwater resources. This should include the detailed mapping of surficial and buried aquifers throughout the Province in terms of areal extent, hydrogeological properties, and water-yielding capabilities.

Most groundwater data are site-specific information that has been generated as a result of individual approvals and planning requirements. There is no system in place to centralize or otherwise link this information in a way that allows understanding of groundwater to be built up cumulatively. The only situation where information is centralized is the water well records program of the MOEE. However, for many years the Water Resources Bulletins which reported on water well activities have not been published, making the data less accessible. More significant, since 1984 there has been an increasing backlog of records which have not been digitized and which lack information concerning well locations. While the MOEE is working to eliminate the backlog few post-1984 records have been entered into the digital data base. Various means of achieving a self-financing program for managing water well records are being explored.

In the absence of a Provincial program some municipalities and conservation authorities have initiated projects to collect groundwater information and map groundwater resources. These activities have drawn on available information from a wide range of disparate sources. In some cases, municipalities have also undertaken groundwater modelling exercises in the vicinity of prime well fields.

Groundwater has often been treated as a separate component from the watershed and has tended to lack the profile of surface water issues (Karvinnen and McAllister 1994:13). As noted above, the expanded scope of watershed studies to include groundwater considerations is a positive development, even though groundwater continues to be one of the weaker components of these studies. Perhaps the greatest benefit of watershed studies with a groundwater component has been to educate participants about the functions groundwater provides and its relationship to other components of the ecosystem. Hydrogeological data is among the most difficult to access for watershed studies. The significant costs involved in acquiring detailed hydrogeological information may discourage it from being implementing widely.

As part of the initiative to encourage watershed studies, an inter-agency Science and Technology Task Group was formed to document the state-of-the-art science and its application in watershed planning. In its final report, the task group found a number of areas needing improvement, including the groundwater component of watershed studies (STTG 1995). It found that current practice often failed to apply the current scientific understanding and knowledge to groundwater issues. This was attributed, in part to the cost of detailed hydrogeological studies and also, to a lessor degree, to the limited experience in conducting studies with respect to groundwater function and its relationship to other components of the ecosystem. Key areas for improvement include: the establishment of an efficient data base and clearing house for groundwater data and information in the province, increased communication and cross-disciplinary research, and more detailed understanding of the characteristics and sensitivity of the groundwater and surface water interactions, and the quantification and sensitivity of groundwater recharge (STTG 1995:41).

Integrated

In Ontario there continues to be a disproportionate emphasis on pollution control, abatement and remediation. The primary legislation governing activities that impact groundwater remain virtually unchanged since enactment. The most significant regulatory effort has been directed at controlling groundwater contamination at waste sites. In a few cases as new concerns emerged, such as leaking underground storage tanks, legislation was amended to require remedial and protective measures. Some legislative and policy instruments available to increase protection of groundwater supplies have never been used. Two examples of are the ability of the MOEE to establish water supply protection zones around communal groundwater supplies, and to apply its reasonable use policy to areas where multiple lot development is being proposed on septic systems. The Comprehensive Provincial Policy Statement on land use planning devotes a single sentence to the provincial interest in the protection of groundwater and surface water.

Since 1991 there have been significant provincial initiatives towards de-regulation and streamlining of environmental approvals, land use planning and environmental assessment. The regulatory reforms have been driven by demands to reduce the complexity, timing and scope of approvals and planning decisions. For all of these processes, average turn-around times have been reduced by up to one-half of pre-1991 levels. There has not been a concomitant analysis of the environmental objectives behind these programs nor on the effectiveness in achieving stated objectives.

The site specific approach to evaluation and approvals of individual contaminant sources, and the case-by-case approach to deal with specific groundwater concerns has not been able to anticipate and prevent problems, or to foster sound planning. It has led to significant and ongoing programs devoted to abatement and remediation rather than prevention. The field offices of the MOEE have found themselves spending the majority of their available resources on approvals, abatement and response activities. For example, between 1980 and 1989, the number of approval documents reviewed doubled, the number of planning documents reviewed tripled, complaint investigations increased by 25 percent, and the number of court appearances increased by a factor of 10 (TSRC 1989). This has led to a decrease in environmental studies, surveys, and surveillance activities to ensure compliance with specific regulations such as those related to well construction and abandonment. It has also left few resources to participate in preventative planning and decision making. In addition, millions of dollars have been spent on clean-up/replacement of contaminated groundwater supplies. Many more millions have been spent through provincial grants to municipalities. Where these grants have funded water projects to replace degraded groundwater supplies, or to extend sewers in areas previously serviced by on-site sewage systems, they have served to mask past deficiencies in regulatory controls or planning decisions.

Adaptable

There has been increased interest in how municipal land use planning might contribute to groundwater protection. The delineation and protection of sensitive aquifers within official plans are an option that some municipalities have pursued. Recent revisions to the Planning Act enable local councils to pass zoning by-laws to prohibit land uses and structures on land that is a sensitive groundwater recharge area or contains a sensitive aquifer. At the same time, it must be recognized that the instrument of zoning has some inherent limitations. As noted in a recent report examining the potential for innovative approaches to development, zoning lacks the flexibility needed for site-level environmental planning:

> Unfortunately, zoning requirements are generic and formula driven, and cannot be adjusted to respond to the unique physical limitations and possibilities which are offered by a particular site. They do not necessarily address the real impact or the cumulative impacts which the intended use of the site will have on the environment, whether in a site-specific context or regionally, nor do they allow much latitude in suggesting alternative solutions. (Ecologistics 1992:29).

The development criteria used in the development permit system on the Niagara Escarpment are applied holistically to ensure consideration of ecosystem impacts. It is an approach to development control that, from an ecological perspective , is unmatched elsewhere in Ontario. Uniform development standards are replaced with performance objectives that might involve re-locating and minimizing the development footprint away from sensitive areas, preclude typical municipal clearing and grading requirements, and encourage non-structural solutions to protect hydrologic functions. Amendments to the *Planning Act* in 1995 offers the potential for use by municipalities of more flexible system of development permits in place of zoning. However, the Province has given no indication that it is working on a plan to develop the appropriate regulations to allow this to happen. Also, initial work on alternative development standards in the early 1990's has not been followed up with specific policies or guidelines.

The planning process does not reflect a precautionary approach in so far as the burden of proof continues to rest with those who are concerned about potential cumulative effects. A recent example is the Joint Board decision relating to a contested proposal for a sand and gravel pit in the Town of Caledon (Joint Board 1996). The proposal to establish a sand and gravel operation up-gradient of the well of a major private water bottler was approved. The contention of the appellant and its expert witnesses that the contested pit accounted for seventy percent of the recharge zone, that there was a direct pathway for contaminants from the pit to the well and that even small spills of contaminants on the floor of the operating pit would eventually contaminate the well water was not sufficient in the Board's view to reject the extractive use. In its decision the Board stated, in part:

> Does the risk of such an occurrence mean that the Board should deny approval to Ambro's application? In carefully considering the evidence, we cannot reach this conclusion. In our opinion, the contamination of Crystal Spring's well is not a certainty but rather a possibility that, once anticipated, should be preventable. On a balance of probabilities, the Board is persuaded that Ambro's extraction operations, as governed by the conditions of approval are unlikely to cause contamination of Crystal Spring's well. (Joint Board 1996:51)

The Board goes on to endorse a reactive approach to environmental management:

> While the Board finds that such contamination should be preventable, human error during extraction operations and the behaviour of the groundwater flow are unpredictable factors. This decision, and the license granted to Ambro, are not to be interpreted as prejudicing any right in common law or by statute that Crystal Springs, or any other person, may have against the applicant or anyone else, in respect of groundwater contamination (Joint Board 1996:51)

The application of pollution prevention principles to groundwater management and protection has received virtually no attention in Ontario. Numerous questions remain unanswered including: incentives to practice pollution prevention, technical assistance and training, consistent approaches to pollution prevention by provincial and municipal governments, and prevention requirements for business and industry. Additional analysis is required of ways to ensure that pollution prevention becomes a major consideration in decision making in all sectors. The only progress of note in this regard is the educational work being led by farm organizations through the Well Steward Program and the Environmental Farm Plan program. Innovative measures such as conservation easements or use of tax incentives for protecting designated groundwater areas have not been implemented in Ontario.

Coordinated

A recent survey of members of a working group of municipal groundwater managers identified numerous issues of concern regarding the rules, responsibilities and relationships in groundwater management and protection in Ontario (Neufeld 1996). The priority concerns of working group respondents included the need for a Provincial policy framework for groundwater protection, the need to clarify roles and responsibilities of all stakeholders, and the importance of addressing information and monitoring needs. Some of the existing rules that were identified as needing to be reviewed for their potential to protect groundwater included: water takings, water well regulations, septic system regulations, application of the *Fisheries Act*, use of land use planning tools and watershed studies to address groundwater issues.

Regarding the relationship between the Province and municipalities, the need to clarify respective roles and responsibilities was highlighted. Increased communication was identified as an important first step. The primary roles advocated for the Province included the development of legislation and provincial policies for groundwater management and protection, enforcement activities and education. The prime roles advocated for regional government included the development of regional groundwater policies, protection programs, and education. Primary local roles included enacting supportive land use policies and zoning by-laws, and implementing provincial and regional policy. The most important roles for Conservation Authorities were coordination of watershed-wide initiatives and studies and educational activities. Voluntary preventative actions by industry and increased monitoring and reporting were identified as important roles for the private sector. A strong public education role was identified for non-government organizations (Neufeld 1996).

There remains confusion and disagreement about the appropriate role of the federal government in groundwater management and protection. As noted earlier, while both internal and external evaluations have advocated increased federal presence in this policy area, there has been a steady decline in their activities. One of the few remaining areas is a federal research function related to improving scientific understanding of groundwater contamination and remediation. The provincial role in groundwater management and protection has been defined primarily in terms of a regulatory function, centred within the MOEE. There are other provincial agencies with interests or responsibilities impinging on groundwater management and protection.

There is no focal point for managing and protecting the resource, and no overarching objectives and priorities to guide all ground-water related programs of the MOEE and other actor groups. At present there is a collection of disparate and declining activities by autonomous agencies and branches within agencies. There is limited inter-agency coordination and no mechanisms for integrating actions across related programs and levels of government to achieve prevention, control and remediation objectives. As noted by Singer (1992):

> It is clear that no single authority, regardless of jurisdiction, can effectively implement

> water management programs without cooperation of other parties involved. Enhanced cooperation, consultation and communication among all parties involved in the area of groundwater management is an essential ingredient for a successful protection of the resource.

To date cooperation among core agencies has been episodic. At times, common interests have stimulated joint study or investigation of specific areas or issues of concern such as agriculture or the Oak Ridges Moraine. There have also been periodic attempts to develop a provincial position on groundwater through provincial policy statements or internal reviews of groundwater management and protection. Cooperation with non-provincial agencies has been undertaken for special purposes, such as to up-date water well records.

Catalytic

There has been a trend toward a reduced presence of senior levels of government in environmental planning and management. Since the mid-1980's the provincial government, through the MOEE, has largely withdrawn from its earlier role in groundwater availability studies and mapping. Continuing responsibilities related to abatement and remediation have reduced the ability of the MOEE to provide ongoing technical and consultative assistance in approvals and planning processes. This removes the primary means of ensuring that groundwater factors are considered up-front in various decision making processes.

There is a perceived need for additional guidance in a range of areas, including industrial design and operating standards to protect groundwater, agriculture best management practice, stormwater infiltration guidelines, acquisition of sensitive areas, and educational activities. In addition, the management and distribution of Provincial water well records was identified as a concern for municipalities (Neufeld 1996).

Approval and planning reforms of the 1990's accelerates the trend toward reduced provincial involvement in decisions that could impact groundwater. It is occurring primarily through exemptions from approval for various types of activities and planning decisions. There are no Provincial incentives for municipalities to adopt preventative planning strategies or use the legal tools at their disposal. There is little technical guidance or other support being provided by the Province in this area. Reduced involvement and support from senior levels of government has, of necessity, generated community-led responses. In the absence of a provincial protection strategy, municipal governments have largely been left to respond to groundwater concerns as they develop. A progress report prepared by the International Joint Commission in 1995 was highly critical of lack of progress in this area.

> Although legislative structure exists to protect groundwater from contamination, federal and provincial development through both Environment Canada and the Ontario Ministry of Environment and Energy is currently at a standstill, due to lack of funding, intervention and, in some cases, personnel.
>
> ... municipalities that rely on groundwater used for drinking water purposes have, with little assistance, been forced to devise and municipally fund their wellhead protection. (IJC 1995:Table 5)

Increased municipal autonomy and responsibility in decision making presents further opportunities to address groundwater concerns in ways that fit local circumstances and priorities. However, questions remain about differing capacity at the local level and the guidance and support that is needed from senior governments for local groundwater initiatives. In addition, the reduced policy review and approval function proposed for upper tier municipal government could impact their ability to effectively plan for groundwater on a region-wide basis. The future role of Conservation Authorities in basin-wide groundwater initiatives is unclear. Recent decisions to eliminate provincial funding may impair their ability to initiate and support such broad studies. Many Conservation Authorities may be forced to limit their activities to a narrow range of regulatory functions, such as flood and fill control.

Increased responsibility is falling to landowners, water users and other proponents whose actions can impact groundwater functioning. However, the only example of a non-government initiative of note, is the coalition of major farm organizations referred to earlier, that have taken some farm-related initiatives, with modest support of federal and provincial governments.

As noted by Karvinnen and McAllister (1994) reaching the conclusion that comprehensive and integrated approaches are needed for management of groundwater, is not the same as taking action:

> It is one thing to state important principles and to improve policy guidelines. It is another matter altogether to see these policies successfully implemented. Success will depend on a number of variables, including adequate financial resources, political will, knowledge of the resource, an ability to generate consensus amongst diverse interests, and effective mechanisms that can translate policy statements into carefully conceived and implemented water use practices. (Karvinnen and McAllister 1994:37)

6.6 Summary

From an ecosystem perspective, the institutional arrangements for groundwater protection in Ontario are fraught with deficiencies. Federal and provincial governments have failed to translate expressions of concern into specific policies and actions. The primary legislation governing activities that impact groundwater remain virtually unchanged since enactment. There continues to be a disproportionate emphasis on pollution control, abatement and remediation. The abatement and remediation focus is suffering from reduced financial and staffing resources, and is giving way to reduced regulation without a re-investment in prevention. In addition, significant public funds continue to be invested in replacement of degraded groundwater supplies rather than making investments in source protection.

There is chronic lack of sufficient and accessible groundwater data for decision making. Initial work on mapping groundwater systems in the Province has given way to declining monitoring systems and a continued site-specific approach to assessment. Watershed studies have demonstrated the benefits of considering groundwater as part of the larger hydrologic cycle. While these studies do not consistently address groundwater issues at the same level of sophistication, they provide an important forum for local municipalities and other core actor groups to develop a common vision and a practical set of guidelines for influencing human activities on a watershed basis.

There continues to be confusion regarding roles and responsibilities of core actor groups. This has resulted in ad hoc cooperation on specific initiatives in a few leading municipalities or conservation authorities. The lack of a support from senior levels of government for community-based action has left the design of pro-active strategies to protect regional groundwater systems to local actor groups.

There is increased potential to apply land use planning measures to implement groundwater protection. A number of innovative measures for encouraging land use decisions to protect groundwater functions over the long term need further examination, such as conservation easements. Regional-scale approaches to groundwater protection offer significant potential. However, the long term erosion of regional planning authority will reduce their ability to effectively influence development decisions in favour of groundwater protection. Limited municipal authority to control the management and use of contaminants combined with a reduced policy and approval function in planning could seriously undermine future development and implementation of pro-active groundwater policy frameworks at the regional level.

CHAPTER 7
ANATOMY OF A GROUNDWATER PROTECTION STRATEGY: THE CASE OF WATERLOO REGION

7.1 Introduction

In Chapter Six, current institutional arrangements for groundwater management and protection in Ontario were reviewed in order to provide the context for considering opportunities and constraints facing regional groundwater strategies in the Province. Currently, the focus and scope of protection activities in Ontario suffers from a disproportionate emphasis on pollution control, abatement and remediation and a general absence of an ecosystem-based approach. Institutional arrangements also are characterized by unclear roles and relationships, limited inter-agency coordination, and declining provincial involvement or support. There is no centralized groundwater information system, and limited groundwater mapping and monitoring on a province-wide basis. At the same time, ad hoc partnerships have formed to increase the information base in specific areas through watershed studies and various local mapping and modelling exercises. Changes in the regulatory regime, in the form of reduced provincial approvals and changes to planning legislation are placing increased responsibility at the community level to protect groundwater.

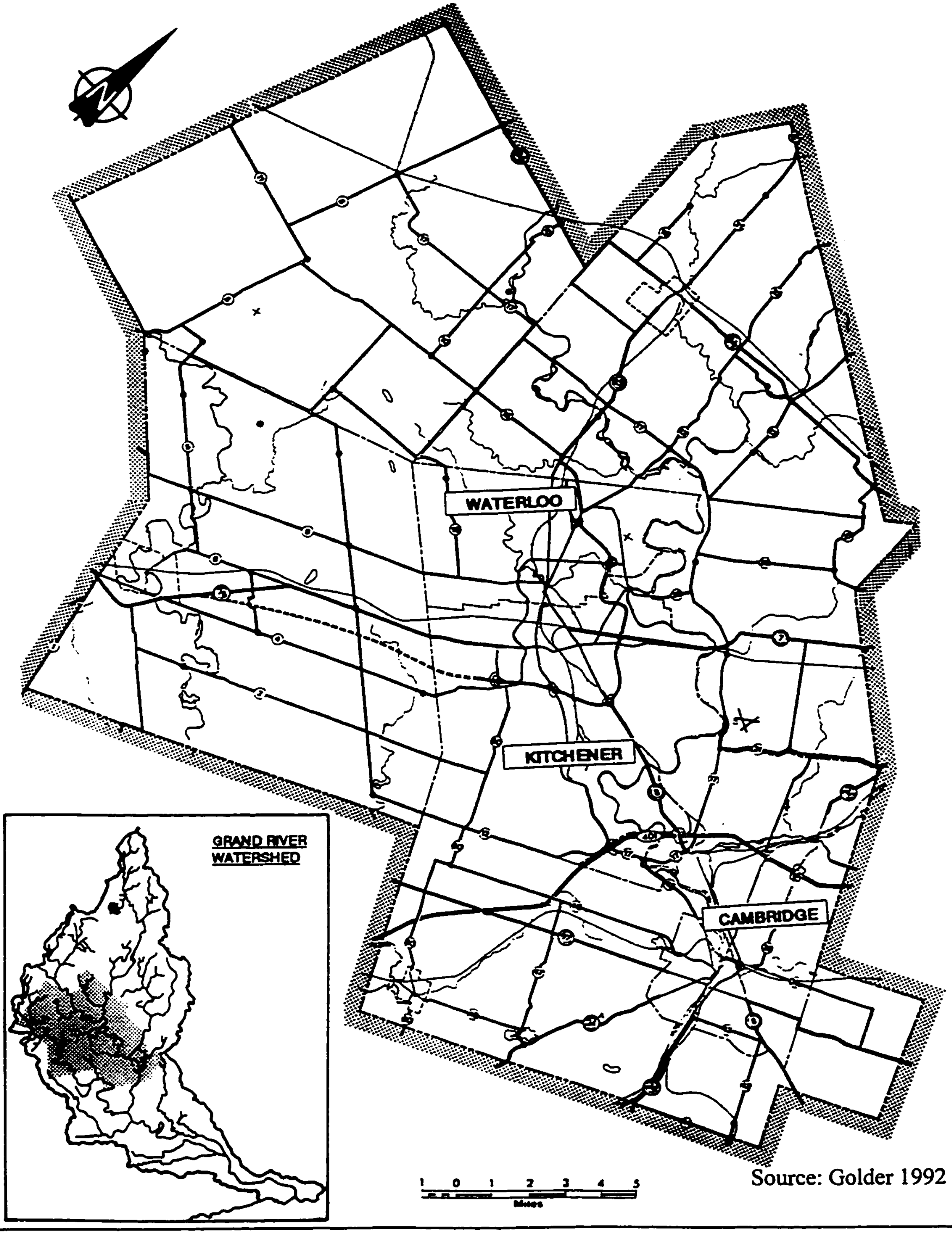
Waterloo's *Water Resources Protection Strategy* provides an excellent opportunity to consider how an ecosystem approach might inform regional groundwater protection strategies in the Province. As noted earlier, in a short period of time the Region has moved to the forefront of efforts in the Province to develop a comprehensive regional strategy (cf. Dames & Moore Canada 1996; Federation of Canadian Municipalities 1995; Karvinnen and McAllister 1994). This chapter describes the Strategy, and its major components, using key documents and decisions that span the period August 1990 to September 1996. Chapter Eight presents a critical analysis of strengths and weaknesses of Waterloo's approach as well as a set of conclusions and recommendations.

7.2 Planning Context

The Regional Municipality of Waterloo Region is located in south-central Ontario in the Grand River Watershed (Figure 4). It encompasses a land area of approximately 138,000 hectares with three urban municipalities (Kitchener, Cambridge, Waterloo) and four rural townships (Woolwich, Wilmot, Wellesley, North Dumfries) (MMA. 1995:181). Its current population is 413,300 (RMOW 1996a:1). Since the mid-1940's the Region has experienced steady economic and urban expansion, having one of the highest rates of population growth in the Province. For example, between 1961 and 1991 the Region's population increased by 106 percent while the population of the population for the whole of Ontario increased 56 percent(MMA 1995:7). Waterloo Region's population is projected to increase another 32 percent by 2011, while the population for the province as a whole is expected to increase by 20 percent over the same period (MMA 1995:8).

The economic base of the Region has continued to grow more rapidly than the rest of the province. For example, its share of the provincial Gross Domestic Product increased from 3.5 percent to 4.1 percent between 1984 and 1993 (Kitchener 1995:5). The value of all goods and services produced in the Region grew by 36 percent between 1984 and 1992. This compares with an overall increase of 20 percent for Ontario as a whole (RMOW 1996a:4). In 1993 its Gross Domestic Product was 11.6 billion dollars. The Region's economic base has shifted away from traditional manufacturing to service industries and more specialized technology-intensive

FIGURE 4: REGIONAL MUNICIPALITY OF WATERLOO



Source: Golder 1992

industry. However, it continues to have a strong manufacturing component in the regional economy. The most recent available data indicates that secondary manufacturing accounts for 26 percent of total employment (Kitchener 1994:18). This compares with approximately 17 percent of total employment in this sector for the Province as a whole. Residential, industrial commercial and institutional uses in the Region's urban and rural settlement areas occupy approximately 15,800 hectares of land (RMOW 1996b). By the year 2016, an additional 6,700 hectares are forecast to be needed to accommodate future residential and employment. Including the 5,900 hectares within settlement areas that have restricted use designations (e.g. hazard lands, flood plains and Environmentally Sensitive Policy Areas), approximately one-quarter of the Region has been designated for human settlement in the Region's Official Policies Plan (RMOW 1996b).

The most recent available data indicates there are approximately 1,000 livestock operations in the Region and 71,000 hectares of active cropland (OMAFRA 1997). The value of agricultural products totalled 258 million dollars in 1991, placing it eleventh among the counties and regions of Ontario. The total rural population is approximately 29,000 persons, one-quarter of whom represent the rural farm population.

Waterloo Region contains the largest concentration of people in Canada who depend on groundwater as their primary source of drinking water, with approximately 375,000 people utilizing the regional water supply (RMOW 1995b). In addition to the three urban centres, seventeen rural communities are served by Region's water supply system. Approximately 28 percent of the total annual water supply is groundwater with the remaining 12 percent withdrawn from the Grand River and treated at the Mannheim facility (RMOW 1995a:1). There are 126 municipal wells in 55 well fields throughout the Region, drawing water from four different aquifer types - confined and unconfined overburden aquifers, and confined and unconfined bedrock aquifer. Almost three-quarters of these wells are in urban areas (CH2M 1996:1-1). There are an additional 7,000 private drilled wells and numerous older dug wells in the Region (RMOW nd).

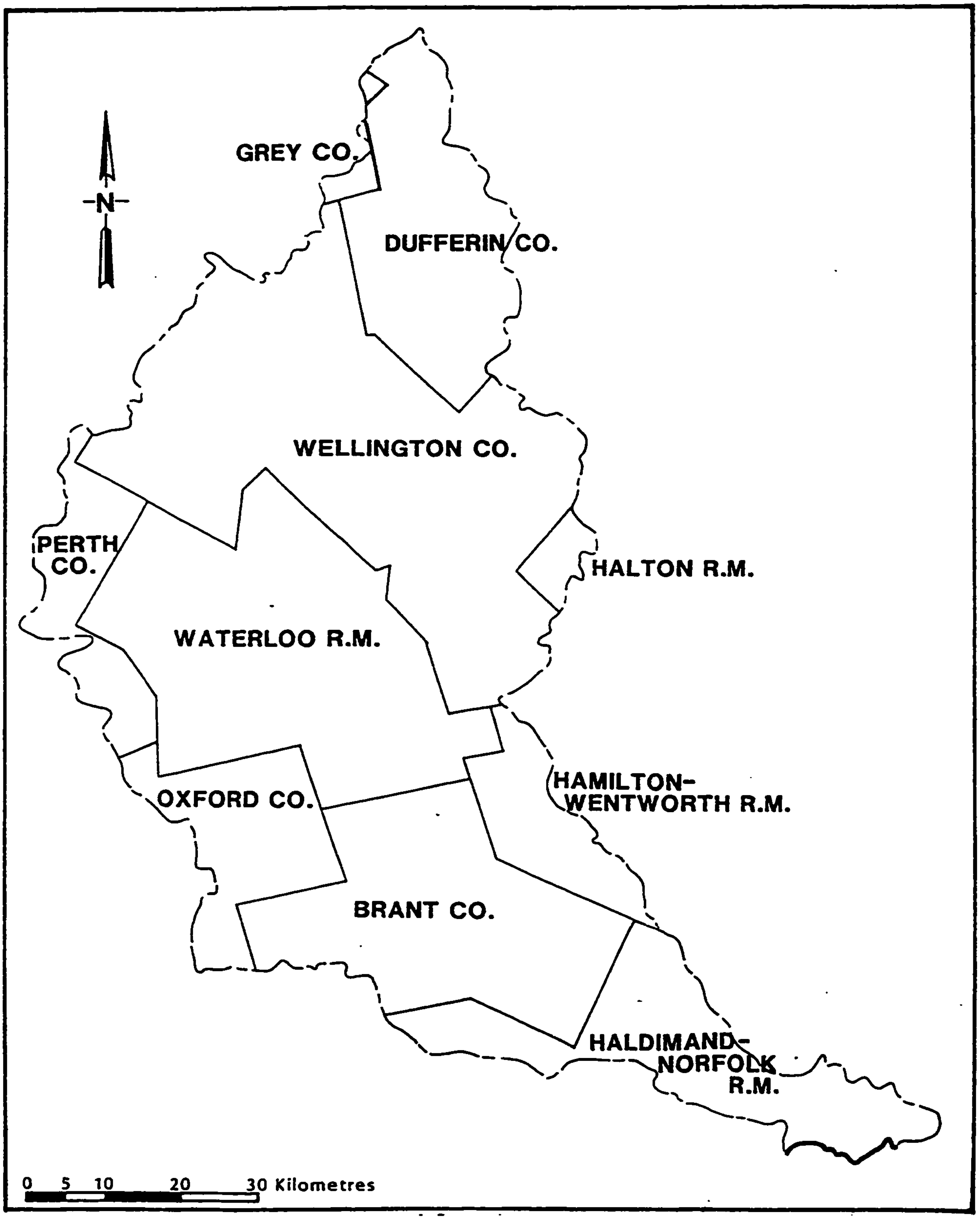
Long term water supply options for the Region have been investigated at various times going back 25 years and more. These protracted processes have been driven by a concern to maintain a secure supply of water to meet the needs of a growing population and economy. Considerable discussion about the long term prospects of groundwater use has been stimulated by divergent interests of rural and urban residents, the Regional municipality, and other actor groups. Already 25 years ago, the Ontario Water Resources Commission undertook groundwater interference investigations in Wilmot Township and Waterloo County after local residents expressed concern that the operation of two new municipal wells " ... would seriously affect surface and groundwater supplies" (OWRC 1972:69). Meetings with the public were held " ... to outline protection afforded to private water supplies in the event of serious interference" (OWRC 1972:70). The subject of water supply planning in Waterloo has been researched by others, and is not the focus of this case study (cf. Badgely 1991; Hofmann 1996). Suffice to say that future decisions on drinking water supplies, in particular the role groundwater plays in the Region's water supply system, may have repercussions on the diligence with which the Region continues to pursue protection of its groundwater resources.

7.3 Bio-physical Context

The water-bearing geologic formations, or aquifers, from which the Region draws its groundwater are extensive and complex. The surficial and bedrock geology of the Grand River watershed, and beyond, forms an important ecological context in planning for groundwater protection in the Region. The Grand River watershed drains 6,800 square kilometres of land, beginning north-east of the village of Dundalk and ending some 300 kilometres to the south near Port Maitland, where the Grand River empties into Lake Erie. Its four major tributaries include the Nith, Conestogo, Eramosa and Speed rivers. (Figure 5). The overburden, or soil and fragmented rock materials lying above bedrock, were deposited as a result of glacial advances and retreats some 14,000 to 24,000 years ago (Sibul, Walmsely and Szudy 1980:10). These overburden materials directly determine groundwater recharge, occurrence, movement and discharge. In the overburden, groundwater occupies the spaces between grains of sand and other unconsolidated material. Silt and clay materials do not permit rapid infiltration of water to the subsurface, but where sand and gravel deposits are found of significant thickness, their relatively large grain size and interconnected pore spaces, give them high permeability and high well yields (Turner 1978).

The upper part of the watershed is gently rolling terrain that has relatively low infiltration rates and a well developed surface drainage network. The central part of the watershed, where Waterloo Region is situated, is dominated by a series of moraines, drumlins and sandhills. The Waterloo Moraine has the thickest overburden deposits in the basin. It provides most of the groundwater supplied to the cities of Kitchener and Waterloo, and several communities in Wellesley and Wilmot townships (RMOW 1996c:4). Waterloo Moraine's permeable sand and gravel cap promotes high rates of infiltration. Extensive sands and gravel units below the cap, intermixed with lower permeability tills, create one of the most extensive overburden aquifers found in southern Ontario (MNR 1984:24).

FIGURE 5: GRAND RIVER WATERSHED



Source: Grand River Conservation Authority 1997

The rivers and streams of the watershed are hydrologically connected to the Waterloo Moraine as well as other aquifer units lying below the surface. For example, the groundwater divide along the Waterloo Moraine corresponds with the surface water drainage divide. Streams originating along a northwest-southeast axis either flow west toward the Nith River or east toward the Grand River, producing local groundwater recharge and stream discharge patterns (Terraqua 1995). Where sand and gravel deposits are found at surface, groundwater contributes a substantial portion of total flow to cold water streams (e.g. Nith River, Laurel creek, Strasbourg creek, upper Blair creek, Doon South creek (Terraqua 1996; GRCA 1996). South of the Waterloo Moraine lies the Paris Moraine and Norfolk sand plain, both of which provide substantial base flows to local rivers and streams. In the lower portion of the watershed, the Grand River traverses the Haldimand clay plain. It has moderate to poor drainage conditions and many water-filled depressions. Streams follow drainage channels provided by small glacial ridges and generally receive little groundwater discharge (GRCA 1996).

Underlying the overburden in the watershed is bedrock. In Precambrian rock, groundwater may be found in rock fractures. In limestone and dolostone, groundwater may be found in openings created by solution channels and joints and bedding planes. Where these channels are wide and interconnected, significant quantities of water can be transmitted (MNR 1984). Cambridge draws most of its water from the upper layers of the bedrock sequences found below the city. The Guelph-Amabel aquifer is one of the major regional bedrock aquifers in southern Ontario with potential for high water yields. It extends from Niagara Falls in the south to Tobermory in the Bruce Peninsula and outcrops on the east as the Niagara Escarpment. Natural dissolution channels in this dolostone produce large quantities of water that is generally hard (elevated concentrations of calcium carbonate) and frequently contains elevated concentrations of iron (Turner 1978).

The western edge of the Guelph-Amabel Formation runs through the centre of Waterloo Region and the Grand River Basin, where it is overlain by the Salina Formation. This latter formation is generally unsuitable for drinking water due to high salinity with high natural concentrations of sulphate and hydrogen sulphide gas. Regional groundwater flows within the bedrock aquifers are not influenced to the same extent as overburden aquifers are by surface water features. Flows are in a southerly direction toward the Grand River which, in places, is hydrologically connected to the upper aquifer (Lotowater 1996).

7.4 Development of Waterloo Region's Protection Strategy

The key milestones in the development of the regional groundwater strategy between 1989 and September 1996 are reviewed in the following sections. For quick reference, key events or activities are summarized below:

1989 - Elmira wells contaminated; poor water quality in shallow groundwater documented.

1990 - Region issues Request for Proposals to develop a *Comprehensive Groundwater and Surface Water Protection Strategy.*

- Consultant hired to develop Regional Water Resource Protection Strategy.

1992 - Objectives and framework of strategy proposed in consultant's report.

- Draft work plans proposed for some elements of the Strategy.

1993 - Work plans finalized for four elements of the Strategy.

- Region forms a Water Resources Protection Group to develop and coordinate implementation of protection policies and programs.

- Regional hydrogeologic studies and capture zone studies initiated.

- Reconnaissance contaminant source inventory initiated.

- Hydrogeological data bases under development.

- Groundwater treatability assessment (ongoing).
- Public consultation on specific studies (ongoing).
- Monitoring water levels, groundwater & surface water quality (ongoing).
- Review of policies, legislation, and other jurisdictions.

1994 - Implementation Plan endorsed by Regional Council.
- Water Resources Liaison Protection Committee established.
- Wellfield risk assessment/priority setting, wellhead audits initiated.
- Groundwater reconnaissance studies and Well field contribution studies continue.
- Education strategy and material under development.

1995 - Groundwater Protection Policy Options paper developed.
- Priorities for Groundwater Protection Policy and Program Development endorsed by Regional Council.
- Working groups formed to address rural, current urban and future urban sources.
- Waterloo Moraine Aquifer study completed.
- Middleton Street capture zone study completed.

1996 - Regional scale hydrogeological studies continuing.
- Detailed investigation of potential sources of initiated.
- Preliminary delineation of capture zones for entire Region.
- Draft policy paper on Groundwater Protection Areas.

7.4.1 Intervention

Throughout periods of rapid growth, Waterloo Region has demonstrated leadership in integrating environmental considerations in its policy framework. For example, in 1976, the Region was the first among its peers to develop a policy for protecting environmentally sensitive areas in its official plan. A more recent example of pro-active environmental policy is the Region's pioneering efforts in *state-of-the-environment* reporting (RMOW 1991). Waterloo continues to experience growth pressures from expanding urban areas, suburban development, and un-serviced rural settlement areas. These pressures have added impetus to protect and maintain clean water supplies for a growing population. Inadequate services in parts of the Region also have prompted costly delays in development approvals. Further concerns regarding the impact of on-site septic systems led to strict requirements for development proposed on private services.

The interest in planning for groundwater protection emerged in the late 1980's. Like most other communities that have undertaken steps to protect their groundwater, the degradation and partial loss of water supplies have been key motivating factors. The decision by Waterloo Region to pursue a groundwater protection strategy was triggered by concerns about costly and immediate threats to its communal groundwater supplies (RMOW 1994:1, RMOW 1995b:2). As noted somewhat cryptically: "In response to concerns about potential threats to water quality the Region initiated work on a comprehensive surface and groundwater protection program" (RMOW 1995c:2). In 1989 Nitroso dimethylamine (NDMA) was found in two municipal wells in the town of Elmira, north of the city of Waterloo. In November of that year the wells were taken out of production (RMOW 1989). One month later, the Uniroyal Chemical manufacturing plant in the Town was notified by the Ministry of Environment and Energy that it was a possible source of this contamination. An Emergency Order was subsequently issued to the company, as was a Director's Order, to control additional surface discharges of the substance and to direct a clean-up operation. The community was provided with an alternative water supply via a pipeline from north Kitchener. Concerns about more widespread deterioration of groundwater quality emerged following a survey which found elevated nitrate levels and almost universal bacterial contamination of the shallow aquifer that underlies much of Waterloo Region (Murray 1995; Thorsen 1991). Also, the discovery of coal tar and related hazardous substances at former sites of coal gasification plants added pressure to prevent further groundwater contamination.

The formal starting point coincided with the release of a Request for Proposals (RFP) by the Regional Municipality of Waterloo in August 1990, entitled *Request for Proposals* to develop a *Comprehensive Groundwater and Surface Water Protection Strategy*. The purpose of the contract was to help the Region identify a set of tasks and priorities for implementing a comprehensive strategy that focussed on groundwater (RMOW 1990:5). The Region required that the strategy and work plan address groundwater, surface water, data management, public participation and education. It identified *groundwater quality* as a critical concern, including: potential contaminant sources, monitoring, remedial measures, and operating practices at municipal wells. A second set of issues was *hydrogeological setting*, including mapping of aquifer units, identifying groundwater flow patterns and recharge areas, assessing susceptibility to contamination and surface water-groundwater relationships. A third set of issues was *aquifer management*, including optimal sustainable supply, new groundwater sources, and storm water management impacts. The fourth groundwater issue identified for the consultants was *groundwater protection policies*, including a review of existing regulations, policies and approaches for protecting water resources, and identification of gaps, limitations and possible remedies (RMOW 1990:6-11).

While the Strategy was intended to focus primarily on issues of groundwater quality and protection, it also was expected to generate information relevant to surface water management and protection. Prospective consultants were directed to consider the existing surface water monitoring network, point and non-point discharges to the Grand River, and to examine groundwater-surface water interactions influencing the flow characteristics of smaller tributary waters, particularly in the vicinity of extraction wells (RMOW 1990:12). Consultants also were directed to consider a mechanism for managing the data bases generated in implementing a water resource protection strategy, including evaluating the potential role of the Region's current Geographic Information System (RMOW 1990:12).

The Region established a steering committee to oversee the consultant's work. Membership included regional staff, three elected Regional Councillors, and representatives from the Grand River Conservation Authority, the Ontario Ministry of Environment, and the Waterloo Centre for Groundwater Research, based at the University of Waterloo (RMOW 1990:12). An external advisory panel of three independent water resources specialists also was established to provide advice to the consultant and to the steering committee. Both committees became inactive following completion of the consultant's report (RMOW 1994:8).

7.4.2 The Golder Report

Approximately seventeen months after it was hired, a team of consultants, led by Golder Associates, completed its report (Golder 1992).[61] The Golder report outlined a protection strategy consisting of the following elements: water resources definition, contamination sources identification, monitoring and management of water quality, data management, integrated watershed management, policies and legislation for water resources protection, emergency

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61 Golder Associates is an international company that was formed in 1959 as a geo-technical engineering firm. It consults extensively on groundwater-related issues, including water supply issues, wellhead protection, groundwater modelling, and contaminant hydrogeology. Currently, Golder has 1,800 staff in offices located in Canada, the United States, Australia and Europe (Petrie, pers. comm.).

preparedness and response, and community consultation and awareness.

7.4.2.1 Water Resources Definition

The Golder report emphasized the importance of having adequate information on the water resources of Waterloo Region. It characterized existing groundwater information as incomplete and fragmented, and requiring considerable effort to better define the Region's groundwater resources (Golder 1992:7). Specific information needs identified included: determining the areal extent and thickness of regional aquifers, the location of recharge and discharge areas, the sensitivity of aquifers to contamination, groundwater flow patterns around municipal well fields, and data on groundwater quality and quantity across the Region (Golder 1992:viii-ix, 2).

Daily recharge to the groundwater flow system was estimated on the basis of a calculated rate of infiltration to groundwater, minus withdrawals. The report suggested that additional recharge to the flow system was available for extraction, subject to certain physical, chemical and policy constraints. One environmental constraint identified was the need to maintain baseflow to smaller streams and creeks and environmentally significant areas to the protect water quality and habitat (Golder 1992:3). The report recommended that a number of studies be undertaken to better define water resources in specific parts of the Region. It recommended installing observation wells and a hydrometric network beyond municipal well fields to better characterize regional hydrogeology, assessing hydrogeological conditions in certain areas, and conducting aquifer recovery tests at selected municipal well fields to identify zones of capture and estimate groundwater yields. Preparation of a preliminary region-wide map outlining areas at risk of groundwater contamination from land use activities, particularly in rural areas, was also recommended.

7.4.2.2 Contaminant Source Identification

The Golder report characterized past and present industries in the Kitchener-Waterloo-Cambridge area as significant potential sources of contamination. It observed that both point and non-point sources could result in serious contamination and that the threat was particularly serious in urban areas adjacent to existing or potential well fields (Golder 1992:ix). Another concern was contaminant pathways to groundwater created through human neglect, such as improper well abandonment (Golder 1992:10). A further concern was poor water quality in some rural domestic wells. A detailed inventory of existing and historic land use practices was recommended, including assessing proposed land uses for their potential to contaminate groundwater (Golder 1992:12).

The report observed that the Region was acquiring information concerning potential contaminant sources, and argued for a more complete listing of data sources together with assessment of the data. The report also suggested that the Region should combine these findings with aquifer sensitivity mapping to guide the review and approval of new development (Golder 1992:12). A number of specific recommendations were made for individual well fields, including assessing possible on-site sources of contamination and potential migration pathways, as well as identifying and ranking potential contaminant source areas within areas of influence around the wells. It also recommended that possible correlations between documented well contamination, well attributes, biophysical and land use conditions be investigated. Analysis of potential groundwater and surface water contaminants in rural areas also was recommended, including development of a data base of the types, loading rates, and distribution of potential contaminants. In addition it was recommended that methods be developed for assessing impact relationships between municipal wells and rural land use activities.

7.4.2.3 Water Quality Monitoring

The Golder report argued that a coordinated and up-to-date monitoring network was important to provide the monitoring data necessary to support measures for protecting water quality. It noted that there was an existing program to monitor water quality in wells, and ongoing sampling of water from regional pumping wells and reservoirs. However, the report observed that the monitoring network provided little advance warning of groundwater contamination (Golder 1992:18). It argued that monitoring should be expanded at strategic points, up-gradient of existing well fields, that would permit characterization of background levels, analysis of trends, and provide an "early warning" capability to allow opportunity to take action before contaminants exceeded drinking water objectives (Golder 1992:21). It also recommended that site-specific water quality objectives be developed, based on provincial and federal water quality objectives and guidelines, taking into account land uses, historic water quality, and specific uses being protected (Golder 1992:19).

A monitoring plan was recommended for one specific well-field of concern (Greenbrook) along with a treatability assessment to describe existing water quality issues and identify preferred treatment options (Golder 1992:Workplan GB-4). The report supported an accessible, up-to-date and integrated data management system for decision making purposes (Golder 1992:x). It noted the ongoing work of the Region to develop various groundwater data bases as well as a state-of-the-art geographic information system to manage this information (Golder 1992:24).

7.4.2.4 Integrated Watershed Management

The report argued that the watershed was the most appropriate boundary within which to consider all aspects of the water protection strategy (Golder 1992:51). The important role played by small streams and creeks in groundwater recharge and discharge was noted. The report also noted the significant impact of urban development on ground and surface water flows, in the form of reduced recharge and increased runoff. Member municipalities were encouraged to participate in setting targets and management guidelines for the protection of surface and groundwater, which could subsequently be incorporated into the policies of the Region and area municipalities (Golder 1992:xi). Other specific recommendations included identifying the impacts of rural land use on surface water, evaluating alternative rural pollution control measures, and examining ways to increase the assimilative capacity of the Grand River (Golder 1992:31).

7.4.2.5 Emergency Response

Ongoing land uses and industrial practices were seen to account for the majority of situations where water resources were threatened. The report also flagged the importance of being able to respond to imminent threats posed by spills or other contamination events (Golder 1992:43). It noted the emergency planning underway in the Region, including adoption of a Regional Emergency Plan, development of a contingency plan for oil and related spills, as well as adoption of an emergency response plan for incidents that could endanger the Mannheim water intake. The main challenge noted was to fully integrate water-related emergency responses into the existing general system of emergency planning in the Region (Golder 1992:52).

7.4.2.6 Policies and Legislation for Water Resources Protection

The report identified several areas to be addressed in legislation and policy for protecting the water resources of the Region including: priority point and non-point sources, protection of known recharge areas, protection of high sensitivity aquifers, modifying existing and future high-risk land uses, addressing surface water and groundwater, considering the requirements of both rural and urban areas, and the need for a high level of public consultation (Golder 1992:34).

It concluded that most of the policy and regulatory framework needed was already in place at the provincial and municipal levels, but that it may have been overlooked, used for other purposes, or never enacted (Golder 1992: xi). Regional sewer-use bylaws were identified as having the potential to reduce the likelihood of future contaminant releases from industrial and commercial operations. The report noted that, while it had never been done before, the sewer use by-law provided for *best management practice plans* to address material storage areas, loading and unloading areas, plant site run-off, in-plant transfer process and materials handling areas, sludge and hazardous waste disposal areas (Golder 992:37-38). The Region's process for designating Environmentally Significant Protection Areas also was identified as having potential for protecting sensitive groundwater areas, although this was not fully explained.

7.4.2.7 Community Consultation and Awareness

The support and understanding of key actor groups in the community was seen as critical to successful implementation of the Strategy. The three objectives were to create awareness of the importance of protecting water resources, provide reassurance that stakeholder interests are being protected, and develop support through participation by the different sectors of the community in implementing the Strategy (Golder 1992:46). Identified interests included the manufacturing and agricultural sectors, commercial enterprises, educators and rate-payers

(Golder 1992:46). The report recommended that the Region identify target audiences, develop appropriate messages for each, and liaise with other agencies (Golder 1992:52).

7.4.3 Water Resources Protection Strategy Implementation Plan

In February 1994, Regional Council adopted a ten million dollar *Implementation Plan* (RMOW 1994). The Plan was based on a detailed review of the work plans contained in the Golder report, as well as a review of groundwater protection programs in the United States. The elements of the comprehensive strategy outlined in the Golder report and the Implementation Plan, are reflective of leading reports and studies on the subject in the United States. This includes, for example the U.S. Environmental Protection Agency's work on strategic activities related to comprehensive groundwater protection (EPA 1992), as well as the recommendations of the U.S. National Research Council (1986) and the U.S. Conservation Foundation (1987) (see Chapter Four).[62] The Region, however, did not mechanically replicate nor limit itself to the American approach. Key concepts appearing in the U.S. literature were translated and modified to fit the priorities of the Region and to reflect the institutional context in Ontario. The Plan was organized around the framework developed in the Golder report, key components of which are reviewed below.[63]

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62 The document states: "This implementation plan includes all aspects of these successful groundwater protection programs [in the United States]" (RMOW 1994:4).

63 The Implementation Plan distinguished monitoring from management activities by replacing Golder's two categories of *monitoring & management of water quality* and *integrated watershed management*, with *water quality monitoring/assessment* and *water quality management*.

7.4.3.1 Water Resources Definition

Definition of regional groundwater resources was planned in two stages. Regional-scale hydrogeological studies were planned for the three areas containing the highest concentration of municipal wells (Figure 6). One study area encompassed much of the Waterloo Moraine, with boundaries coincident with the central core and eastern and western flanks of the Moraine where eight major well fields are found. The second study area encompassed the major well fields in the upper bedrock supplying the city of Cambridge. The third regional-scale study area encompassed two major well fields in the southeastern portion of the Waterloo Moraine in the south Kitchener (the *Parkway area*).The regional studies were to provide the hydrogeological context and technical basis for more detailed studies at individual well fields by defining the major aquifers and aquitards, regional recharge areas, groundwater flow paths, approximate capture zones of municipal well fields, and possible impacts from municipal pumping (RMOW 1994:5, A-1). Detailed studies planned for each of the fifty-five municipal well fields were to identify the land areas contributing water to these wells (i.e. *capture zones*), local groundwater flows, and estimated time of travel of water within the aquifer. In turn, findings of the detailed studies were to form the basis for delineating specific *Wellhead Protection Areas* wherein land use activities deemed to pose a threat to groundwater would be controlled (RMOW 1994:A-1).[64]

7.4.3.2 Contaminant Sources Identification

The assessment of threats to groundwater was planned at two scales: region-wide and at

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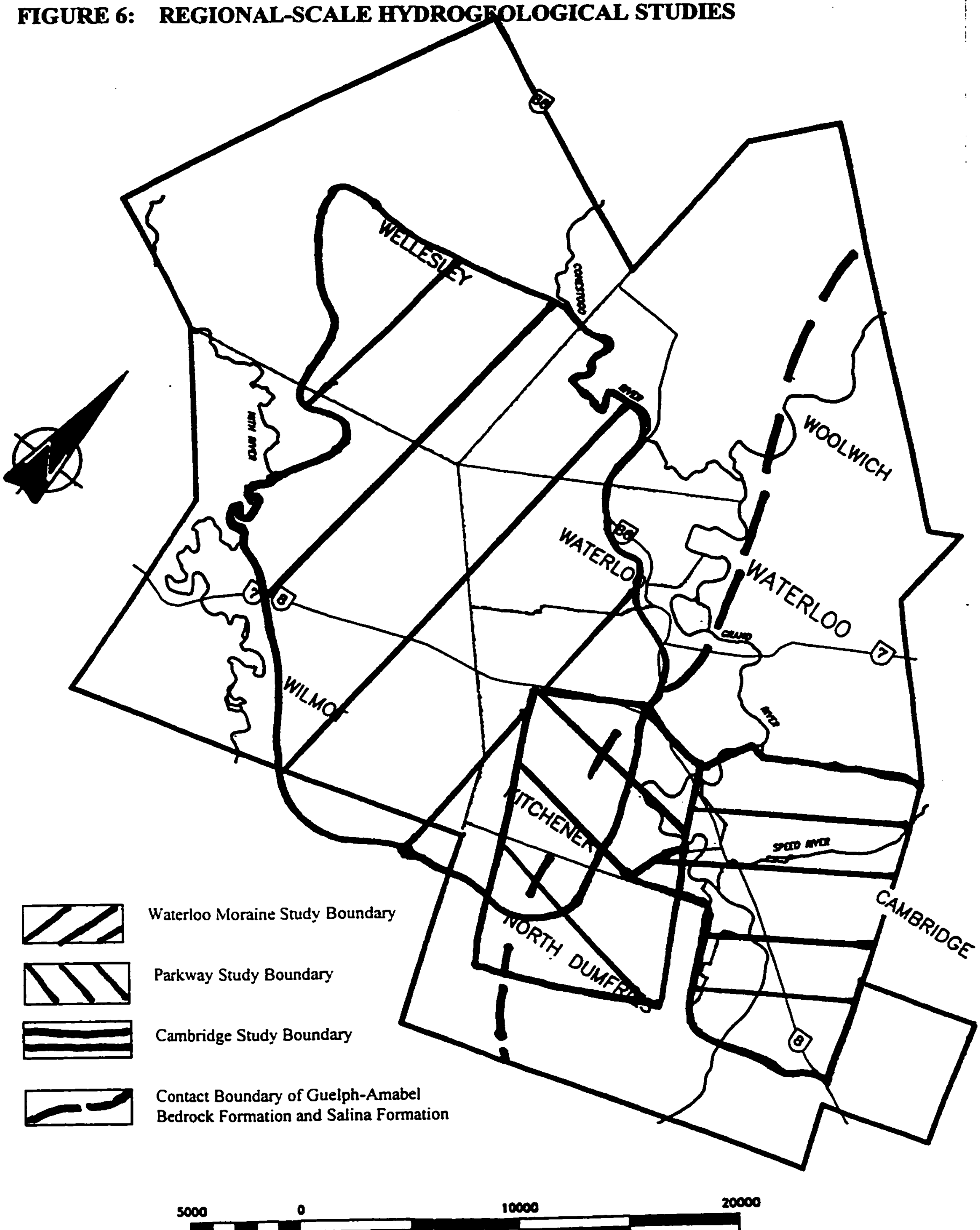
64 Wellhead protection reflects both the terminology and approach first defined in amendments to the *U.S. Safe Drinking Water Act* in 1986 (See Chapter 4).

FIGURE 6: REGIONAL-SCALE HYDROGEOLOGICAL STUDIES



Source: Golder 1991, RMOW 1996c

individual well fields. A region-wide reconnaissance inventory of potential contaminant sources was to provide preliminary information on the type and distribution of potential sources of contamination to ground and surface water throughout the Region. It was to involve collecting and organizing existing data and previous research into past and present uses of land, and interpreting and presenting information in a series of digital maps. The relative concern associated with each source or type of source also was to be estimated (RMOW 1994:A-2). A separate inventory of threats to surface water quality also was planned. It was to provide estimates of the relative contributions and loadings from point and non-point sources in urban and rural areas to surface water (RMOW 1994 A-2).

Following the delineation of well field capture zones and definition of Wellhead Protection Areas, detailed inventories of contaminant sources were planned. Well fields were prioritized on the basis of three factors: those having limited natural protection, those threatened by many potential sources of contamination, and those deemed essential to the operation of the water supply system. (RMOW 1994:5). General estimates of the risk of contamination were to be determined on the basis of the results of the initial inventory of potential contaminant sources, existing hydrogeological information, and discussions with agencies and land owners. Audits also were planned of the water systems operating at each municipal well to identify potential on-site contaminant sources and any required mitigation. Treatability assessments were to be continued for wells and well fields having water quality concerns. Alternatives for resolving current water quality concerns also were to be identified, including preferred treatment methods and treatability testing (RMOW 1994:A-6).

7.4.3.3 Monitoring

The Region planned to continue monitoring groundwater levels and quality at its production and observation wells. In addition, a network of permanent, representative observation well sites in the Region was proposed. Water table and piezometric data would be collected from these sites to record the effects of natural recharge and long term pumping on regional aquifers (RMOW 1994:A-1). Surface water quality also was to be monitored at significant locations. Groundwater monitoring plans were to be developed for each well field following delineation of capture zones. These plans were to be based on a review of the water quality data, hydrogeological data, and potential contamination sources (RMOW 1994:A-4).

A data management system was planned that would provide access to, and the ability to analyze, water resources data including geological, hydrogeological and water quality information (RMOW 1994: Table 1). The plan was to create and maintain a system that included six electronic data bases: high quality borehole logs, updated water well records, construction details and testing results for all regional production wells, water levels and pumping volumes in production and monitoring wells, the location and condition of various monitoring wells used by the Region, and groundwater interference complaints in the Region (RMOW 1994:A-5).

7.4.3.4 Emergency Preparedness and Response

The Implementation Plan listed a number of activities under the heading of *Emergency Preparedness and Response.* Two major components were maintaining up-to-date contingency plans for responding to emergencies which might threaten water resources, and developing plans for providing emergency water supply where contamination forced a shutdown of major water supply sources (RMOW 1994: Table 1). Water supply contingency plans were to be updated for wells and well fields deemed most susceptible to contamination from spills. Contingency plans were also planned for those wells considered most important from a system operation perspective, either due to large volume pumping or to their strategic location. Roles and responsibilities of Regional staff and other agencies in responding to emergencies were to be clarified, and information provided to responsible agencies on wellhead areas with little or no natural protection (RMOW 1994:A-10).

7.4.3.5 Policies/Legislation/Management for Water Resource Protection

A significant number of new policies and programs for protecting groundwater were envisioned (RMOW 1994:1). Preparatory steps included: evaluating pollution control measures for priority urban and rural sources of contamination; reviewing water resource protection experiences in other jurisdictions; and, examining existing bylaws, policies and legislation at municipal and senior levels of government which could be used to protect water resources (RMOW 1994:6, A-7/8/9).

The focus of groundwater protection policy was to be management of land uses in Wellhead Protection Areas. Some measures identified for consideration in urban areas included prohibiting certain activities, establishing reporting requirements for potential polluters, adopting best management practices[65], audits and cleanup of contaminant sources. Measures for rural areas included unspecified "changes" in agricultural practices (RMOW 1994:A-7). For surface water concerns, protection measures cited included watershed studies, modification of

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65 The term *best management practices* is not operationally defined.

land uses, and stream protection and rehabilitation (RMOW 1994: Table 1).

7.4.3.6 Community Consultation and Awareness

A variety of community consultation and awareness activities were planned to inform key actor groups about water protection issues and involve them in decision making. The Implementation Plan proposed that a *Water Resources Protection Liaison Committee* be established. The purpose of this Committee was described as follows: "... provide a forum for discussion of water resource protection issues, ... provide advice to Regional staff, and through staff to Council, on the development and implementation of water resource protection programs and policies" (RMOW 1994:8). Ongoing cooperation with local and Provincial agencies also was deemed necessary to successfully develop and implement a range of measures. Examples of areas for cooperation included:

- local municipal policies to implement the Region's water resource protection policies;
- site inspections/audits/clean-up of high risk contaminant sources;
- technical reviews of hydrogeological reports for privately serviced developments and remediation projects;
- watershed management plans;
- spill response; and
- conducting educational programs

(RMOW 1994:A-9 - A-11).

Various actions were planned to increase awareness and support among key actor groups. An educational program was planned to provide general information on water resources and the protection strategy, as well as specific information on individual wellhead protection areas.

Specific activities included such things as the development of educational materials for target groups and ongoing consultation on specific studies and issues (RMOW 1994:A-11).

7.4.4 Groundwater Protection Policy Options Paper

The first major stage in the policy development process was production of a *Groundwater Protection Policy Options* paper by regional staff in February 1995 (RMOW 1995b). It was organized around major types of contaminant sources, including historic, current and future urban point sources (e.g. industry), rural point sources (e.g. septic systems), urban non-point sources (e.g. stormwater) and rural non-point sources (e.g. pesticide applications). Options and tools for addressing each source type were identified, including an initial evaluation of the advantages and disadvantages of each (RMOW 1995b:3). Approximately forty-five possible protection tools were identified and reviewed on the basis of the following criteria:

- effective in controlling potential contamination sources;
- have an objective basis;
- the Region has the authority to implement measures;
- can be administered and implemented efficiently; and
- likely financial and other impacts on affected landowners are equitable (RMOW 1995b:9)

Few options for protecting groundwater from historic urban point sources were deemed to be available, and it argued that there was no Regional mandate to address them (RMOW 1995b:10). Options identified for managing historic urban point sources included encouraging or requiring site audits and on-site monitoring. However, it was noted that existing Provincial requirements to address these sources only applied where contamination was suspected of causing off-site environmental impacts (RMOW 1995b:10). The report endorsed use of voluntary audits by property owners (RMOW 1995b:11).

Numerous options were identified for addressing current urban point sources. The list included regulating placement of underground storage tanks, controls on storage and use of chemicals in certain areas, hazardous materials registration and inspections, best management practices, household hazardous waste collection, land acquisition, and public education. The options paper concluded that it was unclear whether the Region had the authority to implement bylaws, or equivalent regulations, to control use and storage of chemicals. Also it concluded that "considerable effort" would be required to develop, implement, monitor and enforce regulatory controls and standards for the use and management of hazardous substances (RMOW 1995b:11-12).

The option of land acquisition was deemed an effective groundwater protection measure, but was seen as an economic loss in terms of property tax revenue and an administrative burden (RMOW 1995b:13). The three options for current urban point sources assigned the fewest limitations included an expanded household hazardous waste collection program, public education to encourage voluntary actions by homeowners, and development of industrial best management practices to encourage voluntary actions.

In addition to some of the options already identified, measures for managing future urban point sources included: designating and zoning groundwater protection areas, special permitting to restrict certain land uses, use of holding zones as an interim step to delineating protection areas, subdivision and site-plan control, performance standards, and conservation easements (RMOW

1995b:15-17). The key concerns with designating and zoning groundwater protection areas were the "considerable time, effort and budget" involved in developing technically defensible boundaries for these areas and in preparing comprehensive lists of prohibited uses. Another concern was the inability of zoning to effectively control the activities that could legally occur within broad designations.

The use of special permitting to restrict certain land uses in designated areas was seen as a flexible tool, but resource intensive to administer and enforce due to its site-specific approach. Subdivision control and site plan review were seen as useful tools to address concerns such as servicing requirements and stormwater management. The use of performance standards and criteria for potential contaminant sources also was seen as a potentially useful measure if used in combination with other tools. Conservation easements were identified as an effective measure for permanently restricting development to specified uses, locations and densities on all, or a portion of, a valued site (RMOW 1995b:17).

In addition to previously identified measures, options for managing rural point sources included increased requirements for septic system use and maintenance, tighter controls on well construction and abandonment, private wellhead protection, and agricultural best management practices (RMOW 1995b: 18-19). Strengthened regulatory requirements for septic systems, for private well construction, and well abandonment, was deemed to require "considerable" resources to monitor and enforce (RMOW 1995b:18). Encouraging or requiring the use of best management practices for agriculture in sensitive areas was seen as feasible for the Region to pursue, in co-operation with farm organizations and government agencies (RMOW 1995b:19).

For rural areas, non-point sources of concern were application of sewage sludge, fertilizer use and pesticide use. Restricting land application of sewage sludge in certain sensitive areas was identified as an option, as was the use of best management practices for fertilizer and pesticide applications. Two non-point sources of concern in urban areas were lawn care practices and stormwater management. For both sources the development of guidelines and other forms of encouragement were deemed most appropriate (RMOW 1995b:20).

7.4.5 Program and Policy Development Priorities

In October 1995, Regional Council endorsed a report entitled *Priorities for Groundwater Protection Program and Policy Development*. Based on feedback received on the Options paper, a set of principles for selecting management and protection measures were enumerated. These included:

- proactive protection efforts are preferred over remediating contamination;
- take action on protection measures that are currently within the Region's authority;
- use a balance of regulatory and cooperative/voluntary measures; and
- investigate regulatory options and advocate new regulations if required.

(RMOW 1995c:4)

The three priority sources were future urban point sources, current urban point sources, and rural non-point sources. Future urban point sources were viewed as a priority based on the Region's ability to influence future development. Current urban point sources were identified as a priority based on current problems in urban areas arising from spills and poor housekeeping practices at current commercial and industrial operations. Rural non-point sources were a priority based on the potential impact of farming activities on groundwater resources.
Actions proposed for future urban point sources include:

- amending the Regional Official Policies Plan to establish Wellhead Protection Areas; and define (un)acceptable land uses for these areas;
- working with area municipalities to implement regional policies through zoning by-laws and development approvals; and
- evaluating Provincial, Regional and local municipal regulations to control future land use activities, including the use of specific chemicals (RMOW 1995c:5).

Actions proposed to address current urban point sources revolved around use of best management practices, particularly in Wellhead Protection Areas:

- developing information packages to encourage best management practices;
- education/awareness program for businesses;
- evaluating the need for financial incentives to encourage implementation of best management practices among businesses;
- evaluating the ability of Province or Region to require best management practices;
- advocating new regulations for groundwater protection if necessary; and
- targeting household hazardous water collection through depots and advertising.

(RMOW 1995c:5-6)

Actions proposed to address rural non-point sources in partnership with farm organizations and other levels of government revolved around use of best management practices, particularly in Wellhead Protection Areas:

- developing information packages advocating best management practices;
- education/awareness programs for the rural community;
- evaluating the need for financial incentives to encourage farmers to implement best management practices;

- evaluating regulatory options to require best management practices;
- advocating Environmental Farm Plans;
- initiating demonstration program for nitrogen use efficiency; and
- evaluating the impact of land applications of sewage sludge.

(RMOW 1995c:6)

Three source types assigned a low priority included historic urban point sources, rural point sources, and urban non-point sources. Historic urban point sources were accorded a lower priority because of the perceived technical and legal obstacles to compelling property owners to investigate and remediate contamination. Rural point sources were deemed to have lessor significance when compared with rural non-point sources or urban point sources. Similarly, urban non-point sources were accorded lessor significance when compared with rural non-point sources or urban point sources (RMOW 1995c:5).

7.4.6 Current Situation

The Region has invested over four million dollars in developing its Protection Strategy. Responsibility for providing leadership rests with the Water Resources Protection Group in the Water Services Division of the Regional Municipality of Waterloo. Its formal mandate is " ...to develop and to coordinate the implementation of policies and programs to protect the Region's surface and groundwater resources" (RMOW 1994:4). To date the bulk of the Region's time and resources have been directed toward completion of technical studies, with most of the available funds directed toward hydrogeological studies.[66] The Region has adjusted its

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66 For example, between 1993 and 1995, out of a total expenditure of approximately $3.4 million, less than ten percent was spent on other major activities, including: identifying potential

implementation schedule a number of times since adopting its Implementation Plan in 1994. Four factors contributing to the delays included the extra time needed to complete technical studies, staff shortages, the complexity of developing new protection policies and programs, and the need for public consultation (RMOW 1996c:3).

7.4.6.1 Water Resources Definition

As of September 1996, one of three regional-scale hydrogeological studies was completed. The Waterloo Moraine study was completed in 1995. Its key objectives were to delineate major aquifers and aquitards, define regional recharge areas, estimate capture zones and existing risks to groundwater, and estimate impacts from municipal pumping (Terraqua 1995:72).

The major sand and gravel aquifer, exposed at surface and extending throughout most of the study area, was identified as the main aquifer providing water to well fields located on the Moraine. A conceptual model of the hydrogeology of the Waterloo Moraine was developed as the basis for defining the relationship of individual well fields to major underlying groundwater units (Figure 7). Within the Moraine, a regional recharge area was identified corresponding to an area of high topographic relief. Potential capture zones were identified for each major well wherein a mix of local recharge and regional groundwater contribution occurred.

Water quality concerns identified for some well fields in the Moraine included elevated nitrate and/or chloride concentrations. Agricultural practices and road salting activities, respectively, were identified as possible major contributors (Terraqua 1995: 61,77,80). Qualitative estimates

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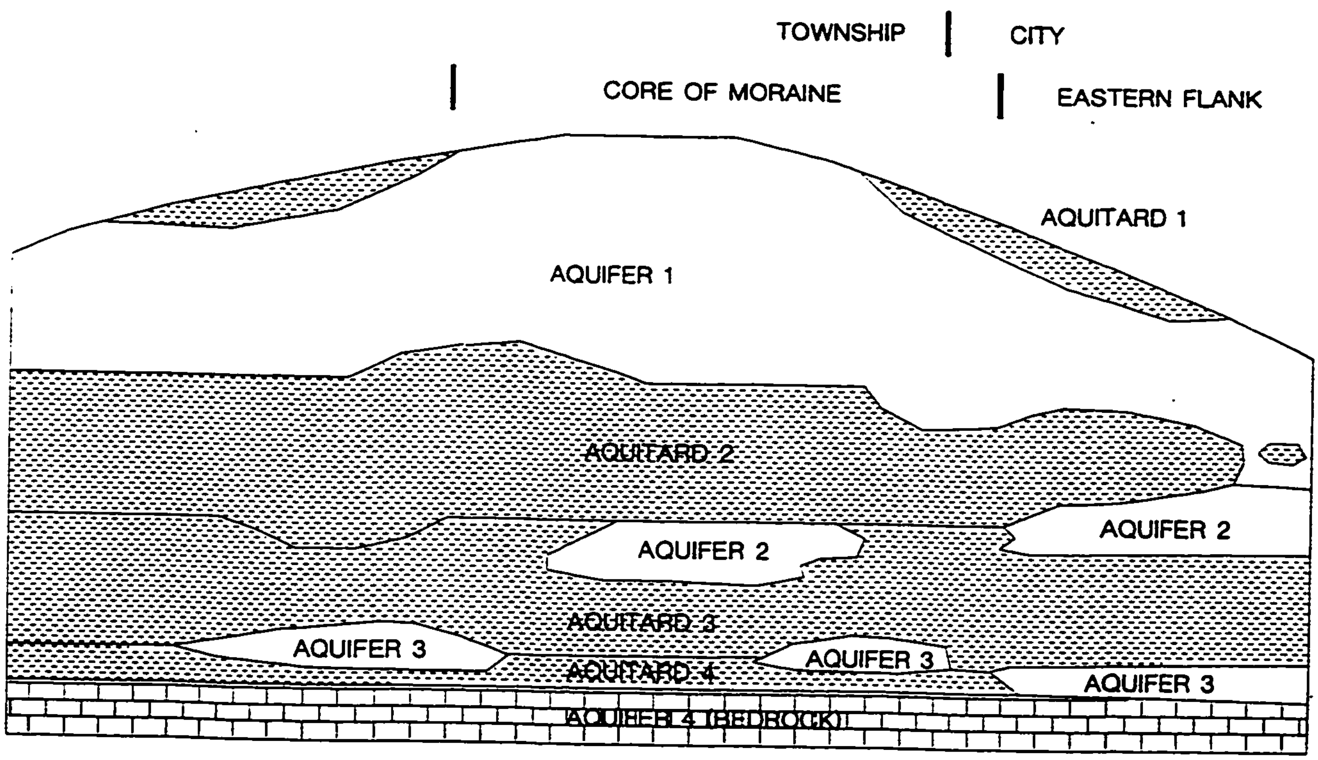
contaminant sources ($150,000), public education ($70,000) and surface water activities ($85,000) (Hodgins pers. comm.)

FIGURE 7 : CONCEPTUAL MODEL - WATERLOO MORAINE



Not to Scale

Source: Terraqua 1995

of potential risk to contamination within identified capture zones were provided, based on interpreted recharge conditions and the presence or absence of an aquitard of clays or silty-clay tills. These deposits provide a natural barrier against the movement of water and potential contaminants down into the aquifer below (Terraqua 1995:26). The study also reported on the effect of groundwater pumping on base flow to streams and interference with private wells. Evidence of historic impacts on a few individual wells in the immediate vicinity of some wells was reported, as were historic impacts on base flows to individual creeks. The study reported no significant volumes of water being taken from groundwater storage and no large scale depletion of the aquifer reservoir (Terraqua 1995:80). A program to monitor water level fluctuations throughout the Region was recommended to separate natural fluctuations from those related to municipal pumping of groundwater. Water quality monitoring was recommended in three areas: the zones of influence of individual pumping wells, regionally-based flow field capture zones, and regional recharge areas contributing to well fields (Terraqua 1995:84). Monitoring of nitrate and chloride distributions in the main recharge area was recommended to determine if the mass of nitrates and chlorides were increasing, and to provide a basis for developing protection strategies for these areas (Terraqua 1995:84).

Preliminary well field capture zones have been delineated for all of the Region's water supply production wells (RMOW 1996c:4). It involved computer-assisted modelling of two-year and ten-year capture zones. This provided a rough estimate of lands that could potentially be affected by groundwater protection policies. These preliminary areas are to be used as the basis for assessing risks and setting priorities for undertaking detailed capture zone studies. Capture zone studies are intended to provide the technical basis for three activities: delineating wellhead protection areas, developing monitoring programs, and conducting detailed contaminant sources inventories.

As of September 1996, the Middleton Street Well field capture zone study in Cambridge was the only detailed capture zone study completed. This well field is a high priority area because it supplies nearly one-half of the city's water demands, has proximate contaminant sources, has shown low levels of volatile organic compounds, and lacks information on its vulnerability to contamination (Beak 1995:ES1). Four capture zones for the Middleton Street Well field were identified, corresponding to one-year, five-year, ten-year and twenty-year travel times. Under average pumping conditions, these zones correspond to the average length of time it would take water from each zone to reach the well intake. However, the report also noted a measure of uncertainty regarding these estimated capture zones and identified additional information needs (Beak 1995:ES1.8).[67]

Approximately twenty additional detailed capture zone studies for individual well fields are to be initiated over the next three years, with a further ten studies to be undertaken each following year, until all the Region's well fields are completed (RMOW 1996c:1).[68] The Region plans to hire groundwater specialists from the United States review its groundwater modelling activities and to confirm the technical validity of the findings (Hodgins pers. comm.).

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67 For example, more information is needed on the hydraulic properties of the bedrock Guelph-Amabel Formation, its horizontal and lateral extent, its thickness, vertical hydraulic conductivity, and its flow porosity.

68 Two capture zone studies underway include the Baden and Wilmot Centre well fields in Wilmot Township. The Baden well field is experiencing high nitrate concentrations and the Wilmot Centre well field is nearby (RMOW 1996c:5).

7.4.6.2 Contaminant Sources Identification

A regional survey of potential contaminant sources was completed in April 1996. The goal of the study was to compile a region-wide inventory of known and potential sources of surface and groundwater contaminants, based on existing data bases and previous studies (CH2M 1996). The results of the inventory are intended to help the Region assess the relative risks posed by potential contaminant sources, prioritize areas for more detailed investigations, evaluate and implement land use management options (CH2M 1996:1-2). Information on three types of point sources were compiled in digital format: "known" sources, "potential present" sources, and "potential historic" contaminant sources. Each source was given a qualitative rating (high, medium, low) of risk to contaminate ground or surface water, based on a set of weighted criteria developed for the study.[69]The detailed ranking process revealed over 1,000 potential present contaminant sources. Of the total, 47 sites were ranked high contamination potential, 845 sites ranked medium and 120 sites ranked low (CH2M Table 2.19).

Potential historic contaminant sources were ranked on the basis of a pre-coded hazard potential table developed from *Standard Industrial Codes* (CH2M 1996:2-53).[70] A previous historical survey for Cambridge and the surrounding rural area identified 947 locations where contaminants may have been used, stored or disposed of. The types of activities with the largest number of locations included the automotive vehicle industry (including gas stations),

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69 For example, the criteria for "present potential" contaminant sources included the following categories: material characteristics (30%), material physical state (20%), material storage, transportation and receipt (20%), volume of material (15%), year of operation (10%), and number of employees (5%) (CH2M 1996:2-50).

70 Standard Industrial Classification (SIC) codes are a method of grouping industries by type of specialization that are established by Statistics Canada (e.g. *Petroleum Refining and Related Industries*, or *Chemicals and Allied Products*).

machinery, transportation, primary metal, primary textile, and household furniture (CH2M 1996:2-36). For the Kitchener-Waterloo area, earlier studies identified 1,381 locations, of which 551 had Standard Industrial Code classifications. Of the latter, the most common activities included fabricated metal products, machinery, furniture and fixtures, printing and publishing and electrical and electronic products (CH2M 1996:2-37).

The investigation of non-point sources focussed on rural land uses. Key sources included sediment loss from rural areas, pesticides and chemical fertilizer use, land-applied livestock manure and sewage sludge (CH2M 1996:3-1). Potential sources were rated for their potential to contaminate surface water or groundwater. Maps of the Region were prepared of the distribution of pesticide, nitrogen and phosphorous applications including the relative risk of contaminating surface water and groundwater from these sources. Large blocks of rural Waterloo Region were identified as high risk areas. The rating system was based on an analysis of application rates combined with potential for soil erosion, in the case of surface water, and soil infiltration potential, in the case of groundwater (CH2M 1996:1-4).

The Region-wide study of contaminant sources is a precursor to more detailed contaminant source studies within the capture zones of specific wells. Identified sources do not necessarily indicate the presence of contaminants that could enter surface or groundwater, and management actions were not considered in assessing possible threats. Some sources, such as urban non-point sources and septic systems, were not assessed for lack of available information (CH2M 1996:1-5). A detailed inventory of contaminant sources has been undertaken for the Middleton Street Wellfield. It provides a detailed listing of businesses and their activities within the well field's capture zone that may be potential sources of contamination. Direct contact with businesses on the list will be used as a means to inform them of their location within a sensitive groundwater area and to encourage preventative action (RMOW 1996c:6).[71] Inventories of potential sources of contamination in rural areas will focus on confirming agricultural practices in well field capture zones and the potential sensitivity of soils to contamination (RMOW 1996c:6).

7.4.6.3 Monitoring

Regional water supplies are currently tested for more than 150 chemical, microbiological, radiological and physical parameters. Approximately 5,000 samples are collected and analyzed yearly (RMOW 1995a). Microbiological testing of each water source and distribution system is done once per week, while testing for chemical and physical parameters are done monthly, quarterly or annually.[72] Aesthetic objectives for hardness, iron and manganese were not met at several locations because of high natural mineral concentrations (RMOW 1995d).

The Region has a *Supervisory Control and Data Acquisition System* that uses remote processing units to enable Regional staff to continually monitor and oversee its entire water supply, treatment and storage system. A wall-size four screen mosaic displays over one hundred sites, providing operators with a geographic and technical view of pressure zones, flows, residuals

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71 An inventory of potential sources of surface water contamination, and their relative contributions to water quality problems in the Grand River has been completed, including an initial evaluation of costs and benefits of various surface water protection measures (RMOW 1995a:9). The long term objectives are to determine what control measures are needed to protect surface water quality, to set priorities, and to undertake detailed studies on the impacts of various land uses on surface water (RMOW 1996c:10).

72 Over a recent monitoring period (Oct. 1993-Sept. 1994) water quality met or exceeded all health-related Ontario Drinking Water Objectives, except in two rural communities that had elevated nitrate levels present (Baden and Rosenville).

and information on the status of significant equipment. The system gives a remote operator manual control of certain equipment and alarm functions related to high or low pressures and water levels, and equipment failure.(RMOW 1995a:8).

The Region plans to add to its network of monitoring wells at individual well fields following capture zone delineation. However, significant work remains to implement plans for monitoring water quality at strategic points up-gradient of municipal well fields so as to provide an "early warning" capability to allow opportunity to take action before contaminants exceed water quality objectives (Hodgins, pers. comm.). In addition, little progress has been made to develop a strategy for monitoring regional water quality trends. The Region has an ongoing program to continuously monitor water levels at 40 observation wells throughout the Region. Long term records from this monitoring are intended to help address the following issues: the ability of an aquifer to sustain present rates of withdrawal; the effects of pumping on private wells and wetlands; conceptual understanding of historic water levels around well fields; calibrating flow and transport models; and providing information for various studies, rehabilitation work and permit requirements (RMOW 1995d).

7.4.6.4 Emergency Preparedness

The Region responds to contamination events as they arise. For example, when monitoring found elevated nitrate concentrations in one of the Region's well fields in 1995, the contaminated well was shut down and a deeper bedrock well was drilled. Also, the Region recently completed treatment facilities to remove iron and manganese from a number of wells having this problem (Robinson, pers. comm.).

With regard to plans to improve emergency preparedness and response, contingency plans for individual well fields have not yet been prepared. While the Region has had internal discussions about how to deal with spills, it has not yet resolved the need for establishing a regional emergency response group.

7.4.6.5 Policies/Legislation/Management for Water Resource Protection

The time-line for finalizing protection policies and programs has shifted significantly from the original time-table approved in 1994. The Implementation Plan proposed that the review of existing bylaws, policies and regulations, including an evaluation of rural pollution control measures and urban groundwater pollution control measures, be completed by the end of 1994. It also indicated that water resource protection policies were to be ready for implementation by mid-1995.

In January 1996 the Regional Official Policies Plan received final approval from the Provincial government. Under its section on Water Resources (ROPP 5.22), the Region committed to implement the Water Resources Protection Strategy, in consultation with government and non-government actors. A schedule is attached to the Plan entitled "Sensitive Groundwater Areas". In these areas certain specified uses (e.g. waste disposal facilities) are prohibited outright, while others (e.g. industrial and warehousing uses) may be permitted subject to approval of a report detailing the proposed activities, use of chemical substances to be used and stored, as well as measures to prevent and contain spills. While only the Mannheim recharge area is identified as a Sensitive Groundwater Area, additional areas and new policies related to these areas will be considered as future amendments to the Regional Plan.

In February 1996, Regional staff indicated that they were considering a range of options for defining protection areas around well fields (WRPLC 1996a:2). They began by examining how other jurisdictions delineated wellhead protection areas and what restrictions applied, in order to develop the basis for defining *Wellhead Protection Areas* and for restricting certain land uses within these areas. By May, the time-table for reviewing bylaws, policies and legislation had been extended to the end of 1996, while water resource protection policies were to be finalized and implemented by mid-1999 (RMOW 1996c).

In September 1996, a draft paper on land use policy was released for discussion with the Water Resources Protection Liaison Committee. The key recommendations put forward in that report addressed groundwater protection areas in well fields as well as regional recharge areas. The draft report recommended that *Wellhead Protection Areas* be established with two-year and ten-year time-of-travel zones delineated for each regional well. These zones would be based on three-dimensional numerical modelling of groundwater flows in order to provide the most accurate method for producing defensible boundaries (RMOW 1996d:16). The rationale for having these two zones was to provide the *minimum* and the *maximum* time required to take action, as follows: respond to a spill, detect contaminant plumes, investigate mitigation options, institute remedial measures, and develop alternative supplies (RMOW 1996d:14).

Land uses of potential concern included businesses that manufacture, handle or produce hazardous materials (RMOW 1996d:14). It recommended that small, medium and large generators of hazardous materials be prohibited from locating in the two-year time-of-travel zone, and that medium and large generators be prohibited from locating within ten-year time-of-travel zone. While not clearly explained, the document suggested that restrictions in the larger ten-year zone were reduced because of the potential for "economic hardship" to the community from placing the same restrictions on land uses in the ten-year zone as those used in the smaller two-year time-of-travel zone (RMOW 1996d:19).

The draft report recommended designation of *Aquifer Recharge and Surface Drainage Areas*, arguing that existing and future water supplies could only be protected by establishing these protection zones for regional aquifers (RMOW 1996d:13). The areas would be defined to include locations where permeable geological materials of a regional aquifer are exposed at ground surface (i.e. less than two metres of till) as well as the surrounding surface area draining toward these permeable deposits (RMOW 1996d:17). The same restrictions proposed for ten-year time-of-travel zones in wellhead protection areas were recommended for these recharge areas (RMOW 1996d:19).

The draft report noted the need for additional work to define required land use restrictions. It recommended further discussions with area municipalities regarding use of local zoning bylaws to restrict new land uses, in support of the proposed Regional policy, and for discussing possible local mechanisms to control existing sources of contamination. The report also observed that discussions of preferred tools for managing contaminant sources and for implementing controls were underway within the working groups established by the Liaison Committee. The Region plans to hire groundwater specialists from the United States provide independent advice on its policy options (Hodgins pers. comm.).

7.4.6.6 Community Consultation and Awareness

The Region planned ongoing consultations to seek input from interested groups on the development of the overall Strategy and the design of specific policies (RMOW 1995a:9). In

1994, a public awareness program was initiated to inform and educate the public about water resources protection, and to develop community support for the Strategy. Three target audiences include urban businesses, urban homeowners, and rural residents (WRPLC 1994b). Since that time, the Region has held numerous open houses and public meetings to communicate the results of technical projects associated with the Strategy (RMOW 1996c:10). A variety of publications also have been produced to promote education and awareness among residents.[73] Over the last two years the focus of the Region's public awareness program has been promoting the month of May as *Water Awareness Month.* Activities include co-sponsoring and publicizing local community events, sponsoring tours of municipal wells and Regional facilities, developing a logo and related memorabilia, and preparing Regional displays and presentations for community fairs (RMOW 1996f). Some of the measures promoted for households include household hazardous waste days for chemical disposal, use of oil recycling facilities at car repair shops, careful storage of household and work-related chemicals, fixing leaks, using environmentally-friendly substitutes for household and garden chemicals, and sealing unused wells (RMOWnd.b; 1996e:2).

The focal point for core actor groups is the Water Resources Protection Liaison Committee. Soon after Regional Council's endorsement of the Implementation Plan in 1994, the Water Resources Protection Liaison Committee held its first formal meeting. The Committee is chaired by a staff member of the Water Services Division of the Region. Its 17 members include Regional Councillors, area municipal staff, one staff from each of the Ministry of Environment

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73 Some of these publications include: *Water quality data report for the Region's municipal water supply system, Facts about, Waterloo Region's drinking water quality, How well is your well?, Feed and care of your septic system, Healthy lawns and gardens with less water, 40 tips to be water wise, Household hazardous waste days, What's the cost of water, Guide to water softeners, Sewer use by-law 1-90, Water supply, treatment, distribution, integration* (RMOW nd.a).

and Energy, the Ministry of Agriculture, Food and Rural Affairs, and the Grand River Conservation Authority, members of the Kitchener-Waterloo and Cambridge Chambers of Commerce, a member of the local APT Environment group, the Waterloo Federation of Agriculture, and a member of the Waterloo Centre for Groundwater Research.[74] Staff support is provided by various regional departments (RMOW 1996c:7).

At its first meeting, members of the Liaison Committee agreed it should provide a forum to share information, to facilitate exchange of ideas regarding water resources protection issues, and to provide advice, through Regional staff, to Regional Council on water resource protection policies and programs (WRPLC 1994a:4). Between May 1994 and August 1996 the Committee met eight times to discuss and debate a wide range of issues. Also, three working groups have been formed by the Liaison Committee to focus on specific tasks enumerated in the 1994 Implementation Plan, The *Future Urban Point Source Working Group*, *Current Urban Point Source Working Group* and *Rural Non-point Source Working Group* are chaired by Regional staff, with representatives from various other actor groups (RMOW 1996c:8). The Rural Non-point Source Working Group has been the most active of the three groups, and contains the largest cross-section of core actor groups, including the Waterloo Federation of Agriculture, Ontario Soil and Crop Improvement Association, Waterloo Region Stewardship Council, Grand River Conservation Authority, Ontario Ministry of Agriculture, Food and Rural Affairs, and the townships of North Dumfries, Wellesley, and Wilmot (RMOWnd.a).

The key issues for discussion by the Future Urban Point working group include amendments

74 Initially the Ministry of Natural Resources had been identified as a member of the Committee. However, due to significant down-sizing in its field office, no representative from the Ministry was appointed to the Committee (Cherry, pers. comm.).

to the Regional Official Policies Plan to establish wellhead protection areas, area municipal zoning by-laws and development control, and a review of regulatory options to control on-site activities (RMOW 1996c:9). At present the two main thrusts of the Current Urban Point working group are to compile information on existing best management practices for industry falling within certain Standard Industrial Codes, and to work at educating the business community. However, o this point it has not been very active (Hodgins, pers. comm.). The Rural Non-point Source Working Group meets on an ongoing basis to provide direction on rural groundwater protection policy and program concerns.

A *Rural Groundwater Awareness Program* is currently under development. This will provide information to the rural farm and non-farm communities on the need to protect groundwater, and will promote voluntary adoption of measures to minimize the impacts of land uses on groundwater quality. The program has the following specific objectives: promote family health benefits of farm and homestead well protection, and publicize the economic benefits of using best management practices (RMOWnd.b). Also, a partnership, lead by a coalition of farm organizations, has formed to examine the efficient use of nitrogen by operating farms in the Region. Five farms will participate, each using different cropping systems (Hunsberger, pers. comm.).

7.5 Summary

The formal starting point of the development of the *Water Resources Protection Strategy* was the release of a Request for Proposals by the Regional Municipality of Waterloo in August, 1990. The purpose was to hire a consultant to identify a set of tasks and priorities for implementing a comprehensive groundwater strategy. The Region described the key issues that the consultant's report was to address, as follows:

- focus on groundwater, in particular quality issues, hydrogeologic setting, aquifer management, and groundwater protection policies;
- generate information relevant to surface water management and protection;
- recommend mechanisms for managing the data generated by the strategy; and
- address public participation and education.

The Golder report that followed played an important role in the development of the Strategy by providing an initial implementation framework for the Region. It addressed each of the issues identified by the Region by means of a critical commentary on the current situation and information gaps, by describing key elements of a comprehensive strategy, and providing recommendations for further study. Less than two years after the report was finalized, Regional Council endorsed a ten million dollar, multi-year *Implementation Plan* for a comprehensive strategy. There is basic continuity between the Golder report and the Region's *Implementation Plan*. The latter is organized around the key elements outlined in the former, and follows from a detailed review of the work plans contained in the Golder report. The Plan also is informed by a review of groundwater protection programs in the United States. The elements of the Strategy are reminiscent of key concepts from the U.S. literature and U.S. federal legislation, such as the orientation to wellhead protection. Key concepts are translated and modified to fit the priorities of the Region and to reflect the institutional context in Ontario.

The Strategy sets out an ambitious agenda for the Region and its partners. Following approval of the *Implementation Plan* by Regional Council, regional staff and the Water Resources Protection Liaison Committee embarked on a series of studies, investigations and discussions. These activities added a level of detail that was previously lacking. Subsequent documents increase understanding of the groundwater resources of the Region, define key concerns and priorities, follow up the key tasks in the *Implementation Plan*, and set the stage for a review of management and policy options. While original time-lines have slipped, the Region has continued to pursue the tasks it set out in its original plan. The adequacy of the Strategy, including the Golder report and the activities and reports which followed, is discussed in the next chapter. Its strengths and weaknesses are evaluated in light of the key principles of an ecosystem approach.

CHAPTER 8
GROUNDWATER PROTECTION STRATEGY IN WATERLOO REGION: CRITICAL ANALYSIS

8.1 Introduction

This chapter presents a critical analysis of Waterloo Region's *Water Resources Protection Strategy*, focussing on the extent to which it incorporates guiding principles of an ecosystem approach. The assessment has been conducted at a relatively early stage in the evolution of the Strategy. Some important decisions with respect to the rules and instruments to be applied and the partnerships necessary for implementing the Strategy are pending. These future decisions will have a direct bearing on the extent to which additional progress can be made toward an ecosystem approach.

While the evaluation concentrates on the Strategy itself, progress toward an ecosystem approach is influenced by the broader institutional context in which the Region and its partners function. Experience in other contexts suggest that obstacles to implementing an ecosystem approach are numerous and pervasive. Issues such as lack of information, limited understanding, confusion over roles and responsibilities, lack of resources for long term monitoring, and competing interests are common (see Chapters Three and Four). Evidence in the Waterloo case suggests that there are a number of similar concerns. The progress achieved to date in Waterloo is remarkable, given constraints such as lack of provincial support, unclear municipal authority, outstanding technical issues, and un-tested actor support for un-precedented policy decisions. Major changes within the broader Provincial sphere are contributing to uncertainty about the future choices available to the Region (see Chapter Six). These changes will impact the regulatory and decision making framework, the roles and responsibilities of key actor groups, and the availability of resources.

8.2 Analysis of the Evidence

Theoretical grounding for addressing the question of how an ecosystem approach might inform the design of new strategies for protecting groundwater was provided in Chapter Three. A set of guiding principles were enunciated which describe an ecosystem approach. In addition, numerous barriers to adopting ecosystem approach were identified which present a continuing challenge to implementation that can impede progress toward an ecosystem approach. Chapter Five introduced a conceptual framework which provides the structure for defining a set of key questions and operational measures to evaluate the degree to which an ecosystem approach is reflected.

The method for evaluating progress is described in Chapter Two. It is based on an understanding of an ecosystem approach as a composite whole made up of multiple and interconnected parts. The individual parts or constituents that together describe an ecosystem approach to groundwater protection are represented by twenty-one attributes. They provide a clear and consistent set of factors or reference points for evaluating progress toward an ecosystem approach. The assessment of the strengths and weaknesses of the Strategy were based on the presence and emphasis accorded the attributes associated with each of the guiding principles (Table 7).

Evidence garnered from written sources, supplemented with interviews, was analyzed in a deductive process involving two steps. The first step was a test for presence/absence to determine whether the Strategy incorporated guiding ecosystem principles and attributes. It involved a search of the evidence based on representational, or manifest, meaning contained in the sources (i.e. *it means what it states*).

TABLE 7: CHECKLIST FOR EVALUATION

PRINCIPLE		√ (attribute screened)
Boundaries	Use ecological boundaries for planning, recognizing a hierarchy of nested systems with variable physical and temporal scales.	• well-fields • regional systems • watersheds and basins
Objectives	Specify objectives, indicators and targets related to valued ecosystem functions.	• hydrogeological processes • biodiversity support • sustainable use
Functions.	Analyze groundwater-ecosystem structure, functions, processes.	• local and regional hydrogeology • surface water-groundwater interaction • aquatic and terrestrial habitat linkages
Cumulative Effects	Assess and monitor potential cumulative effects of multiple stresses on groundwater ecosystems.	• stress-response framework - land use stresses - groundwater-ecosystem functioning
Integrated	Support preventative strategies with integrated set of instruments.	• regulation, economic incentives, voluntary measures • protection, prevention, control, remediation functions
Adaptable	Influence human activities through approaches that are responsive to new information, technological developments, changing conditions and priorities.	• flexible tools and instruments • internal/external review
Coordinated	Secure the participation and accountability of core actors for defining and achieving collective outcomes.	• coordinating mechanisms • protection partnerships
Catalytic	Develop the institutional capacity to design and implement rules and instruments for groundwater protection at the community level.	• authority and policy framework • resources • information management system • technical support • recognition

The second step involved a qualitative judgement regarding the significance, or importance, accorded a given ecosystem principle. While the first step reflects a more or less straight-forward test for presence or absence, the second required judgement concerning the degree of emphasis given a particular theme or characteristic. The significance or *intensity of expression* was inferred from terminology used, the relative attention given to something in the evidence, and the justification provided for certain decisions or actions. Inferences were cross-checked by considering supportive or contrary evidence from additional sources, particularly interview responses.

8.3 Evaluating Progress

This section is structured around eight key questions which direct the analysis to the core principles of an ecosystem approach.

8.3.1 Do the planning boundaries encompass connections among different ecosystem levels?

The Strategy recognizes multiple ecosystem boundaries for planning within the confines of the Regional Municipality. It adequately addresses the boundaries principle as it applies to well fields and regional groundwater system, but does not adequately address linkages to the boundaries defined by the Grand River watershed or major bedrock aquifers extending beyond the Region's borders.

In early discussions with the Water Resources Protection Liaison Committee, the Region identified three sets of planning boundaries, defined by regional recharge areas, capture zones for municipal wells, and time-of-travel zones for groundwater (WRPLC 1994a). The issue of the appropriate physical and temporal boundaries have been discussed has been expressed as a question of planning to protect well fields versus planning for groundwater systems:

> In order to establish land use policy, such questions as the scope of protection need to be addressed (regional water supply versus groundwater resource) as well as the time frame need to be taken into account (WRPLC 1994c).

The primary boundary for planning purposes is based on an interpretation of local hydrogeological conditions around each of the Region's wells, in particular those areas that contribute water directly to these wells. The Strategy also encompasses regional recharge areas associated with the Waterloo Moraine aquifer complex. However, to date most attention has been directed at planning around municipal well fields rather than planning for groundwater on a regional scale. Only a small portion of the major bedrock aquifer system associated with the Guelph-Amabel formation is accounted for, as it relates to Cambridge's water supply. Linkages beyond the borders of the regional municipality to the Grand River Watershed and the Great Lakes Basin of which it is a part, are not enumerated.

Records of Liaison Committee meetings confirm that significantly less attention has been given to planning for regional groundwater systems than protecting well fields. Minutes of Liaison Committee meetings held in 1994, 1995 and 1996 indicate that regional groundwater systems were discussed directly only three times: once with regard to their coincidence with municipal boundaries; once with regard to protecting future water supplies; and once with regard to the idea of classifying sensitive groundwater areas in the Region.

Planning for surface water and planning for groundwater are presented as separate tasks. The following statement illustrates the tendency to compartmentalize the two domains:

> Less effort has been spent to date on surface water protection than groundwater protection, for several reasons. Most of the Region's water supply is currently derived

> from groundwater. Several agencies (e.g. GRCA, MNR) have existing programs for surface water protection; and there is more legislation related to surface water than groundwater (RMOW 1996c:10).

While suggesting that surface water protection activities will be implemented in cooperation with the Grand River Conservation Authority, there is no record of discussion about the relationship of surface watershed boundaries and groundwater system boundaries, and no recognition of the numerous sub-watershed studies that have been undertaken in the last five years in the Region and the Grand River watershed which incorporated groundwater concerns (MOEE 1997a). For example, the Laurel Creek study recommended specific design measures to maintain groundwater quality and quantity, and its contribution to stream flow and natural areas. It included recommended practices that emphasize at source water infiltration controls as well as restrictions on land uses in significant recharge areas posing a contamination threat to groundwater (Triton 1992). The willingness of the city of Waterloo to integrate specific goals, objectives and targets for groundwater into its municipal planning processes and policies represents a critical building blocks for an ecosystem approach to groundwater protection in the Region (Waterloo 1993).

8.3.2 Is decision-making guided by a full range of ecosystem objectives?

The Strategy fails to set clear ecosystem objectives and targets. Written evidence suggests that the concept of ecosystem objectives are not fully appreciated or understood. The Golder report was written without the benefit of a clear set of objectives. It described the general goal for the Strategy in a single phrase: "...to address the risk from existing sources of contamination while minimizing the risk of new sources of contamination occurring" (Golder 1992:vii). Subsequent documents suggest that little progress has been made beyond similar broad goal statements.[75] Long term outcomes have not been supported by clear objectives and indicators covering the full range of groundwater-ecosystem functions. This includes neither quantitative or descriptive measures.

The Strategy's focus on the Region's drinking water supplies lack measurable indicators of long term sustainable yield of groundwater to ensure the system will continue to provide a secure source of drinking water for a growing population. The Strategy also has neglected to integrate goals related to healthy groundwater-ecosystems with sustainable human uses and benefits. Hydrogeological processes and functions are analyzed but no benchmark objectives have been developed. This will make it difficult to interpret the significance of detailed technical descriptions for planning policy. Similarly, the support provided to aquatic and terrestrial habitat by groundwater is addressed peripherally rather than as a core objective. The Strategy only goes so far as to acknowledge its "... beneficial impacts on surface water quality ..." (RMOW 1995:b:2). Without agreed-to outcomes and measurable indicators it will be impossible to assess performance or measure the impact of decisions which might favour one objective at the expense of another.

Evidence from interviews confirms minimal appreciation of the need to plan for a full range of ecosystem objectives.[76] When asked to describe the main objectives of the Strategy, respondents generally provided anthropo-centric descriptions of the objectives of the Strategy. The most

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75 The following is a typical statement found in Strategy documents: "The overall objectives of the strategy are to limit the risk of contamination of surface water or groundwater resources from historic, existing or future land uses" (RMOW 1995b:2; see also RMOW 1996c:2).

76 For a summary of responses to all of the interview questions, see Appendix C.

common response was: *"to protect the groundwater (resources) of the Region"* (9 of 14 respondents). The next most common response was: *"to prevent (further) contamination of groundwater supplies"*(8 of 14). Additional objectives identified by individual respondents included protecting the quality and quantity of groundwater, understanding the movement of contaminants in groundwater, and limiting risk to groundwater. None of the committee members mentioned the importance of developing objectives for maintaining a healthy ecosystem.

The rationale for pursuing the Strategy is limited to groundwater's direct use for drinking water supplies. Core actor groups need to develop a common set of objectives and indicators that affirm the goal of maintaining the full range of ecosystem functions and services provided by groundwater. This will involve seeking agreement on a long term vision that provides guidance on addressing diverse interests and priorities.

8.3.3 How are groundwater-ecosystem processes, functions and linkages characterized?

The Strategy displays significant effort to characterize local and regional groundwater systems. There has been a significant investment of resources in groundwater characterization. Its weaker attributes are qualitative descriptions of groundwater-surface water interactions and linkages to aquatic and terrestrial ecosystems. There has been ongoing discussion by the Liaison Committee about technical criteria for delineating capture zones and wellhead protection areas. Discussions at Committee have focussed on three specific issues: understanding the concept of Time-of -Travel zones, justifying the selection of specific times of travel, and being satisfied that these zones can be technically defended in an adversarial process. Some of the challenges of understanding the Time-of-Travel concept are illustrated in the following statement recorded in the minutes of one of the Liaison Committee meetings:

> It is not implied that a drop of water or chemical at the surface would flow to a well in 2 and 10 years. Rather, this study is meant to outline land areas where land use management may be needed to ensure a long term potable water supply. It is anticipated that more detailed 3-D modelling of wellheads will be used to delineate capture areas which will form the basis for land use policies/programs (WRPLC 1996:4).

When asked to identify major outstanding issues, interview respondents frequently identified technical issues and questions of justification for delineating protection zones. However, the issue mentioned most frequently was the controls to be applied in urban well-fields (10 of 14) and rural well-fields (7 of 14). The juxtaposing of technical concerns and the rules for protecting groundwater suggests an underlying concern for the ability to justify and defend the Strategy to affected landowners and against future potential opponents in forums such as the Ontario Municipal Board.

In the absence of provincial standards or agreed methods for groundwater characterization, the Region perceives that the burden of proof rests with it, to justify any new rules related to groundwater protection. The Region has responded to these expressed concerns with additional investigations, sophisticated groundwater modelling, and introduction of a peer review process. More recently it has begun to turn its attention to fundamental policy decisions that are needed to provide a supportive context for this technical analysis and to qualify the demands and expectations of key actor groups (see section 8.7).

Major hydrogeological functions, such as the movement, storage and discharge of groundwater are investigated at different scales. This includes factors such as the areal extent of recharge areas, the direction of groundwater flow systems and capture zones contributing groundwater to municipal well supplies. Regional systems are described in terms of their contribution to the Region's producing wells, which provides the technical basis for defining local well field capture zones. For example, the Waterloo moraine study noted that its characterization of the geological and hydrological conditions of the moraine: "... have permitted a 'big-picture' to be developed with respect to individual well fields" (Terraqua 1995:75). Significantly less consideration has been given to the ecosystem support functions provided by regional groundwater systems.

The bio-diversity support function provided by groundwater to aquatic and terrestrial ecosystems have not been characterized adequately. The Golder report described the need to maintain base flows provided by groundwater to local streams and rivers as a physical constraint that should limit the use of water resources in the Region. It notes: "... understanding surface water/groundwater relationships is fundamental to prevent one resource from being developed at the expense of the other" (Golder 1992:4).The Waterloo Moraine study provides only a general description of potential interference of municipal groundwater withdrawals on stream flow in proximate creeks (Terraqua 1995). The draft hydrogeological study of the Parkway area considers ecological relationships more explicitly (Terraqua 1996). It identifies certain reaches in nearby streams where considerable groundwater discharge is supporting cold water habitat. It also identifies conditions where well fields are being recharged by surface water. In each case these conditions are described with reference to municipal wells:

> The groundwater/surface water interaction in Blair and Doon South Creeks, while perhaps significant in terms of the ecological function which groundwater discharge plays, is of lessor importance in the evaluation of the two well fields, given the relative distance from production wells. (Terraqua 1996:7)

However, the technical studies do not quantify baseflow contributions of groundwater to area streams and wetlands or calculate water budgets. From an ecosystem perspective, indicators and targets against which to evaluate the significance of these ecological functions are needed.

While surface and groundwater characterization can be undertaken separately, their hydrologic interactions have a direct bearing on both systems, and therefore require integrated analysis (Crowe 1996:248). A model approach to groundwater characterization is provided by the work being undertaken independent of the Strategy by the Grand River Conservation Authority as part of its River Basin Management Strategy. The conservation authority is developing a watershed-scale assessment of groundwater systems. It is integrating information on stream flows and temperature, fisheries, wetlands and surface water hydrology, with hydrogeological considerations, such as geology and groundwater chemistry.

> This broader focus encompasses resource management issues which will include aquatic and terrestrial system issues in addition to the traditional groundwater availability and protection. This approach will require an integrated groundwater and surface water characterization and modelling effort. (GRCA 1995).

The Waterloo Strategy has not yet taken this next step of complementing the considerable hydrogeological analysis of groundwater resources with equivalent effort to characterize the ecosystem and bio-diversity support functions it provides.

8.3.4 How are the stresses associated with diverse land uses and groundwater-ecosystem functioning being assessed and monitored?

The Strategy's strongest attributes related to assessment and monitoring are its consideration of multiple land use stresses, at a local and regional scale, and its attention to data collection and information management. The major weaknesses are the absence of an explicit framework for assessing potential cumulative effects on groundwater functioning and failure to establish clear links between assessment and decision making processes.

The reconnaissance study of potential contaminant sources considers both rural and urban sources, and provides detailed criteria for rank-ordering them. For urban point sources, potential sources are identified on the basis of individual characteristics rather than the potential sensitivity of proximate groundwater systems. For rural non-point sources, areas of high vulnerability to contamination are identified using a limited number of physical criteria and land use conditions. However, it is not clear how these identified areas at risk are related to regional recharge areas that are to be protected from the cumulative impacts of non-point sources. The detailed inventory of contaminant sources, such as for the Middleton Street well field, generate detailed lists of businesses and activities that could pose a concern. However, there is no explanation of how potential threats associated with multiple contaminant sources will be assessed.

The draft land use policy paper highlights concern about hazardous waste generators in the vicinity of regional groundwater recharge areas and municipal wells. However, it appears to have overlooked a wide range of land uses that could have adverse cumulative effects. For example, small waste generators such as schools, offices, car washes, and residential development are not addressed (RMOW 1996f:Table 4).[77] The common concern over potential contamination of groundwater has overshadowed any discussion of the potential cumulative effects of land use change on essential hydrogeological processes. Specifically, the potential impacts of urban and rural land uses on groundwater recharge, storage and discharge are not addressed. Nor are related impacts to the biodiversity support provided by groundwater systems. An explicit framework is lacking for integrating inventories of land use stresses with an analysis of potential cumulative effects on groundwater functioning. Without the benefit of such a framework it is not clear how cumulative effects can be anticipated and prevented.

77 General zoning restrictions in place may impact on one or more of the activities not discussed in the policy options paper (e.g. rural privately-serviced development).

A monitoring framework is needed to systematically track land use stresses over time and to document concomitant changes in groundwater processes and functions. This requires discussion and agreement among actor groups of monitoring objectives, selection of a suite of monitoring indicators, and setting specific targets for land use activities and groundwater-ecosystem functions at various scales. As noted previously, the Region has an intensive program for monitoring the quality of the water it is supplying to its customers, and an ongoing program to monitor groundwater levels at various points across the Region. The Region has not yet addressed the issue of monitoring region-wide trends in groundwater quality, nor has it resolved the issue of developing an early warning system around municipal well fields.

8.3.5 Do an integrated set of rules and instruments provide a complete range of protection functions?

The types of instruments proposed in the Strategy, move well beyond traditional reliance on ad hoc regulation of individual contaminant sources. The Region appears to favour a precautionary approach to protecting groundwater to the extent that they are seeking to prohibit high risk activities in sensitive groundwater areas (RMOW 1996d:18). It is committed to incorporating three major types of instruments: direct regulation, economic incentives, and voluntary approaches. Also the Strategy addresses a full range of functions including groundwater protection, prevention, control and remediation, with an emphasis on the former.

The Golder report defined the Strategy largely in terms of a land use planning exercise that would protect groundwater recharge areas from "inappropriate" activities (Golder 1992:35). The subsequent rationale provided by the Region for adopting land use planning tools reflects an emphasis on the costs of groundwater contamination:

The cost of researching and developing environmentally sound land use practices is far

> outweighed by the costs involved in repairing a contaminated site. The fact that current technology is sometimes unable to return a location to pre-contaminated condition is even more reason for a long term commitment to prevent pollution. (WRPLC 1994c:2)

The use of exclusionary zoning for certain high risk activities emphasizes controls in favour of long term protection and prevention. This instrument can preclude new industrial uses that consume large volumes of water or that manufacture or store hazardous materials. However, the focus on medium to large generators of hazardous contaminants does not address potential cumulative effects of common urban and suburban land uses on groundwater functions. Further, zoning cannot deal effectively with land uses that are in place prior to adoption of new zoning. By-laws to protect groundwater do not prevent existing uses of land, buildings or other structures from continuing. Also, zoning does not readily adapt to varied site conditions or accommodate different management regimes, and lacks positive incentives to existing land users to take preventative measures. For example, zoning does not readily distinguish between two landowners using land for the same purpose, who may have radically different approaches to land management and pollution prevention.

Records of Liaison Committee meetings and interviews with members suggest there is general support among core actors for placing certain restrictions on new land uses in *Wellhead Protection Areas.* Records of Liaison Committee meetings suggest there is general agreement that restrictive zoning will not adequately address ongoing land uses, in particular the activities of existing industry. The arguments offered most frequently for applying regulatory controls were: the limited ability of zoning to control existing uses, the importance of controlling hazardous chemical use in sensitive areas, and to stimulate corrective action.

When asked about the appropriate mix of regulation, voluntary measures and economic incentives, most interview respondents expressed support for the concept of a mix of regulatory and non-regulatory measures, but had difficulty articulating what the balance should be (8 of 14). An emphasis on education activities and raising awareness of the benefits of good management practice were frequently mentioned (6 of 14). A voluntary approach to encouraging best management practice by rural landowners was endorsed by interview respondents. The prime motivation was seen to be increased awareness of the benefits of improved management. However, some also cautioned that landowners could not be expected to act in ways that would hurt themselves economically. In particular, rural landowners were characterized as having limited financial resources or locational choices for their operations. Strategy documents indicate that financial incentives are being considered, and a number of respondents also suggested incentives would be appropriate to deal with "hardships" placed on individual farm operations.

The Region is taking a cautious approach to increasing regulatory controls for existing urban point sources. Written evidence suggests a tendency to juxtapose voluntary measures and regulatory approaches, with the latter being dismissed where it is seen to be difficult to implement. "Voluntary participation in water resources protection by the public is likely to be more successful in the long term than regulatory measures (RMOW 1996a:2)". The Strategy advocates voluntary best management practices:

> Encouraging businesses to change their chemical handling and storage practices to prevent groundwater contamination. and preventing new businesses from locating in sensitive groundwater areas will eliminate threats to groundwater resources. These proactive initiatives can be implemented at a fraction of the cost required to react to groundwater contamination (RMOW 1996a:2).

The Strategy does not explicitly recognize that regulation can provide a base-level of protection and the motivation to act, while voluntary instruments increase awareness, identify opportunities to move beyond minimum standards, and release the creativity of individuals and organizations to implement innovative solutions.

The Liaison Committee discussed various ways of promoting best management practices, including use of peer groups to identify needs and deliver targeted information to key sectors. A few interview respondents suggested that existing regulations were adequate to accomplish the goals of the Strategy and expressed concern about "retro-active application" of new rules to existing land uses (2 of 14). Others suggested that a strong regulatory component of the Strategy was important (3 of 14).

Remedial activities, such as decommissioning contaminated sites, are not a priority in the Strategy. One interview respondent expressed concern about lack of attention to the need to remediate threats posed by historic sources of contamination. This does not mean they have been overlooked. There are various ongoing remedial activities, such as investigations of water quality concerns at individual well fields, and development of treatment facilities to address concerns about naturally high levels of iron and manganese concentrations in water at a number of municipal wells. Records of Liaison Committee meetings indicate remedial issues were rarely discussed.

8.3.6 Is there an emphasis on flexible tools and ongoing evaluation to adapt to new information and diverse conditions?

With regard to an adaptive approach, the Strategy's major strength lies in the ongoing pursuit of information about the programs in other jurisdictions as well as seeking out the experience of knowledgeable individuals and groups. Its major weakness is lack of follow-through with respect to pursuing an adequate number of innovative tools that are sufficiently flexible to address the complex and diverse conditions found in the Region.

The Region recognizes that its dependence on multiple aquifer systems are complicating the process of defining groundwater protection areas, and that land use strategies will need to be tailored to specific geologic settings (RMOW 1996d:10). Even within fairly homogenous areas such as the Waterloo moraine, there are geologic discontinuities among different units of low permeability tills and high permeability granular deposits. In the case of bedrock aquifers, such as those underlying Cambridge, irregular distribution of fractures and solution-leaching enlargements make it difficult to define the nature and occurrence of major producing aquifers within bedrock sequences. The Region argues for a flexible approach that will permit progressively restrictive management of contaminant sources near well fields.

Resources continue to be invested in examining groundwater protection programs that have been developed in other jurisdictions. The Region has investigated land use restrictions and best management practices elsewhere, and has adapted concepts such as wellhead protection zones to its purposes. In remarks to the Liaison Committee following an international groundwater seminar held in 1994 in Waterloo, Regional staff noted:

> There are many common elements in successful protection programs. Despite the common elements ... each protection plan was different due to differences in geology, resources, and specific local concerns. The Region will incorporate the common elements from other successful protection plans, but the protection plan will be modified to fit local needs. (WRPLC 1994b:2)

The use of peer review during preparation of the Golder report and the commitment to external peer review of Waterloo's groundwater characterization and protection policy options is consistent with a commitment to continuous learning. Developing a mechanism for regular reporting and external review would ensure it continues into the future.

Another positive element is the commitment to continue to improve upon, and adjust, the

Strategy based on information gathered through the implementation process. This is best exemplified by a continuing commitment to study a number of rural non-point source issues:

- measuring acceptance of BMPs by rural community;
- examining how well these practices protect groundwater;
- investigating potential impacts of sewage sludge application on groundwater quality; and
- undertaking a long term study of nitrogen use efficiency (RMOW nda).

A similar commitment is needed to support ongoing evaluation of the need for, and effectiveness of , groundwater protection measures for urban land use stresses. The main innovation being pursued is applying groundwater time-of-travel zones as the basis for restricting new development around municipal well fields. While applying such zones is an innovation for Ontario, the concept retains elements of a more traditional approach to environmental management. For example, it is based on the average time to react to detection of a contaminant plume and to develop an alternative water supply. This assumes that contaminants will be detected before they are drawn into the well, which is not assured in complex geologic environments. The approach also is based on certain assumptions about the ability of time and distance to attenuate contaminants of concern. It is not clear how time-of-travel zones address potential threats from mobile, stable or otherwise persistent contaminants which may not attenuate significantly within a given time span or physical distance (e.g. industrial solvents, nitrates, chlorides).

Two innovative regulatory instruments that would complement zoning for groundwater, deserving of further investigation, are use of alternative development standards and examination of the potential for using a development permit system in critical groundwater areas. Alternative development standards represent an up-front commitment by a municipality to encourage creative development solutions that will meet environmental and other key priorities on a given site. Uniform prescriptions are replaced with performance objectives that could relate to minimizing the development footprint in a sensitive area, that relax uniform clearing and grading requirements, and encouraging non-structural measures for protecting hydrologic functions. This approach focuses on outcomes, thereby shifting the burden of proof to potential stressors to demonstrate that they can meet a set of environmental performance objectives. Ontario has over twenty years of experience with use of a development permit system along the Niagara Escarpment. Development permits provide a flexible alternative to zoning controls by using clear criteria and performance standards to tailor approvals to site-specific conditions.

Additional non-regulatory instruments for influencing land use decisions deserve further investigation. Two specific examples are conservation easements and land stewardship agreements. Conservation easements are voluntary legal agreements that can be negotiated between a landowner and a municipality, or conservation organization, to limit activities that might jeopardize environmental values. While voluntary, once entered into, conservation easements are binding on subsequent owners. Easements that are donated may qualify as a tax benefit, or they can be sold at a negotiated price. Land stewardship agreements are verbal or written agreements between landowners and a third party to respect identified environmental values of a site. It is based on increased awareness of the benefits of environmentally responsible land management, and provides a non-binding, semi-formal agreement to forewarn of future changes to management practice, or decisions to sell a property providing a critical groundwater function.

The Strategy's emphasis on *best management practice* for industrial sources represents only a first step towards comprehensive pollution prevention. Voluntary best management practices are unlikely to be applied where short term financial benefits of improved management practice are not evident. The Strategy has not adequately addressed in depth the range of pollution prevention measures that should be examined. This includes actions such as negotiating waste reduction and emission reduction targets for key sources, mandating facility pollution prevention plans as part of stormwater management, and working with industry to put in place mechanisms for public reporting by major contaminant sources.

8.3.7 How does the strategy link decisions and actions among core actors and across jurisdictions?

The strongest attribute reflecting the principle of coordination is the use of coordinating mechanisms to solicit the involvement and contribution of core actor groups. However. significant work is needed to develop groundwater protection partnerships to design and implement the Strategy with core actor groups.

The Water Resources Protection Liaison Committee has provided an effective mechanism for coordinating the involvement of actor groups from government, non-profit and private sectors. All members of the committee interviewed expressed satisfaction with its operation and functions. Most described it as a forum for exchanging views and characterized the committee as providing decision support to Regional Council. The majority expressed satisfaction with their influence on the process to date (10 of 14), and satisfaction with the availability and flow of information from the Region (13 of 14). The concerns expressed most frequently were that the process was slow, that the Committee met too infrequently, and that not enough time was being invested by all members (7 of 14). Some interview respondents also suggested that information flows beyond the committee to other groups such as industry, rural politicians and landowners, could be improved (2 of 14). One expressed a concern about the technical nature of discussions and another expressed the need for more frequent updates on Regional decisions.

A second level of coordination is to be provided by the three working groups, which were formed to make recommendations in the three priority areas. Consideration needs to be given to broadening their membership to ensure that all core actor groups who should participate are included. These groups are in their formative stages and it is premature to consider their role or achievements.

Additional work is needed to accelerate groundwater protection partnerships. Implementing the Strategy will require significant contributions from a range of actor groups. Few partnerships have developed with the Province, but an exception was identified by interview respondents: the Ontario Ministry of Agriculture and Rural Affairs' participation in the nitrogen-efficiency study. Some expressed concern about Provincial withdrawal from direct involvement in groundwater protection issues, and suggested the Province should develop a province-wide groundwater program to provide an overall framework within which municipalities could act (3 of 14). Other roles suggested for the Province include: giving municipalities the authority to work more closely with local industry (3 of 14), providing technical and financial assistance to support local implementation (3 of 14), offering training and education on best management practices and supporting groundwater research (2 of 14).[78]

While the Region has worked hard at community consultation, interview respondents identified the continuing need for educating landowners, citizens and businesses (8 of 14). Local governments as well as the Grand River Conservation Authority were identified as important partners in undertaking groundwater education and awareness activities across the watershed.

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78 While not mentioned by any committee member, there is currently an informal agreement between Waterloo Region and the Ministry of Environment and Energy whereby the Region receives and up-dates water well records that are submitted to the Province annually by well drillers.

Interview respondents also suggested that community groups could play an important advocacy role by providing constructive criticism and bringing to the forefront issues that might otherwise be ignored. An educational role for non-government organizations, including business organizations was identified (4 of 14). The partnership involving non-government actors identified by most respondents was the multi-year nitrogen efficiency study referred to previously. Another partnership identified was the ongoing technical input provided to the Region by the Waterloo Centre for Groundwater Research at the University of Waterloo.

Three citizen-led groundwater initiatives, independent of the Strategy, provide evidence that a community-based network of support is emerging. Education and awareness-raising initiatives are being undertaken under the umbrella of the *Groundwater Guardian Program* of the U.S. Groundwater Foundation.[79] Wilmot Township, under the leadership of its Council-appointed Environmental Committee, was among the first communities to join the North American Groundwater Guardian program in 1994. It sponsored a *Groundwater Festival* and announced that it would pursue a local strategy for addressing groundwater protection issues (WRPLC 1995a:5; 1995b:3). Woolwich Township also was among the first communities to receive recognition under the *Groundwater Guardian* Program. Under the leadership of its local Healthy Communities Group, a series of educational workshops were planned, with a focus on educating the rural community about water issues (WRPLC 1994b:6). In Cambridge, the local Groundwater Alert group was successful in getting the City to agree to the need for a comprehensive plan for groundwater protection (Cambridge 1995:11). In June 1996, City Council agreed to establish a sub-committee of its Environmental Advisory Committee to put together a proposal to become a *Groundwater Guardian* community. It will focus on curriculum development for primary school grades (Souann, pers. comm.).

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79 See Chapter 4, section 4.5, for a description of the Groundwater Guardian program.

The Strategy assumes adoption by local governments of supportive policies and development control mechanisms. While the Region has general authority to adopt official plan policies to protect groundwater areas, only local municipalities have the authority to pass zoning by-laws to prohibit new uses and new structures on lands that are sensitive recharge areas or contain a sensitive aquifer (Planning Act 34 (1) 3.1)). In general, local municipalities have adopted a "wait and see" approach, with few having done preparatory work to develop local policies and measures for implementing the Strategy. Their willingness and ability to play their part in implementing the Strategy has not been confirmed, and significant effort will be needed to garner the support of all seven local municipalities.

While municipal participants have shown some support for the Strategy through its developmental stages, local support for implementing land use controls and other measures is untested. A large number of interview respondents identified potential reluctance of local municipalities to adopt development controls related to groundwater as a possible obstacle to implementation. The urban municipalities in the Region have shown past support for groundwater protection. For example, local policies have been adopted for specific areas in Kitchener and Waterloo that recognize the value of protecting important hydrological functions in managing urban drainage (e.g. Waterloo West Side, Huron Business Park in Kitchener). To date, two rural Townships nominally supported community-led Groundwater Guardian activities. However, it is noteworthy that the two respondents from the Townships suggested they did not have a major stake in implementing the Strategy given their limited resources and few groundwater-related responsibilities. There appears to be little interest in applying zoning controls in regional recharge areas or rural well fields. This highlights the need to work towards a consensus on innovative measures, other than zoning, that will positively influence land use activities in rural areas. A key coordinating mechanism will be the *Future Urban Point Source*

Working Group, which is focussing on regional and local official plan policies and development control options to address new urban point sources.

Private business organizations present another opportunity for developing groundwater partnerships. Interview respondents emphasized the need to increase awareness among industry of the potential impacts of their activities and of the benefits of voluntary environmental management. One opportunity identified was the potential to develop a government-private sector partnership to provide useful information and advice to local businesses. This could take the form of a business resource centre that provided specific information on the Strategy itself and also offered workshops and seminars on responsible business practice.

8.3.8 What measures are taken to strengthen institutional capacity?

The Strategy's strongest attribute with regard to the catalytic principle is the continued leadership of the Regional Municipality and its commitment of technical and financial resources. The weakest attributes are lack of institutional support from the Province, unanswered questions about the capacity of local government to implement the Strategy, and limited development of programs that recognize and encourage voluntary action.

The Regional Municipality is both progenitor and custodian of the Strategy. It has invested significant resources to develop the information base and articulate a framework for protecting groundwater that continues to enjoy the support of regional decision makers. Its 1996 capital budget allocates approximately 1.6 million dollars to Strategy implementation (RMOW 1996c:11). The level of investment, which accounts for 4.3 percent of the Region's water supply budget, is forecast to decline to 0.7 percent of the total by 2005. The source of this revenue. direct billings for water use, is relatively stable and inflation-proof. However, the Region has noted that additional commitments may be required, in the form of financial incentives, to motivate potential contaminant sources to improve their management practices and to take preventative or remedial actions (RMOW 1995b:21). Most interview respondents suggested that the Region will continue to have the prime role in undertaking most of the work associated with the Strategy. Specific responsibilities identified included: continuing to deliver a safe source of drinking water, developing Regional Official Plan Policies, investing financial and other resources, defending the Strategy against opponents, setting the ground rules, and promoting education and awareness.

Limited financial resources was identified by interview respondents as a potential obstacle to implementing and enforcing the Strategy (6 of 14) . The Region continues to be looked upon to cover most of the costs of implementation. However, it has begun to raise the issue of "who pays" for taking the required actions. Some potential revenue sources identified by the Region include regional and local tax levies, water and sewer charges, special levies to fund groundwater projects, and government grants or loans to affected businesses for clean-up and mitigation activities (RMOW 1995b:21).

As noted previously, uncertainty inherent in planning for groundwater protection has implications for the role played by technical information in the decision making process as well as the way in which rules and instruments are applied. However, no direction or guidance has been provided by the Province regarding appropriate protection policies or technical approaches. Neither has it given any formal recognition or encouragement of voluntary actions to protect groundwater resources. Without a supportive provincial system, the Region has been left to develop and defend the Strategy on its own merits and in forums which do not recognize the precautionary approach. Questions also remain regarding the authority of the Region to work with local industry on its use of hazardous substances and to promote advanced environmental management practice. The reticence of the Region may stem from the uncertainty surrounding its current legal authority to control land practices and existing uses to protect groundwater. A recent analysis suggests that many of regulatory tools are currently available exclusively to provincial or other government agencies (Willms and Shier 1997:19). There is no consensus among core actors on the need to pursue additional regulatory authority through the Province.

With regard to an information management system, the Region appears to have made progress integrating groundwater-related data into a common environmental information system. The Region's *Geographic Information System* provides a mechanism to integrate diverse data sets for planning purposes, facilitate modelling of spatially related data, allow for building up records over time, and enable sharing of complete, accurate and timely data between key actor groups. However, it is not clear how this information will be applied by the Region in concert with other actors, to policy development and to management decisions related to groundwater protection.

Interview respondents suggested that the greatest potential obstacle to implementing the Strategy was resistance from businesses and landowners directly impacted by the Strategy (9 of 14). Two specific areas highlighted were the potential for conflict with agricultural operations in rural well fields, and potential conflict with businesses in urban well fields. A number of respondents suggested that this would be particularly acute if measures were taken to regulate changes in management practice.

The numerous public education and awareness efforts of the Region need to be complemented with ways of recognizing and encouraging voluntary action among core actors. As the focus shifts to implementation, public recognition will play an important role in empowering core actors, landowners and individuals at the community level. Most interview respondents advocated education and awareness-raising activities for overcoming potential resistance to the Strategy (8 of 14). It was suggested that, given adequate information and time to make behavioural adjustments, most individuals and organizations would respond positively. Some respondents specifically addressed the need to involve businesses in developing solutions (4 of 14), and the importance of educating business on the economic benefits of improved environmental management practices (3 of 14).

8.4 Findings and Conclusions

The results of the analysis are presented in tabular form in Table 8. An overview of the major findings and conclusions are presented below.

Boundaries

The Strategy is noteworthy for its attention to multiple groundwater systems and multiple scales. While most of the attention has centred around well fields, planning to protect regional groundwater systems will need equal effort. Similarly the Grand River Watershed, and the major aquifer systems underlying it, provide an important bio-regional context for the Strategy. Given the discontinuities between surface waters and groundwater boundaries, additional consideration needs to be given to planning for the aquifers that extend beyond the borders of the Region. At the broadest scale, the Guelph-Amabel Aquifer can be viewed as a planning unit for protection and management. The Strategy should provide a solid foundation for inter-

TABLE 8: SUMMARY EVALUATION

PRINCIPLES	ATTRIBUTES	Present	Adequate
Boundaries	well fields	√	√
	regional systems	√	√
	watersheds & groundwater basins	√	
Objectives	hydrogeological processes		
	biodiversity support		
	sustainable use		
Functions	local and regional hydrogeology	√	√
	groundwater-surface water relationships	√	
	aquatic and terrestrial habitat	√	
Cumulative Effects	stress-response framework		
Integrated	protection, prevention, control, remediation	√	√
	regulation, economic, voluntary instruments	√	
Adaptable	flexible tools		
	internal/external review	√	√
Coordinated	coordinating mechanisms	√	√
	protection partnerships	√	
Catalytic	authority & policy		
	resources	√	√
	information management system	√	
	technical support	√	
	public recognition		

For the explanation of the checkmarks, refer to the text of this chapter and methods section of Chapter 3.

municipal planning exercises at the watershed and groundwater basin scales.

Objectives

A major weakness of the Strategy is its failure to adequately define a set of long term outcomes that are based on a broadly-supported vision for a dynamic and self-sustaining groundwater-ecosystem. A public process is necessary to secure broad agreement on valued ecosystem functions as well as a set of specific indicators and targets for measuring progress toward each objective. This will require increased awareness of and appreciation for the role of groundwater in maintaining a healthy ecosystem that can sustain human uses and benefits. Measurable and descriptive ecosystem objectives should be articulated for all the major functions provided by groundwater. This includes sustainable use objectives for drinking water, agriculture, and industry, essential hydrogeological processes, such as recharge, storage, and discharge, and bio-diversity-support functions for aquatic and terrestrial habitat.

Functions

The Strategy demonstrates commitment to understanding local and regional groundwater systems. However, it would be strengthened by directing more attention to the processes that link groundwater and surface water systems at local and regional scales. This requires improved characterization of these inter-dependencies and their relationship to healthy terrestrial and aquatic ecosystems. An analysis of this sort also would provide a stronger technical basis for defining appropriate indicators of ecosystem health in the Strategy.

The groundwater characterization activities undergirding the Strategy need a supportive policy framework that enumerates expectations and technical requirements. Endorsement of a precautionary approach could help scope the level of technical analysis required. A policy commitment is needed that decisions will favour conservation and prevention under conditions of uncertainty regarding the impact of potential multiple stresses on groundwater ecosystem-functions. The need for such a supportive policy framework is heightened by the lack of agreed-to methods for groundwater characterization, for defining sensitive areas, or for assessing potential cumulative effects of multiple groundwater uses and land use activities.

Cumulative Effects

A framework for assessing the potential cumulative effects of land use stresses is needed which includes assessment of impacts of land use stresses on essential hydrogeological processes, and biodiversity support functions as well as quality impairment. While there has been significant effort to catalogue potential contaminant sources, a systematic means of assessing the individual and collective threat they pose to groundwater is lacking. It is recognized that there are significant challenges inherent in defining cause-effect relationships and in predicting groundwater-ecosystem responses in complex subsurface environments. Iterative analysis is needed that builds upon current understanding of hydrogeological processes and that also considers potential pathways by which multiple sources of contaminants enter and degrade groundwater over the long term.

The monitoring program should contribute to ongoing assessment of potential cumulative effects and be linked to decisions to act to prevent loss or impairment of groundwater system functions. The traditional focus on monitoring raw and treated drinking water is not sufficient. Monitoring for quality and quantity should be supported by a suite of indicators and targets which are representative of land use stresses and ecosystem processes. Such a monitoring system would provide an early warning system of potential loss or impairment of functions provided by groundwater-ecosystems at a regional scale. The assessment and monitoring activities should be integrated with key decision processes for defining desired outcomes as well as the selection of instruments for influencing human activities.

Integrated

The Strategy is moving toward an integrated system of rules and instruments by incorporating a range of protection, prevention, control and remediation activities. However, the potential dichotomy between regulatory controls and voluntary instruments needs to be redressed. The Region should build on the acceptance by core actor groups of the importance of ensuring a base level of environmental protection through regulatory means while, at the same time, guarding against the temptation to impose inflexible controls. The Region needs to pursue an integrated package of measures wherein regulation performs the following functions: provides a mandate to protect groundwater, spurs action by all sectors, and maximizes choice. Voluntary measures and economic instruments should perform the following functions: increase awareness, stimulate action beyond minimum requirements, and support innovative solutions.

One specific option available to the Region for addressing regulatory requirements is to secure the agreement of existing authorities, such as the Ministry of Environment and Energy, to focus their inspection and prevention programs in areas identified as critical to protect groundwater. Another option is for the Region to secure the agreement of existing authorities to delegate authority for promoting improved environmental management practice by land users and potential contaminant sources. Specific areas that could be pursued approval of water takings, powers of inspection for contaminant sources, and the ability to order preventative action to protect groundwater before irreparable harm occurs.[80]

With regard to economic incentives, various creative options should be explored, above and beyond option of direct grants to certain landowners being considered by the Region. These include the following: issuing income tax receipts for donations of lands supporting essential hydrogeological processes, applying property tax benefits for landowners protecting designated groundwater areas, and helping finance a voluntary program of public or private conservation easements in sensitive groundwater areas.

Adaptable

There is a need to experiment with more innovative and adaptive measures for managing land use change. In addition to zoning, two regulatory options that should be examined more closely include adopting alternative development standards and examining the potential for designing a development permit system for critical groundwater areas. This could be used effectively to address concerns related to potential impacts on hydrogeological processes as well as potential contamination of groundwater. Waterloo Region and its member municipalities should pursue discussions with the Province to give them the ability to establish a development permit system to control development in critical groundwater areas. This would provide municipalities with an approach that is considerably more flexible and adaptable to local conditions.

Significant additional work is needed to develop a more comprehensive approach to pollution

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80 These powers are currently the prerogative of *Directors* and *Provincial Officers* appointed pursuant to the *Environmental Protection Act* and *Ontario Water Resources Act*.

prevention. Best management practices do not reflect the full range of prevention tools that could be applied. Specific measures that should be explored include: facility-specific targets for water use, waste generation, and emission reduction, substitution of hazardous chemicals in all sectors, encouraging pollution prevention plans for sources in critical groundwater areas, and regular public reporting by facilities of progress toward pollution prevention targets.

The commitment to continue to learn from other jurisdictions and improve measures and techniques is commendable. The use of peer review early in the process during preparation of the Golder report, and the commitment to external peer review of groundwater characterization and policy options is consistent with a commitment to continuous learning. Regular public forums should be instituted through the implementation process, as should mechanisms for periodic external review of the Strategy.

Coordinated

The Water Resource Protection Liaison Committee appears to be working well as a multi-stakeholder forum. It is providing a mechanism for exchanging information, for increasing appreciation among key actors of issues and options, and for providing decision support to Regional Council. The three working groups offer the promise of a deeper level of cooperation among core actors on specific elements of the Strategy. A key to their success will be to ensure that key government and non-government actors are represented and that they are given authority to negotiate agreements-in-principle on behalf of their sending organizations. Consideration should be given to expanding their mandate to negotiate specific protection partnership agreements for implementing elements of the Strategy.

There is un-tapped potential to connect with community-based organizations to promote the strategy. For example, the *Groundwater Guardian* initiatives in the Region should be developed into a full partnership for implementing a long term vision for groundwater-ecosystems. There also exists the potential to partner with business organizations to develop support networks that promote protection and pollution prevention activities. Such groundwater partnerships should enable the business community to become co-educators with community groups and public agencies on cost-effective measures and options to address groundwater priorities.

Catalytic

The leadership of the Regional municipality has been critical to the progress made thus far. For the foreseeable future, the Region will continue to be the custodian of the Strategy. While necessary, its technical expertise, financial resources, and policy commitments will not be sufficient to ensure the Strategy is fully implemented. The support and participation of other government and non-government actors will be essential to achieve a community-based approach that is sustainable over the long term.

The willingness and capacity among local municipalities to assume significant responsibility for implementation is not confirmed. There are positive indications, particularly among the urban municipalities, of the capacity to protect groundwater. However, it is clear that they will need to be satisfied that the landowners most directly affected are willing participants in the implementation process. Also, there needs to be a willingness to invest the required time and creativity to support the design of innovative measures for managing land uses beyond standard development control. The limited resources and expertise among the rural municipalities suggests a need for significant technical and administrative support.

In addition to applying regulatory instruments and economic incentives to establish a base level of groundwater protection, public recognition programs should be developed. Such programs would publicly recognize the annual contribution of individuals, landowners and groups to protecting groundwater. This would complement the current commitment to increase awareness of the need and benefits of prevention and also would support community-based solutions for protecting the Region's groundwater ecosystems. In addition, support networks within and among key sectors should be developed to communicate critical information and encourage responsible action.

8.5 Summary

The Water Resources Protection Strategy of Waterloo Region is distinguished by the degree to which it embodies many aspects of an ecosystem approach. While the Strategy does not address all principles and attributes adequately when compared against the ecosystem framework, this should not be interpreted as failure. Experience in many other contexts suggests that the ecosystem approach has rarely been applied comprehensively (cf. Lee 1993; Gunderson, Holling and Light 1995). The Strategy's strongest attributes are its attention to multiple groundwater boundaries and its characterization of groundwater systems. The principles of integration and coordination are moderately well developed as are the catalytic principle and principle of adaptation. The Strategy's weakest attributes are its lack of ecosystem objectives and targets, and its lack of a framework for assessing potential cumulative effects.

There are a number of difficult decisions ahead, particularly regarding the rules and instruments to be applied, and regarding the best means for building a community-based approach to implementation. The most significant challenges to be addressed include: seeking consensus on a full range of ecosystem objectives and targets; improved characterization of functional relationships between groundwater and surface water systems; effectively linking the Strategy to planning for groundwater protection throughout the Grand River Watershed and beyond; developing a framework for assessing and monitoring cumulative effects; testing a broader range of innovative regulatory and non-regulatory instruments for influencing land use practice; pursuing groundwater protection partnerships more aggressively; and empowering local actions through technical support and public recognition. Future decisions related to implementing the Strategy will determine whether it will be strengthened relative to an ecosystem approach.

The ability to improve the Strategy points to the larger system of rules and actors that impinge upon the Regional Municipality of Waterloo. For example, there remains the need to seek the cooperation of provincial agencies such as the Ministry of Environment and Energy to provide a supportive policy framework and to be a catalyst for community action. As noted previously, the Ministry of Environment and Energy has a variety of powers to prevent groundwater contamination. The Ministry also could increase awareness and support for the Strategy by designating *Water Supply Protection Areas*, under the authority of the *Ontario Water Resources Act*, consistent with critical areas identified in the approved Strategy. The next and final chapter brings together the major findings and recommendations that flow from the case study, the analysis of the broader institutional context, and the *Ecosystem Approach Framework*.

CHAPTER 9
FINDINGS AND RECOMMENDATIONS

9.1 Introduction

The purpose of this inquiry was to investigate the potential application of an ecosystem approach to planning for groundwater protection in Ontario. Two basic questions framed the investigation: *What strategies have emerged to address deficiencies in planning for groundwater protection?*, and *How might an ecosystem approach inform the development of such strategies?* In pursuing answers to these questions, the inquiry faced a number of significant challenges. From a conceptual standpoint, current research in environmental planning and institutional analysis presents many challenges because of weak theoretical development, unknown variables, and application of disparate evaluation criteria (cf. Mitchell 1989; Ingram 1990; Gormley 1987; O'Toole 1993; Cortner and Marsh 1987).

With few notable exceptions, the development of regional groundwater protection strategies in Ontario is in its infancy. Given the limited theoretical development and few practical applications to planning for groundwater protection, the approach taken was necessarily descriptive and exploratory. This chapter includes a summary of the *Ecosystem Approach Framework*, key findings from the case study of the *Water Resources Protection Strategy* of the Regional Municipality of Waterloo, Ontario, recommendations for implementing an ecosystem approach in Ontario, and areas for further study.

9.2 A New Paradigm in Planning for Groundwater

9.2.1 Guiding Principles

It is critical that research be anchored in an explicit conceptual framework, and it is in this context that the *Ecosystem Approach Framework* was developed. The purpose of the *Ecosystem Approach Framework* is to advance a more coherent and complete representation of an ecosystem approach than has been available to this point, and particularly as it applies to planning for groundwater. The state of knowledge regarding the ecosystem approach reflects an amalgam of concepts and ideas that are not fully mature. Also there is virtually no substantive literature applying ecosystem principles to planning for groundwater protection.

The *Ecosystem Approach Framework* offers new ways of analyzing problems with the promise of constructive solutions. It is pioneering in that it integrates diverse ecosystem principles with the specific challenges of planning for groundwater protection. The framework is based on an understanding of an ecosystem approach as a composite whole made up of multiple and interconnected parts. The individual parts or constituents are defined by a set of strategic activities, eight key principles, also expressed as research questions, and a set of attributes. which are specific properties of an ecosystem approach to groundwater protection.

The guiding principles combined with strategic elements of groundwater protection provide a normative framework for describing an ecosystem approach to groundwater protection. It has implications for the boundaries selected for planning, the information sought, the type of objectives pursued, the way in which potential effects of human activities are assessed and monitored, the types and mix of rules and instruments selected, the accountability of core actor groups, and implementation. Key principles of an ecosystem approach that should be incorporated in the design and implementation of groundwater protection strategies are summarized below.

- The ecosystem approach recognizes the need to plan across jurisdictional boundaries to encompass ecological processes and functions directly related to the goals and objectives being pursued, as well as the activities that are impacting valued ecosystem functions.

- The ecosystem approach bridges sustainable human uses with a long term vision for maintaining and restoring healthy ecosystems. It advocates dialogue to define objectives not only for human use, but also for maintaining essential ecological functions, recognizing that these are inextricably linked.

- In contrast to the conventional practice of collecting data on discrete physical, chemical or biological parameters, the ecosystem approach integrates information on components of the ecosystem through analysis of processes that knit them together. It includes, for example, the movement, storage and cycling of water, the support provided to biological habitats and the provision of clean drinking water for human use.

- The ecosystem approach seeks to understand complex relationships among multiple human stresses and concomitant changes in groundwater-ecosystem functioning over time. It considers effects at multiple levels of ecosystem organization, from the local to the regional, and includes past, present and future change.

- The complex and dynamic nature of ecosystems means that institutions must "expect the unexpected". It rejects a *one-size-fits-all* mentality, in favour of precautionary and flexible measures that ensure future options are not precluded by a failure to act in the absence of complete information and understanding. Innovative and creative solutions are encouraged that adapt to different contexts and dynamic conditions, including continuous review and evaluation of objectives, measures and results.

- The ecosystem approach favours strategies that apply an integrated set of instruments that work together to achieve the long term vision through four key management functions: protection, prevention, control and remediation. Regulatory controls are transformed from a constraining role to providing the mandate for implementing preventative strategies.

- The ecosystem approach re-defines notions of accountability and governance. Old forms of governance characterized by central control and dictated prescriptions are replaced with rules and instruments that support responsible action. The imperative of realizing a long term vision for the ecosystem is pursued by increasing the responsibility and accountability of all actor groups for achieving collective outcomes. Attention shifts from the centre to communities to interpret and apply ecosystem principles in their context. Mechanisms and partnerships are required which facilitate exchange of information, discussion of common interests, and collaborative decision making in the interests of system-wide goals.

- The ecosystem approach recognizes the need to build institutional capacity to sustain implementation by providing a mandate to act, as well as information, technical support, and other resources that recognize and encourage ecosystem perspectives. Differing capacities will impact the intensity and scope of protection efforts. Fully integrated strategies begin with the most feasible steps combined with actions that foster and support community-based solutions. Over time, the level of effective integration and coordination should increase as the benefits of this approach are demonstrated and embraced by core actors.

9.2.2 Key Activities

The ecosystem approach is as much a practical response to extant problems as it is the product of extensive theorizing. There are a number of recurring challenges confronting efforts to improve the management and protection of groundwater, that can be summarized as follows: moving from the site-specific orientation to a groundwater system focus; integrating goals of human health and ecosystem integrity; improving the characterization of groundwater systems and potential cumulative threats; transforming reactive controls to preventative planning; coordinating activities of different actor groups; and addressing limited institutional capacity for implementation. Attention to the guiding principles and attributes of an ecosystem approach provide clues for addressing these deficiencies.

Each of the guiding principles of an ecosystem approach has its corollary in practical actions for implementing regional groundwater strategies. Specifically, strategies for protecting groundwater should include the following critical elements:

- characterizing groundwater-ecosystems;
- monitoring and assessing groundwater stresses and ecosystem responses;
- developing a long term vision supported by measurable outcomes;
- instituting a system of rules and instruments to manage human activities; and
- building capacity to sustain implementation.

The attributes associated with the guiding principles for an ecosystem approach to groundwater protection are summarized below.

Boundaries: *Use multiple ecological boundaries and scales for planning to protect groundwater systems, recognising a hierarchy of nested systems and scales.*

When designing a protection strategy, planning and analysis activities should encompass well fields, local and regional groundwater systems and boundaries that recognize linkages to surface watersheds and major groundwater basins.

Objectives: *Develop a long term vision for groundwater that encompasses a full range of ecosystem objectives.*

Planning for groundwater systems requires measurable objectives for human benefits and long term ecological integrity. Objectives, indicators and targets should be defined for sustainable human uses, essential hydrogeological processes, and bio-diversity support functions provided by groundwater systems.

Functions: *Inform decisions through analysis of ecosystem processes and functions that link physical, chemical and biological components of the ecosystem, that are of direct human benefit and that maintain ecosystem integrity.*

Improved characterization of groundwater systems is needed to address local and regional hydrogeology, groundwater-surface water relationships, and to define functional linkages with aquatic and terrestrial habitat. This should include analysis of the level of groundwater-ecosystem functions provided in different geographic areas.

Effects: *Identify complex relationships among multiple land use stresses and associated short term and long term responses of groundwater-ecosystems.*

An essential component of a groundwater strategy is developing a framework for assessing and monitoring the type and intensity of land and water uses at local and regional scales, and the potential pathways through which groundwater functions may be degraded or otherwise altered. The link between assessment and monitoring activities to decision making processes should be specified.

Adaptable: *Adopt a precautionary approach that can accommodate diverse conditions and is responsive to new information and changing circumstances.*

Pursue innovative and flexible solutions, given limited understanding of groundwater systems and functional responses to land use change. Maximize choices and encourage creativity to address groundwater concerns. Establish mechanisms for ongoing review and evaluation that facilitate continuous learning and adaptation.

Integrated: *Support preventative strategies with an integrated system of rules and instruments that work together to achieve the long term vision.*

Groundwater strategies should provide a supportive framework that mandates, recognizes and encourages public and private protection initiatives through a mix of regulatory, economic and voluntary measures. Regulatory controls should mandate ecosystem-wide perspectives and support other instruments, including zoning for groundwater, alternative development standards, development permit systems, conservation easements, tax incentives and other economic incentives, and pollution prevention planning for contaminant sources.

Coordinated: *Secure the participation and accountability of core actor groups and sectors for defining and achieving collective outcomes.*

Better coordination of programs and activities of government and non-government actor groups is paramount, with a focus on strengthening community capacity for action. Develop mechanisms which coordinate the involvement and contributions of core actor groups from vision development through to monitoring of implementation. Include the following functions: appreciation, resource sharing, decision-support. Establish protection partnerships for delivering key components of the groundwater strategy.

Catalytic: *Develop the institutional capacity to sustain implementation by providing a mandate to act, as well as information, technical support, and other resources that recognize and encourage ecosystem perspectives.*

Existing authority and policy, technical and financial resources will affect the intensity and scope of protection efforts. Various forms of support from senior levels of government are critical, including enabling legislation which provides authority required to implement protection measures, transfer of responsibilities downward where communities and individuals have demonstrated a willingness and a capacity to protect groundwater, ensuring means are available to finance protection activities at the community level, providing base-line standards, information and mapping, technical assistance and training where needed.

While immediate needs are often the catalysts for action, approaches to groundwater protection should increase the scope and level of integration over time. This recognizes the importance of adjusting strategies to varied conditions and circumstances while, at the same time, building in a commitment to strengthen and expand protection initiatives beyond priority threats. In this way groundwater's diverse ecological functions and human uses will be better protected over the long term.

9.3 Water Resources Protection Strategy: Waterloo, Ontario

9.3.1 Major Findings

The case study of the *Water Resources Protection Strategy* in the Regional Municipality of Waterloo provides an excellent opportunity to consider how an ecosystem approach might inform the development of regional groundwater strategies in the Province. Waterloo Region contains the largest concentration of people in Canada who depend on groundwater as their primary source of drinking water, with over 400,000 people in three urban municipalities and four townships. There are over fifty municipal well fields in the Region and thousands of private wells drawing water from confined and unconfined overburden aquifers and confined and unconfined bedrock aquifers.

The decision by Waterloo Region to pursue a groundwater protection strategy was triggered by contamination of Elmira's municipal wells in the late 1980s with industrial organic contaminants. Pervasive degradation of the quality of the region's shallow aquifers by bacterial and nitrate contaminants, as well as discovery of coal tar and related hazardous substances at former sites of coal gasification plants added pressure to prevent further loss of groundwater resources. The six year effort to put in place a groundwater strategy was the subject of the case study.

Waterloo Region's strategy is distinguished by the degree to which it embodies many aspects of an ecosystem approach. While not all principles and attributes are addressed equally or adequately when compared against the ecosystem framework, this should not be interpreted as failure. Experience in many other contexts suggests that the ecosystem approach has rarely been applied comprehensively (cf. Lee 1993; Gunderson, Holling and Light 1995).

The Strategy's strongest attributes are its focus on multiple aquifers at local and regional scales, supported by extensive characterization and modelling of groundwater. At the same time, groundwater's properties present unique challenges. The ability to redress lack of understanding or appreciation for its many values and benefits is complicated by the complexity and variability of groundwater's occurrence, movement and chemical evolution. For example, the bedrock formations from which Cambridge draws much of its water supply were laid down some 400 million years ago. The surficial deposits of the Waterloo Moraine that provide another major source of water for the Region were formed less than 100,000 years ago. Some portion of the water being withdrawn has lain underground for perhaps millions of years, while other water being withdrawn fell as precipitation a few short years ago. Extensive regional and site-specific investigations reveal complex interactions and flows between aquifer units as well as between groundwater and surface water which were influenced by natural conditions as well as groundwater withdrawals.

The case study illustrates the tendency of priorities related to human consumption of groundwater to overshadow consideration of the full range of groundwater services and functions provided by healthy groundwater-ecosystems. The evidence suggests a prime concern for maintaining an adequate supply of good quality drinking water. The tendency to focus on consumptive use of groundwater is common to most groundwater strategies. However, even in this regard, objectives, indicators and targets related to sustained or optimal yield are missing from the Strategy. In addition, the role of groundwater in maintaining essential ecological processes is not adequately accounted for and spelled out in the Strategy.

From a technical perspective, the Strategy has not yet taken the next step of complementing the considerable hydrogeological analysis of groundwater resources with equivalent effort to characterize the linkages with surface water and the bio-diversity support functions provided by groundwater. Unlike the watershed studies in the Region, the technical studies for the Strategy do not quantify baseflow contributions of groundwater to area streams and wetlands, nor calculate water budgets. There has been little effort to integrate information on stream flows and temperature, fisheries, wetlands and surface water hydrology, with hydrogeological considerations, such as geology and groundwater chemistry. Analysis of this type would demonstrate equal regard for these ecological dependencies.

The case also illustrates the need for a supportive policy framework to guide decisions, heightened by the lack of agreed-to methods for groundwater characterization, for assessing potential risks, and for protecting groundwater functions. In Ontario there is little experience with planning policy for protecting groundwater systems, especially with regard to its hydrogeologic functions and the linkages between groundwater and surface water systems. Few rules or instruments are applied beyond the direct regulation of major point sources by provincial authorities. Perhaps as a result, the investment in technical analysis and groundwater characterization has far outweighed analysis of policy options.

The Strategy appears to favour a precautionary approach to protecting groundwater from contamination to the extent that it is seeking to prohibit certain activities in sensitive groundwater areas. There is an express commitment to incorporating three major types of instruments: regulation of new urban land uses, economic incentives for existing rural land uses, and voluntary approaches for existing urban point sources. The primary focus is on management of land uses in the vicinity of municipal wells, and secondarily on regional recharge areas. The application of zoning to preclude medium and high risk activities is an innovation for Ontario, which has been widely used elsewhere. However, zoning is not a particularly flexible instrument. It doesn't make any distinction between different management practices, doesn't address current uses, nor can it readily adapt to diverse site conditions. Also the use of Time-of-Travel as the basis for defining these zones belies a tendency to fall back to a system based on the ability to react to spills or detection of contaminants before they reach a well.

The Strategy also shows a tendency to juxtapose legislated solutions with other measures. The need to "draw lines on maps" (i.e. zone) to protect groundwater in recharge or other critical areas is seen to impose liabilities on those falling within the zones, and could spawn exhaustive technical battles among opposing interests. While zoning is an important tool available to local municipalities, it could result in tremendous energy being expended to define who is "caught" within these zones, and inadvertently contribute to the perception that those who fall outside these lines need not concern themselves with groundwater. Without a supportive policy framework that is grounded in the precautionary approach, the uncertainty will work against pro-active measures to protect groundwater systems.

Finally, the case study demonstrates the value of strong leadership at the regional level. The Regional Municipality of Waterloo is both progenitor and prime custodian of the Strategy. Under its leadership there has been significant progress. However, Waterloo Region cannot implement the Strategy alone. The Strategy is at a relatively early stage in its evolution, and there remain a number of difficult decisions ahead, not the least of which relate to final decisions on the measures for implementation. The participation and support of core actor groups, particularly area municipalities, land owners and private sector will be critical to its success. In addition, the ability to sustain the effort in the midst of significant institutional and structural changes related to governance is not assured. The uncertainty being generated by the broader institutional context also must be addressed (see section 9.4.4).

9.3.2 Priorities For Waterloo Region's Groundwater Strategy

The previous chapter included a detailed discussion of strengths and weaknesses of Waterloo Region's Water Resources Protection Strategy. A number of significant deficiencies were identified. In particular, four priority areas require attention:

1. Develop a Comprehensive Vision

One of the Strategy's weakest attributes is the lack of a long term vision supported by clear outcomes and objectives. Whether by accident or design, the absence of measurable or descriptive objectives and targets leave the Strategy without a clear frame of reference or guide for making difficult decisions within an ecosystem context. A public process is necessary to secure broad agreement on valued ecosystem functions as well as a set of specific indicators and targets for measuring progress toward each objective. This will require increased awareness of and appreciation for the role of groundwater in maintaining a healthy ecosystem that can sustain human uses and benefits. Measurable and descriptive ecosystem objectives should be articulated for all the major functions provided by groundwater. This includes sustainable use objectives for drinking water, agriculture, and industry, essential hydrogeological processes, such as recharge, storage, and discharge, and bio-diversity-support functions for aquatic and terrestrial habitat.

2. Accelerate Partnerships

Protection partnerships with key actor groups should be accelerated to secure participation and accountability for implementing the Strategy. There is un-tapped potential to connect with community-based organizations to promote the strategy. For example, the citizen-led *Groundwater Guardian* initiatives should be developed into a partnership for promoting a long term vision of the Region's groundwater-ecosystems. Increased effort also is needed to secure the cooperation of area municipalities. There are positive indications, particularly among the urban municipalities, of the capacity to protect groundwater. But it is clear that area municipalities will need to be satisfied that the landowners most directly affected are willing participants in the implementation process.

Support networks within and among key sectors should be developed to communicate critical information and encourage responsible action. Partnerships with business organizations should be pursued to increase awareness of the benefits of protection and pollution prevention activities. Such groundwater partnerships would enable the business community to become co-educators with community groups and public agencies on cost-effective measures and options to address groundwater priorities.

3. Pursue Innovation

The potential to apply more innovative measures for managing land use change should be assessed in detail. Given the limited appetite for additional regulatory controls, creative and effective means must be found to foster accountability for protecting groundwater ecosystems which extend beyond the confines of properties directly affected by zoning bylaws or equivalent measures. Increased attention should focus on assessing measures that would maximize choice and flexibility in addressing groundwater concerns throughout the Region. One example is applying a development permit system in specific areas that defines permitted uses, development criteria and targets. There are other creative measures, such as public or private conservation easements in critical groundwater areas, and pollution prevention planning for point and non-point sources of contaminants.

In addition to applying regulatory instruments and economic incentives that establish a base level of groundwater protection, public recognition programs should be developed. Such programs would publicly recognize the annual contribution of individuals, landowners and groups to protecting groundwater. This would complement the current commitment to increase awareness of the need and benefits of prevention and also would support community-based solutions for protecting the Region's groundwater ecosystems.

4. Develop and Test Cumulative Effects Assessment Framework

There has been significant work to date on identifying potential contamination threats to groundwater in the Region. The value of this work is being undermined by the absence of an integrative framework for assessing and monitoring cumulative effects of multiple land use stresses, such as effects on essential hydrogeological processes including recharge, storage and discharge. Little is known about the potential cumulative effects of multiple land use stresses and activities on groundwater hydrogeology and chemistry. The heterogeneity of the geologic environment and associated physical and chemical processes, combined with the many potential pathways for contaminants, make the task of defining the sensitivity of groundwater systems and planning for human activities extremely difficult. Notwithstanding, the Region should investigate leading efforts in this area such as the cumulative effects monitoring program on the Niagara Escarpment (Whitelaw, Neufeld and Carty 1995).

9.4 Implementing An Ecosystem Approach in Ontario

Specific recommendations for developing and implementing an ecosystem approach to groundwater protection in Ontario are provided below. The discussion is organized on the basis of core actor groups.

9.4.1 Municipalities

The first municipalities to take action in Ontario have been those that directly rely on groundwater for public water supplies. The equal, if less direct, benefits of groundwater to sustaining surface water and maintaining a healthy ecosystem suggests that planning for groundwater is vital in other contexts as well. In Ontario, leadership for developing regional groundwater strategies should come from upper tier municipalities. The responsibility to plan for infrastructure, protect public health, and manage growth provide them with the mandate and authority to take action. In addition, they provide an important mechanism to foster inter-municipal dialogue and decision-making among area municipalities.

Infrastructure investments are a key tool available at the upper tier level.[81] The responsibility for providing sewage and water works provide the basis for directing growth and for making strategic investments to protect groundwater that is a direct source of drinking water or that indirectly sustains surface water systems. For example, a portion of the revenue from providing water and sewage services can be directed towards the following:

- characterizing groundwater sources including delineating key geographic areas

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81 Under the *Municipal Act* and the *Public Utilities Act*, some local municipalities and utility commissions retain the authority to acquire, establish, maintain and operate water works.

providing hydrologic and hydrogeologic benefits for public and private water supply (e.g. well capture zones, local and regional recharge and discharge areas);

- assessing and monitoring existing and potential uses of groundwater and potential threats or stresses to groundwater;
- reviewing current protection methods used to protect the water supply and evaluating the application of new tools or methods for source protection; and
- developing partnerships and building local capacity for implementing source protection.

With regard to the latter, various incentive programs should be considered that promote land stewardship to protect groundwater functions. While there is no evidence that it has been used to protect sensitive groundwater areas, the *Planning Act* permits municipalities to acquire any land, building or structure that is used for a purpose that does not conform to its bylaws. Other measures that are beneficial include public recognition of responsible landowners, tax incentives for conserving critical groundwater areas, and support for the establishment of a public/private conservation easement program.

Another key tool at the upper tier level is the authority to adopt regional/county official plan goals, objectives and policies to manage and direct physical change and the effects on the groundwater ecosystems of the municipality. Official plans at both the upper and lower tier should designate areas that provide critical groundwater functions, outline policies to guide future development in these areas, and provide the basis for the adoption of legally enforceable zoning by-laws at the local municipal level to restrict the use of land, the erection, location or use of buildings or structures, and the density of development.

In addition to their responsibility to adopt official plans, local municipalities should take advantage of their ability under the revised *Planning Act* to pass zoning by-laws for prohibiting land uses and buildings or structures on land that is contaminated, that is a sensitive groundwater recharge area, a head-water area, or on land that contains a sensitive aquifer. Local municipalities also control the division of land through approval of plans of subdivision. Municipalities prescribe the information that must accompany an application, including environmental information such as soil conditions, water supplies, and sensitive natural features. Where they exist, information and recommendations from watershed and related studies that address groundwater should be used to encourage alternative development standards that are based on meeting specific performance criteria to protect identified groundwater functions. The processes around the Laurel Creek study in Waterloo provide one example of integrating watershed recommendations with municipal policies for protecting groundwater recharge, discharge, and habitat support functions from the impacts of site clearing and grading, drainage, creation of impermeable surfaces, and from the potential introduction of contaminants to the ground and subsurface.

Creative and effective means must be found to foster accountability for protecting groundwater ecosystems which extend beyond the confines of properties directly affected by zoning bylaws or equivalent measures. One example is the need to develop pollution prevention programs that target potential groundwater stressors. The existing authority for regulating industrial waste discharged into sewer systems should be used to require waste survey reports by dischargers containing description of waste discharge rates, contaminant concentrations, and discharge points. It also should be used to require plans for activities associated with on-site industrial operations, for example: in-plant transfer, process and material handling areas, waste disposal areas, and policies for pollution control.

9.4.2 Conservation Authorities

Conservation authorities play an important role in supporting inter-municipal approaches to groundwater protection. They provide another mechanism through which municipalities can gain a holistic understanding of groundwater systems that traverse municipal boundaries. Watershed studies often reflect a partnership among conservation authorities, municipal government, and other actor groups. These studies foster increased awareness of the importance of groundwater, define objectives and recommend specific measures for protecting valued ecosystem functions. At the same time, the effectiveness of these studies relies on the goodwill of participants, the persuasive powers of participating agencies, and a willingness of local municipalities to reflect their guiding principles in planning decisions on a daily basis.

The future role of conservation authorities in basin-wide groundwater initiatives is unclear. Recent decisions to eliminate provincial funding may limit their ability to launch new initiatives in this area. At the same time, the gap created by the withdrawal of the Province from land use planning could create opportunities for conservation authorities to promote groundwater-ecosystem considerations through their provision of information, review of planning applications and technical assistance to municipalities and landowners.

9.4.3 Non-Government Organizations

While not the focus of this inquiry, non-government organizations can also play an important role in protecting groundwater. As discussed previously in the Waterloo case, three citizen-led groundwater initiatives, independent of the Strategy, provide evidence that a community-based network of support is emerging. Teams with representation from citizen organizations, business, agriculture, education and government are responsible to work with community leaders to develop and implement local goals, objectives and long term plans for protecting groundwater through a set of results-oriented activities. These activities include public awareness, conservation, pollution prevention, land use policy, and best management practice. Each activity should include measurable objectives, implementation timetables and methods for evaluating results.

While there are relatively few programs that promote land stewardship for protecting groundwater resources, the work of the Ontario Farm Environmental Coalition and related organizations is notable. Individual Environmental Farm Plans identify potential pollution problems on specific farms and outline action plans to address them. The *Well Steward Project* is also noteworthy for its effort to heighten awareness, offer education and demonstrate methods for protecting farm wells. Simple techniques are recommended to upgrade existing wells and reduce risk of groundwater contamination, including plugging abandoned wells and upgrading dug and drilled wells.

There also appears to be untapped potential to form partnerships with industry associations to promote voluntary actions that conserve and protect groundwater. An increasing number of companies and institutions consider pollution prevention to be an important emerging issue, and there is increased emphasis on reporting environmental performance as an essential component of pollution prevention. The direct benefits of pollution prevention and ecological efficiencies can encourage voluntary measures. At the same time, industry has acknowledged the need for a supportive regulatory context that provides motivation to act.

Until a few years ago, the ability to hold a conservation easement in Ontario was restricted to the Crown and its agencies. Under amendments to the *Conservation Land Act* in 1995, non-profit organizations as well as municipalities and conservation authorities are authorized to hold conservation easements for the purpose of "conservation, maintenance, restoration or enhancement" of land or wildlife" (s.3(2)). There are more than a dozen "land trusts" in Ontario, which are non-profit organizations set up specifically for the purpose of saving or managing land to protect ecological, agricultural or other social values. They may seek to conserve land through fee simple ownership of special areas by purchase or donation, as well as through conservation easements. There is a need to test the application of private land trusts and related programs to areas providing critical groundwater-ecosystem functions in Ontario.

9.4.4 Senior Governments

The broader institutional context in Ontario affects the ability to implement regional groundwater strategies. Federal and provincial governments have failed to translate expressions of concern into specific policies and actions. This disinterest in groundwater is partly a reflection of the fundamental retreat of senior governments from the broader field of environmental planning and management. There remains confusion and disagreement about the appropriate role of the federal government in groundwater management and protection. As noted earlier, while both internal and external evaluations have advocated increased federal presence in this policy area, there has been a steady decline in federal activities. One of the few remaining areas is a federal research function related to improving scientific understanding of groundwater contamination and remediation. The responsibilities of the federal government under the *Fisheries Act* to protect fish habitat provides a clear mandate to address groundwater-surface water relationships. Notwithstanding its formal commitments under inter-jurisdictional agreements, such as under the *Great Lakes Water Quality Agreement* and the *Canada-Ontario*

Agreement Respecting the Great Lakes the federal government is abdicating responsibility for groundwater issues. Given the steady retreat at the provincial level in addressing groundwater issues there is little room for optimism regarding leadership from senior governments.

The Province has many functions that are poorly coordinated and which are not consistent with an ecosystem approach. At present there is a collection of disparate and declining activities by autonomous agencies and branches within agencies. There is limited inter-agency coordination and no mechanisms for integrating actions across related programs and levels of government to achieve prevention, control and remediation objectives. Provincial capital spending on infrastructure, its regulatory responsibilities for point source contaminants, and provincial planning responsibilities are not woven together to support an ecosystem approach. Reforms related to environmental protection, municipal planning and governance are creating significant uncertainty about the re-alignment of roles and responsibilities, changing approval processes, and shifting accountability for environmental protection and prevention.

Since the mid-1980's the provincial government has largely withdrawn from its earlier role in groundwater availability studies and mapping. Approval and planning reforms of the 1990's has accelerated the trend toward reduced provincial involvement in decisions that could impact groundwater. This is occurring primarily through exemptions from approval for various types of activities and Provincial withdrawal from land use planning. The abatement and remediation focus is suffering from reduced financial and staffing resources, and is giving way to reduced regulation without a re-investment in prevention. In addition reduced government dollars continue to be invested in reactive replacement of degraded groundwater supplies rather than making investments in source protection. There are few Provincial incentives for municipalities to adopt preventative planning strategies or use the legal tools at their disposal. There is little technical guidance or other support being provided by the Province in this area.

Reduced involvement and support from senior levels of government have, of necessity, generated community-led responses without the requisite authority, policy framework, base-line standards, technical assistance or financial support from senior levels of government. In the midst of major institutional change there is a need to ensure that the reforms strengthen and support collective action to protect groundwater-ecosystems. The provincial government has significant legal authority to enact laws and regulations governing human activities and management of land and resources that have a bearing on groundwater-ecosystems. It also has responsibility to provide guidance, technical support and other incentives to encourage actions that protect groundwater. The following recommendations identify improvements and changes at the provincial level required to support regional groundwater strategies.

1. Develop a legislative and policy framework that defines roles and accountability relationships of local, regional and provincial governments, non-profits, and the private sector, based on the guiding principles of an ecosystem approach.

2. Acknowledge provincial responsibility for characterizing major groundwater basins, including uses, stresses and vulnerability, and initiate a consultation process for developing ecosystem objectives and targets for these large aquifer complexes.

3. Commit the Province to re-direct a portion of its capital spending away from end-of-pipe remedial projects, and invest in planning for the protection of groundwater systems.

4. Coordinate field inspection and prevention activities with identified goals and priorities

of regional groundwater strategies. Negotiate agreements with interested and capable Regions who have adopted groundwater strategies, to transfer specific powers of inspection, issuing preventative orders, and directing remedial activities in critical groundwater areas.

5. Provide technical support by outlining a range of accepted techniques for characterizing, delineating and protecting groundwater systems that could be adapted by communities.

6. Demonstrate practical approaches for assessing and monitoring cumulative effects on groundwater-ecosystems and enter into partnerships with municipal, private and non-government actors to demonstrate innovative protection measures, such as applying conservation easements in critical groundwater areas

7. Maintain the ability regional municipalities to exercise leadership in the development of cross-municipal strategies by retaining their policy review and plan approval function under the *Planning Act*, and encourage use of joint planning mechanisms provided in the *Planning Act* to address inter-municipal groundwater issues.

8. Support application of innovative and flexible tools for managing growth to protect groundwater-ecosystems by:

   – drafting and consulting on a regulation pursuant to the *Planning Act*, that would enable municipalities to implement development permit systems in specified areas,

   - making conservation easements and designated groundwater areas eligible for tax exempt status as *conservation lands* under the regulatory provisions of the amended *Assessment Act;*

- developing a process for designating water supply protection areas, under the authority of the *Ontario Water Resources Act*, to increase awareness and support for regional groundwater strategies; and

- introducing regulatory and fiscal inducements and other supports for pollution prevention measures by groundwater contaminant sources.

9.5 Further research

The *Ecosystem Approach Framework* developed through this inquiry has advanced a new paradigm in planning for groundwater protection. The Framework provides a bridge to new approaches to address existing deficiencies. Having said this, much work remains, particularly in moving from an exploratory stage to being able to explain the presence or absence of certain variables and predict successful outcomes.

Although the framework presented here is a useful normative guide, the formative state of knowledge in this field suggests that the conceptual framework be viewed as descriptive and exploratory rather than as an explanatory or predictive tool. A major challenge is enumerating positive or dependent relationships among the different principles. To make this possible, further analysis and testing of the principles and attributes is needed to refine them and to identify key elements.

Each of the principles and many of the identified attributes have multiple elements that confound measurement. This is particularly the case for the principles related to the rule systems that influence human activities and to institutional capacity building. For example, the principle of integration encompasses considerations both of the types of instruments being applied (regulation, economic and voluntary) as well as the functions being addressed (protection, prevention, control, remediation). The principle of coordination incorporates coordinating mechanisms which play multiple functions (appreciation, resource sharing, decision support) and protection partnerships, which involve multiple actors at different stages of the process (agenda setting, solution development, implementation).

While presented as discrete elements, some of the principles are closely related. For example, the principles of ecosystem boundaries, functions and cumulative effects each contribute to the larger understanding of how groundwater-ecosystems function and how they respond to a variety of human activities and stresses. The fact that they share a common interest in holistic description and analysis of groundwater ecosystems and processes make them difficult to separate in practice. Additional testing of the principles and attributes in a variety of settings would explicate and operationalize key concepts. The effect of additional research would be to move closer toward explaining causal factors behind decisions taken, and increase the confidence in predicting successful outcomes.

The Waterloo Strategy is at a relatively early stage in its evolution, and there remain a number of difficult decisions ahead, not the least of which relate to final decisions on the measures for implementation. The Region's commitment to learning from other jurisdictions, its use of peer review at various stages in the process, and its coordinating mechanisms for soliciting the participation of core actor groups, bode well for the future progress toward an ecosystem approach. A future time-series analysis could examine how difficult decisions not yet made were resolved in light of an ecosystem approach.

Another area for productive research is to investigate the potential application of specific innovative tools. Additional case studies could be used to draw cross-comparisons with the Waterloo case. This could include in-depth analysis of cases which have employed alternative development standards, conservation easements, and pollution prevention planning for protecting groundwater through watershed studies and other means. Each of these, to varying degrees, reflect key principles of an ecosystem approach, particularly as adaptive and flexible instruments.

Additional research is needed to identify opportunities to link ecological approaches to groundwater protection with other compatible objectives. For example, the interest in public authorities and large water users in avoiding the cost of remediating contaminated groundwater or replacing groundwater supplies should generate support for investments in prevention. Similarly, the benefits of applying innovative development standards to protect groundwater may increase efficient use of land and infrastructure, and may enhance marketability. The potential convergence of these and similar mutually reinforcing objectives could accelerate progress toward an ecosystem approach.

Finally, investigation is needed of the impact of a policy framework that incorporates precautionary principles in the decision making processes affecting groundwater. For example, the land use planning process in Ontario does not reflect a precautionary approach in so far as the burden of proof continues to rest with those who are concerned about potential cumulative effects. In the case study, evidence suggests that the need for the Region to defend the Strategy in a forum which does not recognize the precautionary approach is retarding implementation of pro-active measures to protect groundwater systems. The costs and benefits of such an approach deserve further analysis.

9.6 Concluding Remarks

An ecosystem approach defines problems and opportunities in a way that bridges societal and ecosystem needs, recognizes the imperative of planning at multiple levels and scales, informs decisions through an understanding of ecosystem functions and processes, favours a precautionary and adaptive approach, links actors across jurisdictions and sectors, and utilizes a wide range of policy instruments to prevent loss or degradation of ecosystem functions.

This inquiry found evidence that elements of an ecosystem approach are being incorporated in progressive contexts, even if partially. A critical challenge will be securing and sustaining the commitment to move forward. Much remains to be learned and acted upon. Recognized deficiencies in past practice and crises arising from loss or impairment of groundwater will continue to reinforce the need to adopt an ecosystem approach. The ecosystem approach offers a coherent vision that will inspire and guide action. Nothing less will foster the shared accountability and long term perspective that is needed to successfully protect healthy groundwater-ecosystems and ensure sustainable human uses and benefits over the long term. Where it offers the promise of workable solutions to recognized limitations of past approaches and demonstrates positive results, the ecosystem approach will continue to gain currency.

APPENDIX A

LETTER TO MEMBERS OF WATER RESOURCES PROTECTION LIAISON COMMITTEE

REGIONAL MUNICIPALITY OF WATERLOO

ENGINEERING DEPARTMENT
Water Services Division

150 Frederick Street, Kitchener, Ontario N2G 4J3
Telephone: (519) 575-4426
Fax: (519) 575-4452

August 2, 1996

File: A02-40\WRPLC

To Members of the Water Resource
Protection Liaison Committee

As part of the Region's involvement in promoting water resource protection in Southern Ontario, we have had frequent discussions with the Ministry of Environment and Energy's Policy and Planning Branch. It is through this forum that we have crossed paths with Mr. David Neufeld, a planner in the above office. Mr. Neufeld is currently working on a Ph.D. in Planning at the University of Waterloo examining strategies for protecting groundwater in urban regions. As part of his research, he is studying the progress that has been made in Waterloo Region to develop a strategy to protect groundwater.

As part of his research, Mr. Neufeld would like to interview members of the Water Resources Protection Liaison Committee. These interviews will be an important source of information concerning the perspectives of key stakeholders, especially with regard to the rules and approaches proposed for protecting the Region's groundwater systems, the roles identified for public and private groups, and the cooperation required to implement different elements of the Strategy. These comments will provide a critical source of information for his analysis.

To maximize your convenience, and the efficiency of the process, he is planning to conduct the interviews by phone and will be contacting you in the near future to set up a mutually agreeable time for the interview. He will provide a copy of the results of the Waterloo Region case study to all interviewees who request it.

Yours truly,

Eric Hodgins, M.Sc.
Manager, Water Resources Protection
Water Services Division

EH/pp

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APPENDIX B

INTERVIEW GUIDE

- Understanding and support of the goals and objectives of the Water Resources Protection Strategy.

- Agreement with current priorities.

- Satisfaction with the emphasis of the Strategy and its mix of regulation, voluntary measures and economic incentives.

- Functions played by the Water Resources Protection Liaison Committee and working groups.

- Participation in joint projects or other partnerships related to the Strategy.

- Appropriate roles for the private sector, landowners, interest groups, different levels of government in achieving the goals of the Strategy.

- Current performance of the identified roles by above groups (private and public).

- Un-resolved issues related to the Strategy.

- Obstacles to successful implementation of the strategy in short and long term.

- Means for addressing obstacles.

- Other comments

APPENDIX C

SUMMARY OF INTERVIEW RESPONSES

How would you describe the main objectives of the Region's Water Resources Protection Strategy?	
Protect the groundwater resources of the Region	9
Protect the drinking water supplies of the Region	5
Prevent (further) contamination of resources/drinking water supplies	8
Protect groundwater quality and quantity	4
Limit risk to groundwater	2
Understand groundwater flows and the movement of contaminants	2
Protect sensitive groundwater areas	1
Correct current problems	1

Do you support these objectives? Do you see any potential conflict with the interests of your organization?	
Unqualified support for objectives of the Strategy	6
Qualified Support for objectives of the Strategy	
- potential for conflict with active farming operations in rural well fields	3
- potential for conflict with owners/businesses in urban well fields	2
- potential conflict over the means to achieve objectives	1
No position until see final policies proposed by the Region	2

Are you satisfied with the way the Water Resources Liaison Protection Committee, and working groups have operated and the functions they have played to date (information sharing, opinion exchange, decision support)? Are you satisfied with your influence on decisions made to date?	
Committee provides a forum for information exchange	12
Committee provides decision support role for Regional Council	9
Committee provides educational role for members	6
Satisfied with functions played by committee	14
Satisfied with influence on decisions to date	10
Satisfied with flow of information between Region and members	13
Committee process too slow, meets too infrequently, limited investment of time by members	7

Are you satisfied with the mix of regulation, voluntary measures and economic incentives being considered? e.g. use of regulations to control behaviour versus voluntary agreements. If not, what should be the appropriate mix?	
Support expressed for mix of regulatory and non-regulatory measures	8
Emphasize voluntary measures, education and awareness of benefits of goof management practice	6
Economic incentives to address hardships placed on individual land owners	4
Zoning is of limited use for existing uses	3
Regulate chemical use in sensitive urban areas	2
Have adequate regulation now.	2
Regulation currently isn't strict enough	2
Use regulations to stimulate/motivate action	1

How important is the strategy to your organization? Will it have a major impact on your organization (how you operate, what you do in the future)?	
Important or very important to organization.	12
Do not have a large stake in the Strategy	2
Will not have a major impact on future activities of organization.	10
Will have a major impact on future activities of organization.	4
Groups likely to be most affected by Strategy -business/industry - Regional municipality - farming operations	 4 3 3

Are you involved in any partnerships or joint projects that are underway or planned as part of the strategy? (developing policy/implement options, data sharing, research, demonstration projects, education/awareness). Please describe your contributions. e.g. information, money, expertise.	
Groundwater Guardian Program	3
Farm nitrogen efficiency study	3
watershed planning	3
groundwater modelling with Region	1

What issues have not yet been resolved to your satisfaction? e.g. goals of strategy, the rules to implement it (policies, regulation, BMPs), who is responsible for implementing it.	
Controls to be applied in urban well fields	10
Controls to be used in rural well fields	7
Potential impacts of any new rules on farm operations	5
Groundwater time-of-travel concept - calculation, justification, rationale	4
Resources that will be made available to implement strategy	3
Getting cooperation from all sectors to implement strategy	2

What roles should the private sector play in achieving the goals of the strategy e.g. deciding what is to be done, paying for it, and actually doing it?	
Voluntary cooperation with Strategy	4
Increase awareness of impacts of activities on groundwater	4
Invest some funds in clean-up activities	4
Participate in deciding how best to achieve goals	3
Adopt improved environmental management practices	2

What roles should rural landowners play in achieving the goals of the strategy e.g. deciding what is to be done, paying for it, and actually doing it?	
Make some adjustments in land management practice	11
increase awareness of impact of activities on groundwater	3
take action if provided economic incentives for hardship	3

What roles should interest groups play in achieving the goals of the strategy e.g. deciding what is to be done, paying for it, and actually doing it?	
Constructive criticism/advocacy role	7
education role	4

What roles should the Province play in achieving the goals of the strategy e.g. deciding what is to be done, paying for it, and actually doing it?	
Provide Region legal authority to regulate chemical use by industry	3
Provide technical assistance	3
Establish Province-wide framework for local/regional activities	3
Provide financial assistance to support local implementation	3
Undertake groundwater research	2

What roles should the Region play in achieving the goals of the strategy e.g. deciding what is to be done, paying for it, and actually doing it?	
Play lead role in implementation of Strategy	7
Continue to deliver safe drinking water	4
Develop regional official plan policies	4
Invest financial resources	3
Education and awareness role	2
Defend the strategy against opponents	2
Establish some level of regulatory control	2
What roles should local government play in achieving the goals of the strategy e.g. deciding what is to be done, paying for it, and actually doing it?	
Adopt local policies that conform to regional policies	5
Institute development controls through zoning or site plan control	5
Educate landowners, citizens and business	5

What things, at present and in the future, might impede successful implementation of the strategy and achieving its goals? (authority, policy, technical, financial resources, support of public, actors and decision makers)	
Resistance by businesses and landowners directly impacted by Strategy	9
Lack of financial resources for implementation	6
General lack of awareness among population	3
Getting support for legislative changes	2
Accepting limits to growth	1
Communicating technical information effectively	1

How could these obstacles or impediments be overcome?	
Education and awareness raising activities	8
Educate business on benefits of improved environmental management	3
Involve business in developing the solutions	4
Involve supportive businesses in education process	2
Local municipalities should test limits of their authority under Planning Act to be innovative	1
Take short term actions that are feasible while working on longer term issues	1

APPENDIX D

PERSONAL COMMUNICATIONS

1. Drew Cherry. Area Supervisor. Waterloo-Wellington/Brant Area Team, Ministry of Natural Resources, Cambridge, ON.

2. Peter Fischer. Executive Officer. Environmental Compensation Corporation, Ontario Ministry of Environment and Energy. Toronto.

3. Eric Hodgins. Manager. Water Services Division, Regional Municipality of Waterloo. Waterloo, ON.

4. Ken Hunsberger. Waterloo Federation of Agriculture. Waterloo, ON.

5. Kent Novakowski. Chief. Groundwater Remediation Project. Canadian Centre for Inland Waters. Burlington, ON.

6. John Petrie, Golder Associates Inc., Toronto, ON.

7. Jim Robinson. Engineer. Water Services Division, Regional Municipality of Waterloo. Waterloo, ON.

8. Della Ross. Planner. Planning and Culture Department, Regional Municipality of Waterloo. Waterloo, ON.

9. April Souann. Environmental Coordinator. City of Cambridge. Cambridge, ON.

10. KimYee. Water Well Management Coordinator, Ontario Ministry of Environment and Energy. Toronto, ON.

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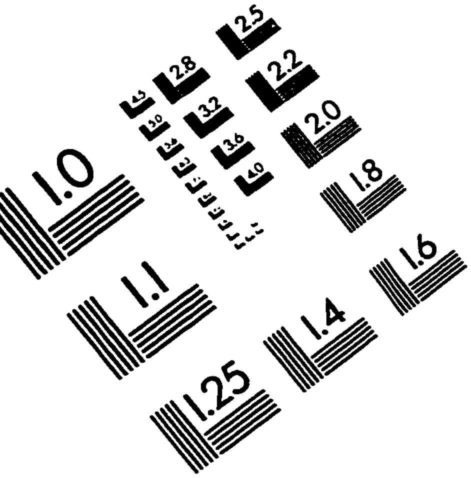
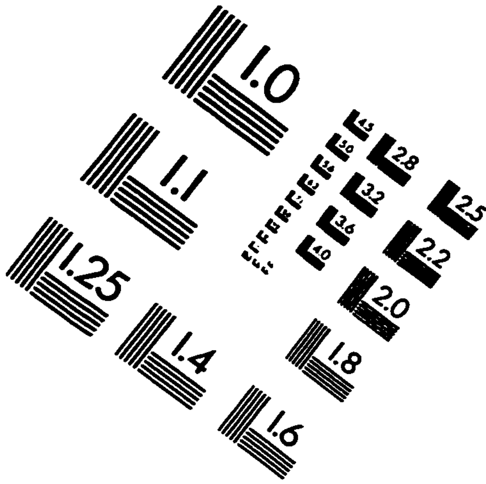
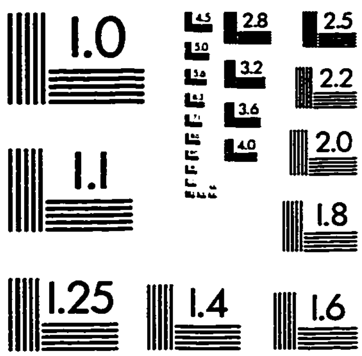
IMAGE EVALUATION TEST TARGET (QA-3)







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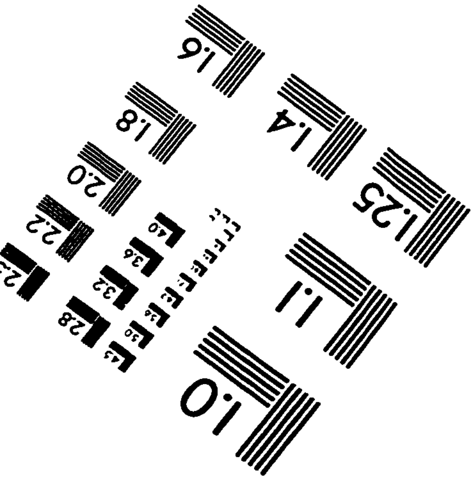

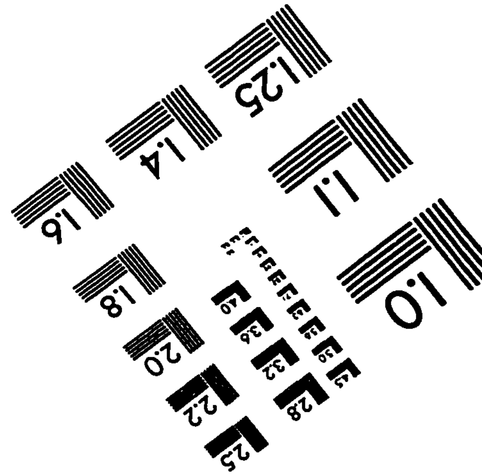

APPLIED IMAGE . Inc
1653 East Main Street
Rochester, NY 14609 USA
Phone: 716/482-0300
Fax: 716/288-5989