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An evaluative framework for assessing information management in watershed management: The case of the Grand River Conservation Authority (Ontario)

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AN EVALUATIVE FRAMEWORK FOR ASSESSING INFORMATION MANAGEMENT IN WATERSHED MANAGEMENT: THE CASE OF THE GRAND RIVER CONSERVATION AUTHORITY

By

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ABSTRACT

Watershed management has been rapidly evolving over the last 5o years. The current focus has been adaptive and ecosystem-based approaches to watershed management, redefining roles, responsibilities, and relationships of watershed organizations. While entire management models need to be heavily scrutinized, the practices and policies surrounding information are fundamentally important. Information forms the understanding and knowledge for watershed decision-making. Watershed organizations need to be critical of the policies and practices affecting their collection, storage, processing, analysis, monitoring, and reporting of data and information.

Among the Conservation Authorities, the GRCA has developed a proficiency at information management, doing it as well as any other watershed agency in the Province. Through interviewing participants involved in the information management process with the GRCA, drawing on experiences from other significant watershed management organizations, and reviewing the relevant literature, this research critically assesses information management practices. This supports the development of an evaluative framework for information management, designed to aid practitioners in the assessment of their own information practices and policies. Specifically, this framework identifies areas for identifying areas in need of improvement within a watershed management agency, including information planning and design; data management, processing, and design; data management, processing, and analysis; information sharing and coordination; information management technology; and internal and external considerations.

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CA – Conservation Authority
CAG – Canadian Association of Geographers
CIMS – Chesapeake Information Management System
CVC – Credit Valley Conservation
ESA – Ecological Sensitive Area
ELC – Credit Valley Conservation Ecological Land Classification
FDRP – Credit Valley Conservation Flood Damage Reduction Program
FIRMA – Freshwater Integrated Resource Management with Agents
GIS – Geographic Information System
GRCA – Grand River Conservation Authority
I & IT – Ministry of Natural Resources Information and Information Technology
IWMP – Credit Valley Conservation Integrated Water Monitoring Program
IS – Grand River Conservation Authority Information Services
LIO – Land Information Ontario
MOH – Ministry of Health
MMAH – Ministry of Municipal Affairs and Housing
MNDM – Ministry of Northern Development and Mines
MNR – Ministry of Natural Resources
MOE – Ministry of the Environment
NRVIS – Natural Resources and Values Information System
OGDE – Ontario Geospatial Data Exchange
OLID – Ontario Land Information Directory
OMAF – Ontario Ministry of Agriculture and Food
OWRA – Ontario Water Resources Association
PWQMN – Provincial Water Quality Monitoring Network
PGWMN – Provincial Groundwater Monitoring Network
PUC – Walkerton Public Utilities Commission
SAMPA – Science and Management of Protected Areas Association
USEPA – United States Environmental Protection Agency
WRIP – Water Resources Information Project

CHAPTER ONE – INTRODUCTION

1.1 INTRODUCTION

This thesis presents research that looks at the information management practices of watershed management organizations in support of environmental decision-making. The aim of this research is to provide practitioners working in the watershed management field with an improved conceptual understanding of information management and to develop a set of tools that will aid in evaluating related approaches and practices. Presented in this Chapter is the research problem, leading to the thesis goals and objectives, and setting of the research parameters. Watershed management in the Canadian context is introduced next with a short summary of recent trends, including an explanation of information management and key elements. The final section outlines the structure of the thesis.

1.2 RESEARCH PROBLEM

The watershed has emerged as a useful and practical geographical unit for many regional management efforts as it is a more meaningful boundary and scale for environmental problems than political municipal/regional/provincial boundaries. However, watershed management efforts are still constrained by the effectiveness of decision-making and planning, which depend on understanding of the watershed system and stresses. Management on a watershed basis still presents an enormous challenge to practitioners who try to make sense of the complex set of environmental variables. For their part, most watershed management organizations have developed either a formal or an informal means of information management aimed at making sense of their watershed to support decision-making and planning. These efforts usually involve a process for

collecting data, some degree of managing data in preparation for processing and analysis, and finally making the information accessible to decision-makers. However, to facilitate effective decision-making and planning for watershed management organizations, practices must be in place to optimize information management efforts. This is especially true with respect to the nature of ecosystem complexities, stresses caused by human activity and development, and natural environmental and climate change. While the natural environment is inherently complex and difficult, many scholars and professionals continue to bemoan our inability to adequately utilise existing potential for understanding watersheds adequately because of institutional limitations (Hooper, Mcdonald, & Mitchell, 1999). Institutional inefficiencies reduce the effectiveness of watershed management efforts and unnecessarily pose many challenges to watershed management practitioners.

Problems associated with institutional limitations and effective information management are the product of existing management structures, approaches, policies, and practices. The issues include planning, leadership, technical expertise, financial resources, departmental boundaries, isolated parties, existing practices/policies, ignorance, communication, technology gaps, technology literacy, institutional culture/structure, political will, personalities, trust levels, consultation, monitoring/tracking information, historical practices, and inter/intra-agency co-ordination. There are also many technical conditions that limit management abilities including computer system potential and capacity, data availability, accuracy, processing power, storage, system maintenance, meta-data, data integration, and format. In consideration of these challenges facing information management practices for watershed

management, the ability of watershed organizations to avoid any number of potentially preventable crises in the future is questionable.

1.3 GOALS AND OBJECTIVES

Upon reflection of the research problem stated above, the goal of this investigation is to explore the problems and challenges facing information management as practised by watershed management organizations and to provide an evaluative information management framework to improve the institutional effectiveness of watershed management organizations. To achieve this goal, this research will meet the following objectives:

1) To identify the information challenges and opportunities in watershed management organizations in Ontario and elsewhere

2) To develop an evaluative framework for information management useful for watershed management organizations

3) To apply it to the GRCA and identify opportunities for improving information management at the CA and in general in Ontario

An evaluative framework will be produced which will enable practitioners to assess the condition of their own information management practices and facilitate improvements aimed at gaining a better understanding of their respective watershed. The purpose of this framework is to serve as a useful tool for evaluating an agency's current watershed management practices and help practitioners to self-diagnose information management challenges, supporting improved watershed management decision-making. The working assumption is that if watershed organizations adopt more open and strategic approaches to information management, watershed management will be more effective.

Development of this information management framework will use principles determined to be fundamentally important for effective information management as identified through a literature review, case study, and an interview process. In addition to the framework, the research will also provide recommendations for improving information management within the province of Ontario.

1.4 THE CHALLENGE OF WATERSHED MANAGEMENT

As a life sustaining resource, fresh water is arguably the most precious resource the earth provides for life on earth. Watersheds, the natural boundaries that divide watercourses, are the sources of fresh water necessary for crop irrigation, drinking water, natural transportation networks, hydro-electric energy, and numerous other needs (Mitchell, 1995; Mitchell & Krueger, 1977; Mitchell, Mcbean, & Policy, 1985; Mitchell & Sewell, 1981; O'Connor, 2002). As impacts on the watershed upstream can affect users downstream regardless of political boundaries, watershed management is the institutional response to moderate the watershed conditions, ensure the livelihood of watershed communities, maintain resource quantity and quality, and protect the environment. Watershed management, discussed in detail in Chapter Two, involves investigating and characterizing the watershed; establishing priorities for action; developing watershed plans; implementing plans; monitoring implementation against watershed plans; evaluating management efforts; and updating plans (Grand River Conservation Authority, 1998d, p.9,). Effective watershed management intends to prevent water shortages, poor water quality, flooding, and erosion; and to ensure high water quality and supply, adequate hydroelectric power, and a healthy natural environment. Unfortunately, the relationship that has existed between watershed

communities and their rivers has been far from compatible. Watershed communities have suffered the effects of drought, floods, and more recently side effects from pollution and contamination, while the impact of communities can cause extensive environmental degradation of the watershed. Because of water quality crises such as the *E. coli* contamination in Walkerton, Ontario (2000) and the cryptosporidium crisis in North Battleford, Saskatchewan (2001), watershed management has become more visible to the public eye, falling under greater scrutiny. Amidst such crises and public scrutiny, watershed organizations need to ensure management programs and projects are effective at preventing such crises from repeating, as well as ensuring resources are optimally used. Walkerton was considered a wake-up call to governments, politicians, and decision-makers across the province and the nation as it resulted in a thorough investigation and recommendation process into how water resources should be adequately protected and managed (Government of Ontario, 2002). This rigorous investigation, led by Chief Justice O'Connor resulted in recommendations aimed at protecting drinking water sources through improved watershed management. Discussed in more detail in Chapter Two, these recommendations demonstrate that there is room for improvement within the Ontario watershed management model, especially with respect to ensuring that both the public and practitioners have access to adequate and appropriate information. At this stage in watershed management in Ontario, the questions this thesis is aiming to investigate are timely because of both recent successes and failures experienced by practitioners. While this approach to decision-making for water resources has been refined over the past 50 years, the access to information, supporting technologies, human pressures on the natural environment and awareness of

related environmental variables have all grown exponentially. Within Ontario, the organizations responsible for watershed management are going through some organisational and jurisdictional changes, which are effectively changing roles and responsibilities. Such organizations will have a need to continually revisit and revise their information management practices. It is the purpose of this research to explore the relationship that exists between the success of a watershed management agency and institutional practices surrounding information management.

1.4.1 The Importance of Information Management

The Provincial Government, Conservation Authorities, and Municipalities share watershed management responsibilities in Ontario. Conservation Authorities, established through the Conservation Authority Act (RSO 1990, c. 27), aim to co-ordinate resource management between municipalities based on a watershed scale. As result, Conservation Authorities have become the primary watershed management institution in Southern Ontario. Conservation Ontario, the provincial representative of the 36 Conservation Authorities, raised concerns about the condition of watershed management in the province. They addressed concerns about the lack of baseline information to support decision making and variance in provincial versus local priorities, suggesting the Province is focused on information sharing, database structures, standards, database integration and information management systems, whereas the Conservation Authorities are concerned about in-field information gathering (Conservation Ontario, 2001, appendix, p.10-11).

The report of the Walkerton Inquiry (discussed in detail in Chapter Two) identified and evaluated elements of successful watershed management based on practices in Ontario, including political endorsement, enabling legislation, co-ordination and a coordinating, body at the watershed /sub-watershed level, sustainable funding, a multi-disciplinary integrated approach, clear goals and objectives, good data, appropriate technical and analytical skills, useful decision-support tools, public involvement, partner collaboration, shared action plans, proactive planning, monitoring, and dynamic leadership. These elements cover the wide range of conditions that need to be present for watershed management to achieve its objectives. As for information management, these elements influence the level of resources available, ability to work with other organizations, organisational culture and attitudes, and the effectiveness of information management. Without political endorsement or sustainable funding for watershed management, there is little likelihood of heavy investment or commitment required for long-term information management. Enabling legislation provides a functional need and demand for better data and information. Co-ordination at different scales, multi-disciplinary, integrated approach, clear goals, and objectives, all work to define the scope, focus, and organisational support for information management.

1.4.2 INVESTIGATING INFORMATION MANAGEMENT

"*Information* is data that has been refined to have meaning and can be communicated so that it can be understood as knowledge". Information is the means of communicating knowledge from one person to another and is therefore fundamental to the operations of a successful organisation (Orna, 1999, p.8). For an organisation,

information management is the implementation of a strategy aimed at achieving specific information objectives that support the organisation's business activities, services, programs, and projects by addressing issues such as:

- How information is acquired, recorded, and stored?
- Where information resources are located in the organisation, and who has responsibility for them?
- How it flows within the organisation and between the organisation and its outside world?
- How the organisation uses it?
- How people who handle it apply their skills and co-operate with one another?
- How information technology supports the users of information?
- What information costs and what value it contributes?
- How effectively all these information-related activities contribute towards achievement of the organisation's objectives? (p.10)

Watershed management organizations employ numerous strategies and efforts to develop understanding of their watersheds beginning with some basic form of planning and assessment of information needs. Once the planning has been completed, collection of the actual data is performed which, depending on the type of data, will have its own unique considerations. After the data has been collected, watershed management organizations are faced with the task of processing the information, and preparing it for storage, sharing, and use, a process that can vary in length and task depending on the form, quality, and eventual use of the data collected. Manipulation of the data and analysis represents the first steps in trying to add value to the data and create information. Policies and established networks usually guide the use and sharing of information for watershed management organizations. These practices tend to be iterative and ongoing,

but can vary from agency to agency, program to program, and project to project. McLain and Lee suggest that effective environmental management requires organizations to do more than simply acquire information. Organizations must have the ability to respond to new knowledge and have the capacity to act and change their behaviour while they develop new understanding of how the world operates (Mclain & Lee, 1996, p.438).

Building on the concept of ecosystem-based approaches to watershed management, one of the core goals of any management process has to be the development of understanding. Slocombe (1998) suggests that effective management requires an ongoing understanding of the system state, necessitating a management approach that will provide the required ongoing information support. Despite attempts to redefine and restructure watershed management, management behaviour remains difficult or slow to change. Hooper, McDonald, and Mitchell remark that managers often lack the necessary information and skills to make decisions adequately. In an ever-worse scenario, management organizations do no seem to have the necessary structure and policies in place to substantially rectify the situation (Hooper, et al., 1999, p.756). Denning and Grieco support these claims, adding, "there is less recognition that the growing complexity is not yet fully reflected in the organisational processes and interactions that are deployed in development assistance" (Denning & Grieco, 2001, p.1868). Also, in a status report of the Grand River Basin Change Project, Slocombe and Sharpe indicate that further research should be undertaken to explore wider and systematic examination of tools and methods for developing understanding for ecosystem-based management (Slocombe & Sharpe, 1995, p.7).

1.5 ORGANIZATION OF THESIS

Following this introduction, the next Chapter will review the relevant literature and develop the central themes surrounding information management. The findings from the literature review provide an understanding of information management conditions required for effective watershed management. Chapter Three presents the methods for this research, focusing primarily on the interview process and the development of the evaluative information management framework. To explore information management and to develop a framework, the methods discussed in Chapter Three reveal in detail how a review of relevant literature including watershed management, information management, technology, decision-making, environmental management, planning, and institutional behaviour formed the basis of the framework. This information identified the principle elements and characteristics of effective information management. After a first draft of the framework based on the literature, consultation with practitioners served to refine the framework and help apply it to the research case study. In the fourth Chapter, a close look at the Grand River watershed and the practices of the Grand River Conservation Authority demonstrates a practical example of information management in support of watershed management decision-making. In Chapter Five, results from the interview process with watershed management practitioners are presented and the evaluative framework for information management is applied to the GRCA, fostering a discussion on the necessary conditions and processes for effective information management. Finally, the concluding Chapter provides a closing summary of the findings, identifies limitations of this work, and suggests opportunities for future research.

CHAPTER TWO – LITERATURE REVIEW
ASPECTS OF INFORMATION MANAGEMENT

2.1 INTRODUCTION

This Chapter will critically examine the literature on information management practices for watershed management. As was introduced in the first Chapter, the role of information management in decision-making and planning for watershed organizations is the focus of this research. This Chapter aims to develop the various elements of information management as they relate to watershed management through exploring the relevant literature and documenting some notable examples of information management.

2.2 INVESTIGATING THE ELEMENTS OF INFORMATION MANAGEMENT

As was introduced in Chapter One, information management as a set of approaches, tools, and practices has direct implications for ecosystem-based approaches to watershed management. Modern watershed management inherits many of the main tenets of ecosystem-based approaches to environmental management. As overarching goals, these include: a sense of system processes, an ecological unit as the primary management unit (i.e. the watershed), an adaptive approach to management, and ecosystem integrity with sustainable human benefits (Coulson, Saarenmaa, Rykiel, Saunders, & Fitzgerald, 1999; Grumbine, 1997; Slocombe, 1998a). The primary distinction of watershed management is that the watershed defines the management unit, which automatically defines many of the core management activities (e.g. flood control and forecasting; low water monitoring and flow augmentation; floodplain regulation; land use planning; recreation, heritage and conservation management; wetland and forestry conservation; and, many more

examples). For watershed management organizations adopting an ecosystem-based approach, one of the core goals of any management process has to be developing understanding. Slocombe suggests that effective management requires an ongoing understanding of the system state, necessitating a management approach that will provide the required ongoing information support (Slocombe, 1998a, p.490). However, many practitioners lament the barriers to their efforts or to a management process that arise directly from shortcomings around being able to gain a deeper understanding about their watershed (Grumbine, 1997; Hooper, et al., 1999; Mclain & Lee, 1996; Slocombe, 1998a, 1998b). Despite attempts to redefine and restructure management, management behaviour remains difficult or slow to change. Hooper, et al., remark that managers often lack the necessary information and skills to make decisions effectively. In an even worse scenario, management organizations do no seem to have the necessary structure and policies in place to substantially rectify the situation (Hooper, et al., 1999, p.756). Denning and Grieco support these claims, adding, "there is less recognition that the growing complexity is not yet fully reflected in the organisational processes and interactions that are deployed in development assistance" (Denning & Grieco, 2001, p.1868). Also, in a status report of the Grand River Basin Change Project, Slocombe and Sharpe indicate that further research should be undertaken to explore wider and systematic examination of tools and methods for developing understanding for ecosystem-based management (Slocombe & Sharpe, 1995, p.7). Finally, in a formal report for the Walkerton inquiry (summarised in Table 2.1); Conservation Ontario identified several challenges facing watershed management, many of which relate back to information management practices. Sustainable funding or lack there of, is also a

TABLE 2.1: COMMON CHALLENGES FACING WATERSHED MANAGEMENT

BARRIER	DESCRIPTION
Lack of sustainable funding	If funding is not available for the length of the process, the process will be suspended prematurely.
Excessive bureaucracy	Excessive bureaucracy or politics can prevent relationships or co-ordination between organizations.
Limited data or tools	Existing or accessible information does not adequately support required decision-making.
Lack of technical expertise	At times, budgets do not allow technical professionals to support the process or there is an oversight in a specific area of focus.
Lack of monitoring	Money is spent on data collection up front and there is no budget to continue the process for evaluation or monitoring purposes.
Fragmentation among organizations	Unclear and often duplication of responsibilities causes errors, oversights, and redundancy between watershed management organizations.
Resistance to change	Practices and attitudes become institutionalized are reluctant to accept new directions.
Unrealistic expectations	At times, goals or objectives are not pragmatically set, often beyond the capabilities of the agency.
Weak legislation	Lack of penalties, standards, or requirements can undermine the efforts of the watershed management organizations.

Source: Adapted from (Conservation Ontario, 2001, p.33)

problem for practitioners who are expected to develop projects and programs that address an issue that lasts years or decades, but fluctuating funding support is much more nearsighted. This results in programs skimping in areas, which often include long-term monitoring, expert staffing, technology infrastructure, or data collection. Excessive bureaucracy can add time delays to this process, stretching limited resources over an even lengthier project or program timeline. Limited resources for a project/program usually result in data, tools, expertise, and monitoring being reduced, which can undermine the integrity of the project or program objectives as data error, inaccurate assumptions, and skewed results can increase. The culture within watershed management organisations creates some unique challenges also. Fragmentation within and between organizations creates unnecessary barriers as do historical or cultural patterns of conducting business and unrealistic expectations. All of these conditions can cause an agency to resist change and avoid improving practices. Finally, weak legislation can undermine work or work against project or program progress.

The following sections will investigate the dimensions of information management. As is indicated later in the problem scoping section of Chapter Three, some initial considerations were identified through a preliminary review of the literature and some initial interviews with practitioners as a staring point for examining information management in detail. The subsections address watershed management in Ontario and information management; information planning and design; data management, processing, and analysis; information sharing and co-ordination; and, information management technology. This part of the research is used to identify practices and approaches related to these elements of information management that are fundamental to effective watershed management for building the evaluative framework for information management.

2.2.1 Watershed Management in Ontario and Information Management

Information management has been evolving rapidly as a part of watershed management over the last few decades, especially in Ontario. Watershed management has had a long history in Ontario, formally emerging as a solution to flooding, irregular water levels, transportation, power supply, irrigation, and drainage. Water control structures were built to regulate flow to support growth and protect the communities and settlements along the floodplains of Ontario's rivers. In 1946, the provincial government enacted the Conservation Authorities Act, formally establishing Regional Authorities based on watersheds to oversee water regulation and flood control (Heathcote, Plewes, & Moinar, 2003; Shrubsole, 1996). Over the past 30 years, the focus of watershed

management has changed in Ontario, incorporating more responsibilities, especially in non-structural management responses, which has encouraged the rapid growth of information management concerns and practices (illustrated in Table 2.2). The current integrated ecosystem-based approach to water resource and land use management both produces and requires a lot of information.

Within Ontario, there are four primary levels responsible for watershed management: the Federal Government, the Provincial government, the Municipal governments, and the Conservation Authorities. Federal and provincial ministries are mostly responsible for administering legislation, regulations, and guidelines, implementing multi-regional/watershed scale projects, and enforcement. Specifically at the federal level, the Constitution Act establishes the framework for water resources, delegating all water management activities to the federal government except for inland waters, limiting their role in this regard to fisheries, navigation, and multi-provincial co-operative partnerships (empowered by the Canada Water Act) (Conservation Ontario, 2001; Pearse, 1986).

A Federal inquiry on water policy identified integrated approaches to watershed management as an effective approach. Additionally, the inquiry offered the following direction for watershed management:

- A watershed plan sufficiently comprehensive to take into account all uses of the water system and other activities that affect water flow and quality characteristics to provide a reference for management;
- Information about the watershed's full hydrological regime;
- An analytical system or model capable of revealing the full range of impacts that would be produced by particular uses and developments in the watershed;
- Specified management objectives for the watershed, with criteria for assessing management alternatives in an objective an unbiased way;
- Participation or co-operation of all relevant regulatory organizations;
- Provisions for public participation in determining objectives in management decisions

Source: Pearse, 1986 in Kennett, 2001

TABLE 2.2: EVOLUTION OF WATERSHED MANAGEMENT FOCUS IN ONTARIO				
1980	1985	1990	1992	1993 - 2003
			Cultural and Recreational Resources	Integration: Ecosystem-based approach to water resource and land use management suing the boundaries of a subwatershed.
			Geomorphology	
			Terrestrial Habitat	
			Groundwater	
			Wetlands/ESAs/ANSIs	
			Woodlands	
		Monitoring and Mitigation Strategies	Monitoring and Mitigation Strategies	
		Enhancement Opportunities	Enhancement Opportunities	
		Infiltration	Infiltration	
		Water Temperature	Water Temperature	
		Baseflow Maintenance	Baseflow Maintenance	
		Fisheries/Aquatic Habitat	Fisheries/Aquatic Habitat	
	Water Quality	Water Quality	Water Quality	
	Erosion/Sediment Control	Erosion/Sediment Control	Erosion/Sediment Control	
Floodplain management	Floodplain management	Floodplain management	Floodplain management	
Runoff quality Control	Runoff quality Control	Runoff quality Control	Runoff quality Control	
Erosion/Flood Control Works	Erosion/Flood Control Works	Erosion/Flood Control Works	Erosion/Flood Control Works	
Major/Minor system Design	Major/Minor system Design	Major/Minor system Design	Major/Minor system Design	
Culvert Improvements	Culvert Improvements	Culvert Improvements	Culvert Improvements	
Source: Adapted from (Ministry of Environment and Energy and Ministry of Natural Resources, 1993a; Uma Environmental, 1998)				

The limited involvement of the Federal Government leaves the provinces with the majority of water resource responsibilities and delegation of authority for watershed management. For Ontario, the province must do its best to balance the roles and responsibilities between what the federal government's involvement, several ministries with varying degrees of involvement, and the 36 different Conservation Authorities, all with different needs and capacities. The MOE is involved in water quality, while the Ministry of Natural Resources' (MNR) focus is on water quantity and supply. The Ministry of Agriculture and Food (OMAF) has the lead role in rural affairs affecting non-

point source pollution and rural land use and Ministry of Northern Development and Mines (MNDM) has some responsibilities that have implications for ground water and northern land use. The Ministry of Municipal Affairs and Housing (MMAH) is responsible for land use planning, while the Ministry of Health (MOH) has jurisdiction wherever water quality has human health implications. Table 2.3 summarises some of the major provincial legislation and associated organizations. Having so many organizations involved has caused a degree of fragmentation among different organizations about specific water management roles and responsibilities, especially as it relates to implementation in an environment that underwent dramatic budget cuts in 1995 (Conservation Ontario, 2001). For the most part, implementation falls on local municipalities or land stewardship organizations in partnership with the Province (northern regions) or on Conservation Authorities in partnership with municipalities and the province (Mostly Southern or more populated areas). Conservation Authorities are empowered by the Ministry of Natural Resources to provide programs that improve water conditions (quality & quantity), reduce floods, protect natural areas, educate the public and improve watershed recreation (Conservation Ontario, 2001). While this model is effective, variance among watershed problems, demographics, urban/rural development, climate patterns, vegetation, topography, and municipalities has resulted in disproportionate differences among Conservation Authorities, resulting in there being very few uniform programs and expertise across the province (Uma Environmental, 1998).

TABLE 2.3: MAJOR PROVINCIAL LEGISLATION RELATED TO WATER MANAGEMENT			
Provincial Legislation	**Administering Agency**	**Description of Legislation**	**Implementing Organizations**
Ontario Water Resources Act	MOE	• Allows for the regulation of water supply • Allows surveillance and monitoring of all surface and ground water in Ontario • Regulates sewage disposal and controls water pollution • Allows MOE to construct and operate waste water facilitate or require this to be done by an industry or municipality	MOE Municipalities
Environmental Protection Act	MOE	• Forbids the discharge of any containment to the natural environment in amounts exceeding regulations • Prohibits the discharge of any substance that is likely to impair the natural environment • Requires that spills of pollutants be reported and cleaned up promptly and establishes a liability on the party at fault	MOE
Environmental Assessment Act	MOE	• Requires the assessment of any major public or private undertaking so that it may be altered or cancelled if found to be environmentally unacceptable	MOE
Pesticides Act	MOE	• Controls the use of chemicals for the destruction of plant and animal pests, and investigates possible harmful effects of pesticides on the environment	MOE
Conservation Authorities Act	MNR	• Establishes Conservation Authorities and provides them with a mandate to operate dams for water control, undertake water quality surveys, and to comment on planning documents • Authorises CAs to prohibit or regulate fill, construction and watercourse alterations • Allows for construction and maintenance of flood and erosion control structures	CAs
Lakes & Rivers Improvement Act	MNR	• Ensures that proposed water works do not adversely affect water quality nor cause undue erosion and silting • Empowers MNR to regulate the construction and operation of works • Requires that new water works be approved	MNR
Planning Act	MMAH	• Guides municipal planning activities (i.e. requires local governments to assess the impact of a proposed new subdivision on existing water supplies)	MMAH
Public Lands Act	MNR	• Authorises MNR to construct and operate dams and acquire land for their purposes • Authorises power generation projects on Crown Land	MNR
Municipal Act	MMAH	• Allows municipalities to enact bylaws for the construction, repair and maintenance of drains • Prohibits the injury or fouling of drains in rivers • Empowers municipalities to pass bylaws governing the construction and maintenance of dams and the straightening of water courses for flood protection	MMAH Municipalities
Public Utilities Act	MMAH	• Empowers municipalities to acquire and operate water works and divert a lake or river for their purposes	MMAH Municipalities
Ontario Water Resources Act	MOE	• Requires that a permit be obtained for water withdrawals greater than 50,000 litres per day • Requires that a well construction permit be obtained for groundwater withdrawals • Allows MOE to allocate water among competing users • Allows municipalities to establish or replace water works with Ministerial approval	MOE Municipalities
(Conservation Ontario, 2001; Uma Environmental, 1998)			

Finally, among the various watershed management jurisdictions, municipalities usually operate water works services, sewage treatment, provide municipal drainage, and administer local land use planning (Conservation Ontario, 2001). It is through land use

planning that municipalities can have their most significant impact on watershed management, often having a strong voice in areas of water resource related conflicts (Uma Environmental, 1998).

Efforts of all of these management organizations are aimed at ensuring the natural function of the watershed and protecting the health of watershed communities. While no system is perfect, in May 2000, it became evident that watershed management in Ontario was in need of improvement. Walkerton's local drinking water system became contaminated with *Escherichia coli* 0157:H7 and *Campylobacter jejuni*, which resulted in seven deaths and 2,300 related illnesses (O'Connor, 2002). The resulting inquiry determined the outbreak would have been prevented by the use of continuous chlorine residual and turbidity monitors at Well 5 in Walkerton. However, a complicated set of events and circumstances compounded this problem. Failure to use continuous monitors at Well 5 resulted from shortcomings in the approvals and inspections programs of the Ministry of the Environment. Operators at the Walkerton Public Utilities Commission (PUC) lacked the necessary expertise to identify the vulnerability of Well 5 to surface contamination. Improper operating practices were common practice for the PUC operators, including failing to use adequate does of chlorine, failing to monitor chlorine residuals daily, making false entries about residuals in daily operation records, and mis-rating the locations at which microbiological samples were taken. While the MOE's inspections program should have detected the Walkerton PUC's improper operating practices, budget cuts by the provincial government resulted in inadequate inspection staff and resources, reducing the likelihood of the MOE's to identifying the vulnerabilities. The provincial government's budget reductions led to the discontinuation

of government laboratory testing services for municipalities in 1996. Upon implementation of this decision, the government failed to address the resulting shortfall in monitoring by not enacting a regulation to require reporting of testing information by laboratories and consulting firms to the MOE and the Medical Officer of Health of adverse conditions (O'Connor, 2002). Failure to respond to the outbreak resulted in hundreds of more individuals becoming sick. Mitchell stated, "the general view was that the tragic events at Walkerton highlighted the need in Ontario for a strong, co-ordinated, holistic and ecosystem approach to water management...what appears to be needed is leadership and commitment at provincial and local levels in order that appropriate actions are not only planned but effectively implemented" (Mitchell & Shrubsole, 2001).

Since the events of Walkerton took place in 2001, Justice O'Connor, the Ontario government, and non-government organisations such as Conservation Ontario have made recommendations for improving watershed management in Ontario. Table 2.4 summarises just a few of the recommendations that resulted from the reviews of watershed management in Ontario conducted by Conservation Ontario, Chief Justice O'Connor, and the Ontario government that related back to information management. The recommendations listed identify a number of core themes that include allocating more sufficient resources to watershed management for knowledge building, maintaining minimum levels of expertise to interpret and respond to information, sharing the information with others, and reporting to the public and monitoring ongoing water management activities for adaptive management. These recommendations suggest creation of new sections and long-term investment in information management for the sake of gaining a better understanding of Ontario's water resources.

TABLE 2.4: RECOMMENDATIONS FOR WATERSHED MANAGEMENT IN ONTARIO

Recommendations
The MOE should maintain an information data system that includes all relevant information arising from an approval application process – in particular, information relating to the quality of source water and relevant details from expert reports and tests
All municipal water providers in Ontario should have, as a minimum, continuous inline monitoring of turbidity, disinfectant residual, and pressure at the treatment plant, together with alarms that signal immediately when any regulatory parameters are exceeded.
The provincial government should create a watershed management branch within the Ministry of the Environment to be responsible for oversight of watershed-based source protection plans and, if implemented, watershed management plans
The Ministry of the Environment should create an Integrated Divisional System which provides central electronic access to information: relevant to source protection; relevant to each drinking water system in Ontario
The Drinking Water Branch should prepare an annual "State of Ontario's Drinking Water Report," which should be tabled in the Legislature.
The province undertakes an assessment of the capacity of current and planned monitoring networks to support the needs of source protection planning.
The province has the lead for information management, recognising that other stakeholders will play an important role in the collection of information and maintenance of local monitoring programs.
The following activities, related to information, need to be carried out or co-ordinated at the provincial level: • Centralized compilation, collection, and improvement of data sets. (This includes the work being done by Land Information Ontario to develop mapping and geo-referencing standards that will ensure source protection plans fit together); • Provision of provincial data to support the development of initial source protection plans; • Development of data standards with the involvement of stakeholders, including a mechanism to ensure that all participants are working with the same or compatible data; • A central repository and conduit for provincial data access and sharing with planning participants, to complement the sharing of data and information amongst planning areas, conservation authorities and municipalities; • Provision of advice, training and expertise to planning participants; • Development of, and input into, the selection of specific modelling tools; and aggregation of source protection plans and reporting at a provincial level that ensures consistency of mapping.
Conservation authorities and municipalities would be responsible for managing and collecting information relevant to source protection that is not already being collected by the province or another body. Their roles would include: • Co-ordination of the local compilation, collection and improvement of data sets; • Sharing data and information with other planning areas, conservation authorities and municipalities; • Integration of local data with provincial data sets; • Aggregation and reporting of data and information into a central repository; • Analysis of the integrated information sets to create source protection plan products; • Development of appropriate specific models for watershed planning purposes; and, • Provision of local information support through the development of the source protection plan.
To the extent possible, data should be as available to all those involved, including the dissemination of data and information to the public (e.g., non-proprietary information).
Source: (Advisory Committee on Watershed-Based Source Protection Planning, 2003; Conservation Ontario, 2001executive summary, p.2-4; O'Connor, 2002); (Conservation Ontario, 2002b)

2.2.1.1 Water Resources Information Project and other Developments Supporting Ontario Water Resources

Based on the needs identified by the Walkerton Inquiry and earlier government reviews (e.g. "Managing the Environment Report", Val Gibbons, 1999), the Ontario government has been working to develop some programs that address the information management needs within watershed management. Across Ontario, there is a strong need and interest in doing geo-spatial mapping work, but there are many institutional challenges to co-ordinating all of the ministries, municipalities, and conservation authorities. Initiated in 2000, the Water Resources Information Project (WRIP) is a significant project within the Information and Information Technology (I & IT) Strategy, which has been a cornerstone for change within the provincial government and amongst Conservation Authorities and Conservation Ontario. The aim was to create an environment where information could be easily shared and integrated among water management organizations, ensuring that high quality information and tools were provided to those who needed them (Ministry of Natural Resources, 2003b). To achieve this, WRIP has identified four primary objectives:

- A common I&IT infrastructure across the entire government:
  a. *Technology Infrastructures - hardware- including servers, network connections, routers, mainframes, desktops, laptops, and telephones*
  b. *Application infrastructure – software*
  c. *Information infrastructure – data definitions, information architecture and data structure*
- Corporate, government-wide I&IT policies and standards
- The restructuring of the I&IT organization
- Governance and accountabilities for I&IT resources

Source: (Ministry of Natural Resources, 2003b; Officer, 2002)

WRIP is primarily about strengthening the water information base and ensuring it is accessible, a departure from historical practices, which resulted in most information being collected in isolation and poor accessibility. As a project, WRIP attempts to connect information about surface water and groundwater, water quality and water use, soils, nutrients, and geology. This is achieved through developing standards, applications, and most importantly establishing partnership commitment. Integration with existing data warehouses is important too. WRIP is fully compatible with Land Information Ontario's (LIO) programs and services, which will further support its use and integration with data other than just water data. LIO provide a searchable card catalogue of land information known as the Ontario Land Information Directory (OLID), and provides access to seamless geospatial, base, and thematic data in the Ontario Land Information Warehouse (OLIW), and supports the Ontario Geospatial Data Exchange (OGDE), promoting the flow and sharing of land information among producers of information in Ontario (Ministry of Natural Resources, 2003a).

WRIP draws upon many water related information projects to support its objectives, including:

- **Groundwater Studies Information:** WRIP has assisted with the implementation of standards for collecting and describing information about aquifers, including their susceptibility to pollution.
- **Water Wells:** The information that has been collected by the Ministry of Environment about each well in the province is being referenced to a geographic point.
- **Provincial Watersheds:** This project focuses on creating various layers of digital data including various levels of digital watershed map layers, a provincial Digital Elevation Model (DEM), and continuous digital stream networks. These layers will help managers make decisions on a watershed basis.
- **Water Resource Use and Demand:** WRIP is enabling the collection of information about the use of surface and groundwater in Ontario and throughout the Great Lakes basin. The project is even supporting the collection of information about future use and demand in the tributaries of Ontario watersheds.

- **Nutrient Management**: Tracking the origin and application of nutrients, agricultural fields, and manure storage systems needs to be identified, because water resources can be affected by them. In this project, farm field boundaries are delineated from satellite imagery, which has reasonable levels of accuracy.
- **Soils Ontario:** WRIP has assisted with the resources required to standardize and integrate all the existing information about soils and soil surveys in Ontario.
- **Constructed Drains:** WRIP is automating information about constructed drains in the province and integrating drainage information with other data collected by municipalities, conservation authorities, the Ministry of Natural Resources, the Department of Fisheries and Oceans, and others.
- **Waterpower:** When new hydroelectric facilities are being planned or existing structures changed, managers need a wide range of information about everything from existing dams and water flows to fish habitat and water use on a river system. WRIP is helping collect, organize and assemble all these data sets for every watershed in Ontario.
- **Geology:** Water resources are affected by Ontario's geology. WRIP has initiated the automation and assemblage of all the information through the Ontario Geological Survey, resolving map discrepancies and establishing a uniform geology legend for all on Ontario.
- **Permit to Take Water**: Taking large quantities of water in Ontario require a permit from the Ministry of the Environment (MOE). This project involved geo-referencing all of those permits from the MOE's Permit to Take Water Program as well as enhancing existing permit information.

Source: (Ministry of Natural Resources, 2003b)

The opportunities for WRIP to partner and coordinate data for watershed management are seemingly endless provided the project receives adequate endorsement and cooperation. Providing that WRIP is adopted and supported by both provincial ministries and external organizations alike, it promises to be an example of an effective partnering approach to information collection, processing, analysis, and sharing.

2.2.2 INFORMATION PLANNING AND DESIGN

Identifying problem areas, establishing values, and setting goals and objectives pose a unique challenge for any watershed management process and play an important role in establishing objectives, priorities, and resources for information management. As in any process, values are used by the participants to set goals, objectives, and priorities. Much of how values form and evolve depends greatly on the understanding and

perception of a specific issue, often derived from knowledge and a given set of experiences. Defining 'values' is important in deciding what kind of information is collected and at what scale it will be collected (Ministry of Environment and Energy and Ministry of Natural Resources, 1993b). At the base of a management issue, there need to be values. Values need to be embedded in the mandate of the agency, providing a sense of direction on issues. As such, values need to be revisited and re-articulated from time to time to ensure that the agency is on track. Similarly, goals of any process need to be nested within those same values. This has been found to be critical to the environmental management process as it plays an important role in setting any process on the right course. Through a strategic visioning process for establishing values and goals, it begins to frame the management goals, from which information needs can be identified and designed for accordingly. Fortunately, there are many tools available to facilitate this process. Gregory, conducting research for the National Centre for Environmental Decision-Making Research provides an excellent summary (Table 2.5) of the various tools that are readily used at all levels of government for just such a task.

While Gregory goes on to identify various strengths and weaknesses for each approach, from this table alone, we are able to get a sense of the many strategies available. In addition, we can begin to see that some of these approaches in fact can possibly overlap in the information collection process. It is conceivable that a small-group elicitation if you were dealing with a group of experts on a specific water issue might yield volumes of knowledge that may be useful later in the process.

TABLE 2.5: TOOLS FOR IDENTIFYING ENVIRONMENTAL VALUES	
TOOL	**USE**
ECONOMIC MEASURES	
Restoration/Replacement Costs	Assign economic cost to environmental damages
Travel Costs	Assign economic value to resource based on visitation
Hedonic Pricing	Assigns economic worth to component of resource values
Damage Schedules	Estimates the relative seriousness of adverse impacts
Ecological Relationships	
Health	Relates ecosystem quality to the performance of key indicators
Integrity	Focuses on synergistic and system relationships
Resilience	Assess the long-term viability of a resource
Carrying Capacity	Relates fundamental qualities of ecosystem value to productivity
Expressed Preference Surveys	
Attitudinal and Opinion Surveys	Gather Information about ecological understanding and support for policies
Contingent Valuation	Places an economic value on a resource not sold in conventional markets
Constructed Preference	Elicit values used in making decisions about environmental choices
Image	Assesses affective and psychological reactions to scenarios or events
Narrative and Affect	Elicits concerns off stakeholders through dialogue and conversation
Referenda	Ask individuals to vote for or against a specific proposed action
Small-Group Elicitations	
Focus groups	Elicit responses to proposed action through informal small group discussions
Advisory Committees	Develop a broad perspective on an issue; involved interested and knowledgeable representatives
Multi-Attribute elicitations	Structure the objectives and tradeoffs of participants vis-à-vis policy alternatives
	Source: (Gregory, 1999, p. 38-39)

Establishing goals and objectives for watershed management can be a complicated, often contentious process, but it is critical to the success and effectiveness of the management decisions. With respect to information management, the goals and objectives set at the corporate level of a watershed agency ultimately affect the scale, scope, and purpose of its programs and projects. During the stage of planning information gathering, an area that must be considered is the timeliness and long-term value of the information (Bee & Bee, 1999). More often than not, information is

collected to serve short-term needs, an unfortunate scenario considering the time and resources required for information gathering. This situation is even more unfortunate if an opportunity to collect data that yield longer-term value is missed by not consulting other departments and specialists with similar data needs. Similar to this problem is the nature of data collection itself. Since data does take a considerable amount of time to collect, the process must consider time requirements for collecting and processing data/information so that is available when needed (Bee & Bee, 1999). As identified by Probst, Raub, and Romhardt in Table 2.6, depending on the level of goal, and objective setting, different components of information management must be considered.

TABLE 2.6: INFORMATION MANAGEMENT CONSIDERATIONS AT DIFFERENT GOAL LEVELS

	Structures	**Activities**	**Behaviour**
NORMATIVE MANAGEMENT	**Organisation Charter** - legal structures sets parameters for organisation	**Organisation Policy** - vision and mission statement identify critical areas of knowledge	**Organisation Culture** - culture sets attitude toward knowledge sharing, innovation, openness, and communication
STRATEGIC MANAGEMENT	**Organisation Structures** - conferences, reporting structure, R&D organisation, group experience establishes internal flow and capacity of information	**Programmes** - building core competencies in specific areas	**Problem Solving** - Approach to resolving knowledge gaps
OPERATIONAL MANAGEMENT	**Organisational Processes** - Control of knowledge flows - knowledge infrastructure - supply of knowledge	**Tasks** - knowledge projects - build expert databanks	**Performance and co-operation** - knowledge sharing - Knowledge use

Source: Adapted from (Orna, 1999, p.320; Probst, et al., 2000); (Prakken, 2000, p.88-89)

Normative management is the general vision of an organisation, including policy, cultures, and, mandate. Strategic includes the long-term planning and thinking needed to achieve the normative declarations. Operational level ensures the strategic vision is implemented. For effective watershed management, all three levels of goals need to complement each other, which requires the supporting information to also be complementary (Prakken, 2000, p.88-89; Probst, Raub, & Romhardt, 2000). The danger

of the concept of information management is its emphasis on the role of management; which may impose restrictions on the knowledge that is gained through personal biases introduced through the decision and resource allocation process of an organization. To reduce the effect of such restrictions, it is necessary to embed decisions about how information management is conducted in wider organisational policy frameworks, as illustrated by the following:

1. Information policy is insufficiently attuned to the information needs of organisational participants.
2. The fine tuning between subsystems in the field of information policy is missing,
3. The phenomenon of more or less continuous changes of organisations and of their control
4. The lack of clear criteria for capital budgeting decisions
5. Obsolete – automated – systems are still functioning
6. Top management is insufficiently involved in the organisation's automation policy
7. Unclear responsibilities in the field of information processing activities,
8. Reorientation of the organisation's strategic position
9. A lack of awareness of the opportunities offered by new technologies

(Prakken, 2000 p.86)

It is evident watershed management agencies must carefully consider what the information management capacity and potential is when establishing values, goals, and objectives. Goal setting must arise out of the value setting process and goals must have information in mind, as much as information needs to have goals in mind (Gregory, 1999). An avenue for information management to be addressed at a normative or strategic level is through integration with planning processes and documents, which are influential in defining the management approach, discussed in the next section (Ministry of Environment and Energy and Ministry of Natural Resources, 1993b).

2.2.2.1 Management Approach

Finally, after decades of top-down management, we are beginning to see changes in the management approach to watershed management (Calheiros, Seidl, & Ferreira,

2000; Rhoads, Wilson, Urban, & Herricks, 1999; Slocombe, 2001). In research focusing on various approaches to ecosystem management, Brunner and Clark (1997) address some of these related issues in their evaluation of approaches to ecosystem management. The evaluated approaches include: (1) setting clearer goals; (2) constructing a scientific basis for ecosystem management; and, (3) practising what can be learned from the approach (Brunner & Clark, 1997). Brunner and Clark's findings suggest that the single most important approach for practitioners coping with the challenges of ecosystem management is learning from the process (p. 56). This represents a change in emphasis on actual decision outcomes toward an appreciation for the entire decision process (Sparrow, 1998, p1-2). Such an approach requires practitioners to be more self-aware and search for lessons and insight during the entire management process. That is, where ecosystem-based management approaches may be difficult to implement at first, the strength of the approach is that it grows stronger with adaptation, innovation, and co-ordination, requiring organisational learning.

Organisational learning has two distinct sets of factors: technical and social/cultural. Technical factors affecting learning include the effective processing, interpretation of, and response to, information both inside and outside the organisation, while social organisation learning factors are more likely to influence most individuals as it includes social interactions and work setting and culture (Easterby-Smith, Burgoyne, & Araujo, 1999). One of the most fundamental areas for an organisation to have successful information management practices is the organisation's ability to be self-aware of its information management practices (Sparrow, 1998 p.2-3, 8). This requires an organisation to be continually assessing its decision processes, as this may reveal areas of

risk or uncertainty, lack of understanding, unrealistic expectations, or perhaps new areas for investigation. Learning from this can reveal new directions for the information management process to head in or, contrarily, return the process to the intended track. Most importantly, learning allows the organisation to enhance, improve, and modify the process, ideally improving the future success of the information management-working group. As is suggested in Sparrow's investigation in *Knowledge in Organisations*, "Meta-Dialogue" presents an opportunity for those in the same work environment to discuss together their knowledge of information and related practices to gain a better understanding about what they know about information (Sparrow, 1998, p.9).

Finger and Bran suggest there are certain activities, elements, contributions, or interventions that are conducive to better organisational learning. These include educational and training activities, optimal use of sources internal to the organisation, optimal use of sources external to the organisation, and creating an environment conducive to learning (Finger & Brand, 1999, p.148). One challenge an organisation can face is learning across organisational boundaries. Dixon examined this in the Canadian public sector, using museums as a case study to explore: (1) How institutions might better organize themselves to be more efficient and productive; and, (2) How organisations can co-ordinate and support learning amongst each other (Dixon, 1999). In her previous work, principles fundamental to learning were developed and are summarised in Table 2.7.

The type of decision-making model commonly used by an organization determines the level and type of information that is used in the decision-making process. This ultimately defines the information priorities of the information management process

TABLE 2.7: PRINCIPLES CRITICAL TO COLLECTIVE LEARNING	
1.	*Individuals learn as a team or unit*
2.	*Organisational assumptions are not limiting and all assumptions are questioned*
3.	Learning how to learn is a priority
4.	*Co-Inquiry* – Role of 'Expert' is diminished and individuals across the organisation are encourage to participate in learning
5.	Information is collectively interpreted
6.	Determining what worked and what did not work is rewarded
7.	Risks can be taken without fear of punishment
8.	There is a climate of trust
9.	Continually measure how well they are doing and hold organisation members accountable for progress
10.	Past experiences are valued
11.	There are opportunities to reflect on experience
12.	*Learning occurs over time*
13.	*Collaboration and alliances* – There is a new spirit of collaboration among organisations that is recognition that there is much one organisation can learn from another. In the corporate world, this collaboration is manifested in an increase in benchmarking, study visits and supplier and customer training.
14.	A spirit of enquiry exists
15.	Open and honest communication is honoured
16.	There is widespread generation of, access to, and use of information
17.	Data are turned into useful knowledge
18.	There are opportunities to share knowledge, skills and creative abilities which create new understandings and meanings
19.	There is an established process for planning and decision-making
20.	Provide "information regarding the bigger picture
21.	There is an urgency to act
22.	Change is seen as an opportunity for growth and improvement
23.	Learning is applied to solve problems and resolve issues
	Source: (Dixon, 1994; Preskill & Torre, 1999, p.94-64)

in the long-term (Yoder, 1999, p.16-19). In research conducted for the National Centre for Environmental Decision-Making Research, English, et al., identify four common dimensions of environmental decision making: (1) the types of environmental issues on which decisions might be made; (2) the physical setting of the prospective environmental decision, including its spatial scale; (3) the types of individuals and groups who might interact in a process leading up to an environmental decision; and, (4) the time frame within which the decision must be made (English, et al., 1999). Regardless of the types of variables that may be present for any one of these settings, the decision-making process involves each of the following steps: (1) Problem Identification; (2) Value

Setting; (3) Information Gathering; (4) Information Integration; (5) Scenario/Options building; (6) Forecast; (7) Evaluate and Refine Options; (8) Make Decision; and, (9) Post Decision Assessment (English, et al., 1999, p.20,). While this is a very systematic approach to decision-making, Joslin and Nicholas noted that a significant critical barrier is the complexity of the decision-making that involves not only technical and scientific assessments, but also consideration of economic, social, political, and individual needs and values (Joslin & Nicholas, 1999, p.6). This illustrates the link between decision-making and values, goals, and objectives setting, which influences the information management practices of a watershed management agency. While there are several well-formulated approaches to decision-making in addition to the rational theory, there are potentially different circumstances when each approach is applied. When decision-making is for natural resources or similar complex systems, involving many factors and stakeholders, two axioms should be recognised: (1) rationality and logic may have limited roles in the decision-making process; and, (2) decision-making processes directly influence decision-making outcomes (Sparrow, 1998). The very nature of decision-making, problem solving, and management has a great deal to do with perception. Depending on the nature of the management objectives, perception of the challenges facing the process ultimately has a large influence in how the approach or process is designed (Sparrow, 1998, p.4). Adding to the influence of perception is the dynamic and mindset of the work group responsible for the information management. Simon noted that organizations are "institutionalized brains that fragment, routinize, and bound the decision-making process in order to make it manageable for the individual or group responsible" (Morgan, 1986, p.81). Ultimately, these factors have a role in how

management priorities are defined, perceived, interpreted, and addressed, directly affecting the function of the group, and indeed the effectiveness of the information management process. Recognition of these issues is an important step in improving the process and knowing the limitations of the management approach. Therefore, organizations should be careful in planning their approach, technique, and processes concerning information management. Their approach must be adaptive in nature, balancing the level of understanding with risk, addressing factors both individually and as a whole. In addition, the process must embrace the presence of chaos and unpredictability (Sparrow, 1998, p.8). This especially means that strategies for decision-making must be able to conform to changes within the system quickly, as systems are known to change.

2.2.3 Data Management, Processing, and Analysis

Data gathering, pre-processing, and management involve collecting data, converting it to a useable format, and making it accessible, while ensuring integrity is maintained. Data gathering is a part of the process that is led by a program or project area and the information collected is intended to support specific objectives of that same area. Over the years, with so many program and project areas collecting information, there has been a build up of volumes of data and information that are being underused or are not available in formats compatible with other data sources, introducing the notion of data integration. While the concept of integrating data and information from different sources is not new, in the past two decades information integration efforts have received greater attention. As we have noted in the previous section, environmental management has evolved to incorporate more sources of knowledge including non-traditional types.

Local knowledge and less traditional forms of knowledge are thought to provide the decision-making process an important perspective. Where we have established that goals of environmental management vary with the scale and scope of the activities, the integration of different types of information is needed to ensure that decisions are not made with limited knowledge or understanding (Slocombe, 2001, p.119). In addition, integration efforts combined with new technologies have potential for integrating, combining, manipulating, accessing, and re-visualising existing and new information in new ways (Slocombe, 2001, p.119). In theory, new technologies integrating different types and sources of information allow watershed management practitioners to investigate relationships and ideas quickly and efficiently as never before.

Conceptually, integration is a straightforward task where essentially different types of data are formatted for a common use; however, the technical and managerial task of integrating data proves to be complex, especially across organisational boundaries. Illustrated in Table 2.8, Slocombe provides a summary of issues facing those seeking to integrate information: (1) integrating information about different kinds of things; (2) integrating information from different sources; and (3) integrating information that is in very different forms (Slocombe, 2001, p.119).

For practitioners working in watershed management in Ontario, each of these integration issues will need to be addressed as a part of their organisation's information management if they want to optimize all potential sources of information. Table 2.9 identifies effective integration approaches and tools. Building on the topic of integration, there has been growing recognition of the importance of local knowledge. Unfortunately,

there is still a great deal of scepticism about local knowledge as it is not thought to have been derived with the same rigour as scientific data (Calheiros, et al., 2000, p.685).

TABLE 2.8: CORE ISSUES FOR INTEGRATING DIFFERENT KINDS OF INFORMATION

INTEGRATING ACROSS DOMAINS	INTEGRATION ACROSS FORMATS	INTEGRATION ACROSS SOURCES
Identifying points of connection between domains	Different units	Different variable definitions
Certain-uncertain knowledge. Predictive or not predictive. Quantitative vs. qualitative	Different accuracy and standards	Different system characteristics considered significant
Space and time variation Generating new knowledge	Different scales, resolution, and degrees of aggregation	Oral and written traditions
Interdisciplinary communication	Different hardware and software	Information based on experience rather than experiment of formal study
Flexible, accessible products	Different digital file formats	Cross-cultural communication

Source: (Slocombe, 2001, p.120)

TABLE 2.9: EFFECTIVE INTEGRATION APPROACHES AND TOOLS

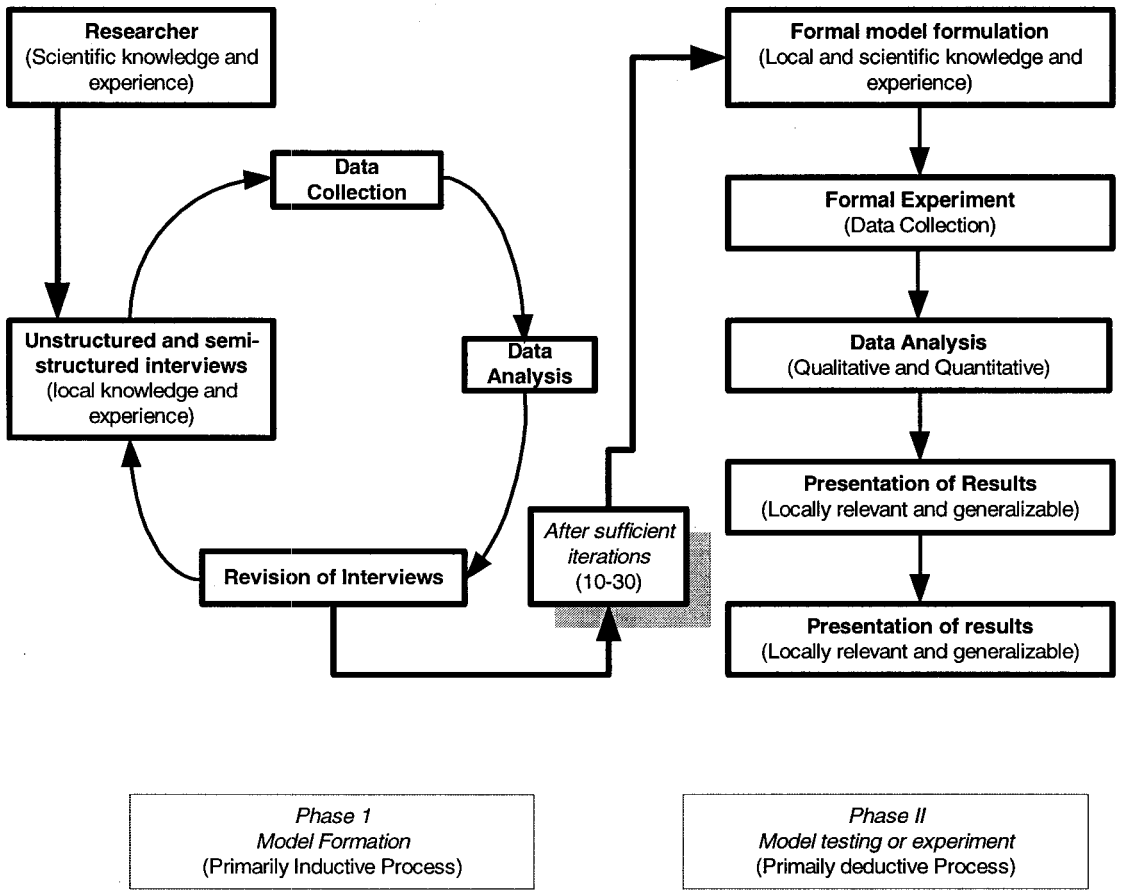
	Define process goals and products	Define standardisation goals	System studies	Key variables, processes, functions	Conceptual starting points or foci	Identify patterns and processes at all scales	Multiplicity of analytical tools	Seek coherent narrative	Multidisciplinary teams	Dialectic, iterative, non-linear process	Facilitated workshops	Consultation, negotiation	Reporting and pilot testing	Environmental information system, GIS	Simulation systems	Knowledge-based tools	Hypermedia	Internet, communication technologies
INTEGRATION ACROSS DOMAINS																		
Quantitative Qualitative	X		X			X	X	X			X	X		X	X	X		
Identifying points of connection between Domains			X	X	X	X		X	X	X	X				X	X	X	
Certain-Uncertain knowledge			X	X				X		X		X			X	X		
Discovering new knowledge				X	X	X	X		X	X	X		X	X	X	X	X	X
Space and time variation	X		X		X	X	X	X						X	X			
Interdisciplinary communication	X		X	X	X	X	X	X	X	X	X	X		X	X	X		X
Flexible, accessible products	X	X					X					X	X	X		X	X	X
INTEGRATION ACROSS FORMATS																		
Different Units		X												X	X			
Different accuracy and standards		X				X			X		X	X		X		X		
Different scales and resolution		X				X			X		X	X		X		X		
Different degrees of aggregation		X				X			X		X	X		X		X		
Different hardware and software		X							X		X	X		X				
Different digital file formats		X							X		X	X		X				
Data organisation and availability	X	X										X				X	X	X
INTEGRATION ACROSS SOURCES																		
Oral and written traditions				X			X	X		X	X	X		X		X		
Different views of cause and effect			X				X	X	X			X			X	X		
Different variable definitions			X	X	X				X	X	X	X			X			
Different system characteristics considered significant	X			X	X	X	X	X	X	X	X	X		X	X	X	X	
Experimental information				X		X	X	X		X		X				X	X	
Cross cultural communication				X		X	X	X	X	X		X		X		X	X	X
Usefulness of Products	X	X		X					X			X	X	X		X	X	X

Source: (Slocombe, 2001, p.128)

Further, scientific egos have a tendency to get in the way of co-operation – it can be difficult for a working professional to admit that a person with less training may have a better understanding of the problems at hand (Mackinson & Nottestand, 1998, p.483). However, it is very likely that a person who experiences their environment daily or depends on certain natural conditions has a much better sense of the relationships and behaviours of their surroundings than a professional who is foreign to the area. It is more likely that the combination of these different sources of information applied in tandem will yield a deeper understanding of the management unit. In a study of a limnological phenomenon in the Pantanal wetland of Brazil, Calheiros, Seidl, and Ferreira (2000) applied a participatory research method to integrate deep local knowledge with scientific understanding. The phenomenon was that a high volume of fish kills locally known as 'dequada', had been associated with the local flooding season and resulting changes in hydrology. Initial findings suggested that urbanisation and ash from burning forest cover, human waste, agrochemicals, and heavy metals were responsible (Calheiros, et al., 2000, p687). The research method, as illustrated in Figure 2.1, was designed to combine local and scientific knowledge with the assumption that people can understand their circumstances better than people from outside the area (p.689). In their results, they found that the local knowledge generally agreed with the majority of the scientific findings. However, interviews revealed new information that was able to advance the scientific process to new conclusions, linking the fish kill to a drastic change in respiratory gas percentages that resulted from unusually high water. Without the local knowledge integrated in this process, it might have been some time before scientific research discovered the linkages between increasing carbon dioxide levels, decreasing

oxygen levels, and the fish. While personal interviews can be a time and resource-consuming endeavour, when they are well matched to the scale and scope of the project, it seems a superior management process can evolve.

FIGURE 2.1: A RESEARCH METHODOLOGY COMBINING LOCAL AND SCIENTIFIC KNOWLEDGE



Source: Calheios, Seidl, Ferreira. 2000. p.689

Making a similar argument as in the Brazilian example, Mackinson and Nottestad (1998), using references to the fishing industry, suggest that local knowledge may have a lot to offer the struggling fisheries sciences. Where fisheries sciences in the past have been largely dependent on mathematical models and prediction, Mackinson and Nottestad suggest that the combination of many information sources may lead to entirely new directions (Mackinson & Nottestand, 1998, p482). Fishermen, interested in

maximizing returns with minimal inputs, closely observe natural processes and environmental features and have compiled generations of knowledge (p.483). They propose a relatively simple process to integrate local and scientific knowledge, which includes an expert system as the primary juncture for interaction, between practical knowledge and scientific knowledge. With an expert system, the process of collecting the required knowledge will result in fostering stronger relationships and understanding between the parties involved (Mackinson & Nottestand, 1998).

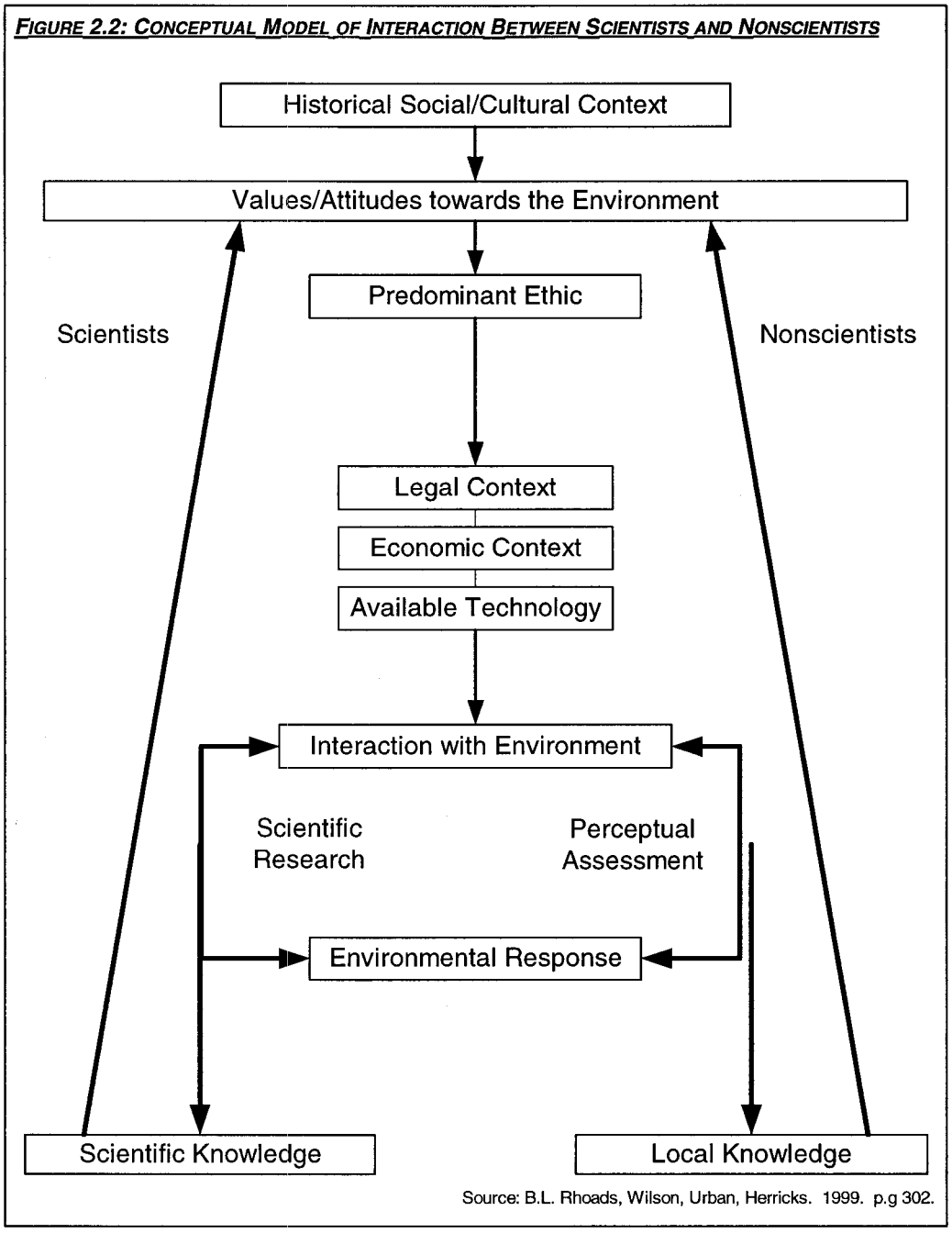
Wilson, Urban, and Herricks acknowledge that over the past 2 decades, environmental management philosophies have gradually changed: shifting away from top-down toward bottom-up strategies where policy formulation and decision-making have come to involve all relevant parties including local groups (Rhoads, et al., 1999). They cite examples including US Environmental Protection Agency (USEPA) programs that adopt co-operative, collaborative, and social negotiation as central to their management paradigm (p.298). For Rhoads, et al., it is directions such as the USEPA's that hold promise, arguing that effective integration of information (both scientific and non-scientific) is essential if management activities are going to be successfully adopted by all parties involved. In a critique of traditional approaches, they emphasise that although watershed management heavily relies upon hard science and engineering, science cannot derive social constructions, and watershed management is fundamentally social in nature (Rhoads, et al., 1999, p.298). Failure to recognise that watershed management is fundamentally social can result in a management process that will be inherently challenged. It is the acceptance of social values and knowledge, and not the imposition of hard science that fosters co-operation and commitment to the management

activities. Otherwise, one type of knowledge, usually the scientific, is intrinsically privileged relative to others at the outset of the management process. Rhoads, et al. propose that the challenge to scientists and managers is threefold: (1) improve self-awareness between knowledge and values; (2) remove privileged perceptions of views and knowledge; and, (3) develop place specific knowledge of non-scientists, sensitive to the socio-cultural life world of non-scientists personal values (p.298). Figure 2.2 illustrates the conceptual model of interaction between scientists and non-scientists as proposed by Rhoads, et al. In their interaction with the commissioners from the Embarras River Mutual Drainage District, the disparities between local knowledge and scientific knowledge were reconciled largely through careful listening and understanding. Where there had been misunderstandings in the past, information was conveyed in such a manner that it did not cast the public as wrong, rather the presentation cultivated further discussion and development (p.301). The Upper Embarras River Watershed in East central Illinois as an example illustrates that genuine interaction between scientists, managers, and the public, not prescribed public consultation, as a part of the information integration process as an important source of information. Scientists must have an understanding of the social and cultural context of the area they are attempting to manage (p.306).

2.2.4 INFORMATION SHARING AND COORDINATION

Watershed management, partly out of need to find financial savings and efficiencies is increasingly carried out by partnerships (Mandell, 1999). Randolph comments those collaboration methods and efforts are likely driven by practical necessity rather than any abstract theory. Groups get involved together to resolve conflicts,

develop a shared vision, and to formulate creative solutions (Randolph & Bauer, 1999, p.174). While groups generally deal better with information sharing, complexity evaluation, acceptance, interest, and synergy issues, working together can also be a cost-saving strategy, can be viewed positively by the public, and can advance institutional agendas (Jones & De Vreede, 2000, p.212). Agranoff and McGuire identify five primary areas where co-ordination and collaboration efforts strengthen environmental management efforts: (1) increase an agency's ability to diffuse information among several organized entities and disciplines; (2) foster a culture of trust as diverse organisational representatives learn to work together; (3) increase education and levels of cognitive complexity brought to bear on problems; (4) expand the knowledge base; and, (5) help combat the rapid shift and replacement of technologies (Agranoff & Mcguire, 1999, p.21). Co-ordination and collaboration between organizations and groups seem to be a part of the larger post-modern trend, where governments and organizations are expected to be more interactive, inclusive, and publicly accountable (Agranoff & Mcguire, 1999, p.21-22; Mandell, 1999, p5-6). To this extent, separate groups are not faced with the question of whether or not they should participate in network and collaborative efforts, but must decide how they should participate and which approach best suits the information management objectives and goals. Such relationships are usually very different from single agency efforts and are usually based on informal, equal, and at times contractual horizontal partnerships between government organizations, private, non-profit, and community representatives working together (Mandell and Agranoff, 1999, p.5). Mandell and Agranoff provide a summary of typical relationships for management networks, illustrated in Table 2.10.



Networks can take on a variety of structures or shapes, depending largely on the goals and objectives of the process, as well as the particular organizations involved. For the most part, the relationships vary with respect to how formalised the relationship is, what the commitment is from the parties involved, and in general how well established the network structure is.

TABLE 2.10: TYPES OF CO-ORDINATION AND COLLABORATIVE RELATIONSHIPS	
1	Linkages or interactive contacts between two or more organisations
2	Intermittent co-ordination or mutual adjustment of the policies and procedures of two or more organisations to accomplish some objective
3	Ad hoc or temporary task force activity among organisations to accomplish a purpose or purposes
4	A coalition where interdependent and strategic actions are taken, but where purposes are narrow in scope and all actions occur within the participant organisations themselves or involve the sequential or simultaneous activity of the participant organisations
5	A collective or network structure where there is a broad mission as well as joint and strategically interdependent action. The structural arrangement takes on broad tasks that reach beyond the simultaneous actions of independently operating organisations (i.e., action may include, but reaches beyond, linkages, co-ordination, task force or coalitions

Source: (Mandell and Agranoff, 1999); (Agranoff & Mcguire, 1999)

Collaborative management efforts can add an assortment of complications to a management process. Randalph and Bauer suggest six key elements important to address during a collaborative environmental decision-making process, illustrated in Table 2.11.

TABLE 2.11: ELEMENTS OF COLLABORATIVE ENVIRONMENTAL DECISION-MAKING	
STAKEHOLDER INVOLVEMENT	Early engagement of stakeholders in the process of planning and implementation
KNOWLEDGE BASED	Strong and sound information exchange by the process participants
HOLISTIC, PROACTIVE APPROACH	Holistic understanding of environmental problems, and proactive efforts to resolve and prevent them
SHARING OF POWER	Parties in authoritative positions relinquish some control to other participants
JOINT RESPONSIBILITY	Participants share credit for success and acknowledgements of failures
INTEGRATED SOLUTIONS	Integration of a wide range of creative solutions to problems, such as flexible regulation, economic incentives and compensation, negotiated agreements, voluntary actions, and educational programs

Source: (Randolph & Bauer, 1999)

In developing a collaborative approach, many existing practices and approaches must be dismantled or modified, often presenting a unique set of challenges. In consideration of these challenges, Randolph and Bauer also identify some of the prerequisites and barriers for collaboration efforts. To ensure a positive working environment for the network, it has been found that equality among the partners is essential (Agranoff & Mcguire, 1999, p.21). That is to say, no single partner has more or less authority in the process or that no single partner is more or less at risk. Other criteria important to the networking process include internal support, needed expertise,

purposeful interaction, trust, mutual goals and objectives, and a trans-disciplinary understanding (Agranoff & Mcguire, 1999p.28-30). Table 2.12 provides a summary of additional conditions critical for successful collaboration.

TABLE 2.12: PREREQUISITES FOR, AND BARRIERS TO, SUCCESSFUL COLLABORATION

PREREQUISITE FOR COLLABORATION	BARRIERS TO COLLABORATION
Good information	Misleading Information
Time to participate to build trust, to learn, to resolve disputes, to create solutions	Immediate problem, no time to deliberate
Commitment of participants	Lack of commitment by participants
Willingness to learn	High level of advocacy; entrenched positions
Responsibility to affect and implement decision	No responsibility given to stakeholders
Resolution of the problem is the goal	Litigation or precedent is the goal

Source: (Randolph & Bauer, 1999)

Margerum and Born (1997) present a number of lessons learned with respect to co-ordination, networking, collaboration and participatory approaches based on linkages they made to environmental management, related fields, and some additional key cases. At the onset of their research, they state that practitioners at nearly all levels of government are dissatisfied with approaches to environmental management that fail to address the interconnectedness, complexities, and reality (p.371). Margerum and Born observe the sentiment held by practitioners who are frustrated by the conundrum of managing an ecosystem (p.372-373). Sympathising with practitioners, Margerum and Born suggest there is likely a void in the research stemming from research making a case for more adaptive approaches to management; and a lag in research on the implementation of such adaptive approaches that is useful to practitioners. Choosing to focus on the latter, and more specifically, the procedural goals for the broader field of environmental management, Margerum and Born synthesise the major characteristics of environmental management as offered through the lessons learned from: water resources management; ecosystem management; natural resource management; public

administration and environmental policy analysis; urban and regional planning; organisational theory; and, management studies. As illustrated in Table 2.13, Margerum and Born attempt to answer the "How to" question for co-ordination based on their research and that described by Parker, et al., (1975).

TABLE 2.13: SOME TOOLS FOR THE PROCESS OF CO-ORDINATION

1.	Information and data sharing procedures
2.	Common database or data gathering
3.	Joint forecasting or scenarios
4.	Joint Models or jointly used GIS
5.	Regular communication mechanisms (e.g. Newsletters, e-mail)
6.	Informal communication
7.	Co-location of personal or creation of common jurisdictional boundaries
8.	Joint review of plans or environmental impact statements
9.	Formal review or clearance procedures
10.	Supervisory oversight
11.	Joint budgeting process
12.	Scheduled meetings
13.	Co-ordinating committees
14.	Joint staffing or joint staff work groups
15.	Joint permit reviews or common standards for review
16.	Joint planning process
17.	Plans (Projects, Programmes, Policy, Other)

Source: (Margerum & Born, 1995, p.380)

In a review of two cases, the Winnebago System in Wisconsin, and the Lower Wisconsin River way, Margerum and Born conclude that effective co-ordination is fundamentally important to the overall management process (p.382). In both cases an inclusive approach was taken, stakeholders identified goals after assessing the ecosystem processes and the jurisdictional structure, after which each group was given the opportunity to decide how they wanted to contribute (p.382). Participants from the two cases identified informal communication, joint staffing, information sharing, co-ordinating committees, joint planning, scheduled meetings, and joint databases as all critical for the process as they promoted the free flow of ideas and communication (p.384). Where conflicts arose, it was usually the result of inadequate information or

misperceptions. This problem was alleviated by both parties working to gain an understanding of each other aimed at overcoming difference (p.384).

In research conducted by McLain and Lee (1996), the promises made by advocates of adaptive approaches to environmental management were investigated, in particular the assurance that more adaptive approaches will enhance the flow and acquisition of knowledge through the involvement of the public and increasing communication. However, evidence gathered through their research efforts in New Brunswick, British Columbia and the Columbia River Basin suggests that such promises have not been fulfilled (Mclain & Lee, 1996). In studying these three cases, they observed how poor communication between practitioners and stakeholders, misassumption, and flawed models could derail a management process. McLain and Lee suggest that if management approaches are going to be successful, they must incorporate knowledge from multiple sources, make use of multiple system models, and support new forms of co-operation (p.445 – 446). These conclusions suggest that the problem is not adaptive forms of management; rather, failure is experienced during application because there is little instruction or experience for practitioners to draw from. An assumption is made that this systematic failure is not so much an oversight, as a condition that has resulted from the accelerated evolution and adoption of ecosystem-based management and other forms of adaptive management over the last thirty years. Established channels of communication and networks have simply not developed as quickly as the theory between practitioners, researchers, and the community with respect to public involvement (Mclain & Lee, 1996).

In a comparison of three watershed organisations, Wooley and Mckinnis (1999) began looking at the contrasting efforts of watershed organizations to restore ecosystem health, specifically, how watershed organizations are dealing with the urgent matter of the depleted salmon populations. The nature of their study, focusing on the Yakima River in Central Washington, Santa Ynez Basin, and the Sacramento River in California, led to some unexpected findings with interesting ramifications for watershed organizations and approaches to public involvement. They suggest that in theory, watershed management ought not to focus on water and water use alone, rather watershed management should encompass a wide range of factors/variables surrounding watershed management. They suggest that in practice, sensitivity must be had toward prevailing perceptions to prevent the process from falling victim to "political deadlock, intergovernmental conflict, and bureaucratic inertia" (p.578). The significant event that altered the course of their original study was the unexpected collapse of the Santa Ynez watershed agency, due to a conflict that arose between the watershed agency and property owners. In the conflict arising within the steering committee, communication broke down in a disagreement over how and who should define the watershed's boundaries. This ultimately resulted in sponsoring organizations withdrawing their project funding (p. 85), leaving the management effort without any support or ability to operate. In their survey of the three watersheds, Wooley and Mckinnis revealed that unlike the Yakima and Upper Sacramento cases, Santa Ynez survey respondents held significantly different views than participants from the other watersheds on four matters. From these results, Wooley and McKinnis concluded that the failure of the Santa Ynez watershed management efforts, although complex, is at least in part due to a breakdown in

communication during the planning phase. This not only provides some explanation of the failed Santa Ynez watershed efforts, but also suggests that efforts in the Upper Sacramento River and the Yakima River were successful because of a different approach. Without the parties involved adequately communicating their knowledge in the planning phase, a lack of trust on the part of the private landowners grew, as did the sentiment that the practitioners had insufficient information about the watershed's ecosystem. The experience from the Santa Ynez emphasises the need for effective communication and co-ordination even in the early stages to maintain the commitment and co-ordination of the parties involved.

Practitioners are expected to make decisions that are representative of the public. Processes that do not include public participation to some degree are frequently characterized as having a top-down approach. In this style, public involvement has traditionally spurred on a lot of process conflict, a direct result of the top-down managerial process that has imposed certain restraints on the various involved interests, resulting in a lack of support form the public, and general misunderstanding on all sides (Griffin, 1999). Although a top-down approach can be appropriate and recommended for some issues, situations that are more complex require the added benefits gained through public participation. Griffin (1999) suggests that public participation in environmental management is "experiencing a paradigm shift from the adversarial, top-down, public meeting approach to a collaborative, bottom up, citizen led, and citizen organized approach" (Griffin, 1999, p.505). One example of a new form of watershed management that has emerged from this paradigm shift is watershed councils: a group of locals

forming collaborative partnerships to participate in the decision-making process of water management (Griffin, 1999505).

Beierle (1999) identifies 6 goals of public participation including: (1) educating the public; (2) incorporating public values, assumptions, and preferences into decision making; (3) increasing sustainable and quality decisions; (4) fostering trust in institutions; (5) reducing conflict; and (6) making decisions cost effective (Beierle, 1999, p.81). In reality, most environmental management issues require some degree of public input and participation, as technical and scientific input at some point requires some social perspective, – referring back to Rhoads,et al., point out that environmental watershed management is effectively a social process. However, as we have seen, in the area of the environment, public participation is a challenging process because decisions are value laden, technically complex, and mistrust can be inherited (Beierle, 1999, p.76). Illustrated in Table 2.14, Johnson and Campbell suggest several mechanisms for involving the public, categorised under three main areas: (1) ecosystem analysis; (2) linking science to the public via community outreach and education, and, (3) economic development as an ecosystem restoration and management strategy (Johnson & Campbell, 1999, p.517). As the Table demonstrates effective public involvement and communication is an integral part of the entire watershed management process, as well, there are valuable opportunities for collecting and disseminating information throughout the management process. Therefore, we see that regardless of the phase of management, if public participation and communication are effectively incorporated into the process, public involvement is an integral aspect of the information management process.

TABLE 2.14: LINKING TO THE PUBLIC VIA COMMUNITY OUTREACH AND EDUCATION

ECOSYSTEM ANALYSIS
• Provide a common framework for all assessments that integrate ecological and cultural phenomena
• Recognise community well since an ecosystem health concern. Assessments should include social and economic health
• Employ a conceptual model of ecosystem function that can guide decision-making and that can link qualitative and quantitative assessments
• Develop local resources to support high-quality research, as well as for use by local resource users and land managers
• Use public involvement to help shape the research agenda
• Develop a range of alternative future scenarios based on stakeholder input, and then analyse their ecological consequences
LINKING SCIENCE TO THE PUBLIC VIA COMMUNITY OUTREACH AND EDUCATION
• Develop multiple forms of outreach to bring science to the community
• Develop quantitative/qualitative metrics for fostering common goals, public process, including scientific research, and into implementation phases
• Develop adaptive, flexible formats that can be used to engage appropriate mixes of stakeholders, researchers, and managers on an as-needed basis
• Create visualisation tools that provide a common frame of reference for experts and lay people to compare alternative future scenarios
• Engage in local projects that benefit both residents and the environment.
ECONOMIC DEVELOPMENT AS AN ECOSYSTEM RESTORATION AND MANAGEMENT STRATEGY
• Develop the infrastructure, including technical assistance and financing, to link economic development to conservative-related activities
• Explore new ideas to link restoration activities to the development of local employment products, and markets
• Improve ecological function on degraded lands in ways that produce a sustainable form of annual economic return

Source: (Johnson & Campbell, 1999, p.517)

Attempting to shed some light on what effective mechanisms for involving the public are, Duram and Brown (1999) investigate watershed initiatives by a survey. Based on findings from 64 returned mail surveys targeting federally-funded watershed planning initiatives in the USA, Duram and Brown found that the factors that affect successful watershed management the most are: approaches to management, planning stages, methods to solicit participation, level of participation, and potential positive impacts of participation on watershed (Duram & Brown, 1999, p.457). Similarly, Beierle offers a summary of mechanisms for facilitating the implementation of his social goals for environmental management (illustrated in Table 2.15).

TABLE 2.15: GOALS AND MECHANISMS							
	Goal 1 Education and Information		Goal 2 Values	Goal 3 Substantive Quality	Goal 4 Trust	Goal 5 Conflict	Goal 6 Cost Effectiveness
Mechanisms	Educate Active Public	Inform Wider Public					
Surveys, Focus Groups, and Public Comment							
Survey	1	1	3	3	1	1	3
Focus Group	1	1	3	3	1	1	3
Public Comments	1	1	3	3	1	1	3
Information Provision, Public Notices, and Public Education							
Information Provision	2	3	1	1	3	1	3
Public Notice	1	3	1	1	2	1	3
Public Education	3	2	1	1	2	2	3
Traditional Participatory Mechanisms							
Public Hearing	2	3	3	3	2	2	3
Citizen Advisory Com.	3	2	3	3	3	3	3
Alternative Dispute Resolution							
Mediation	3	1	3	3	2	3	3
Regulatory Negotiation	3	1	2	3	2	3	3
Public Deliberation							
Citizen Juries/Panels	3	2	3	3	1	2	3
Consensus Conference	3	2	3	3	1	2	3
1=Not likely to achieve goal; 2=may be expected to achieve goal; 3=ought to achieve goal							

(Beierle, 1999)

2.2.5 *INFORMATION TECHNOLOGY*

Information Technology (IT) is an ever-evolving set of tools that has new and promising opportunities for watershed practitioners. Many IT advancements have been central to the development of adaptive ecosystem-based approaches to watershed management, as IT creates potential for changing how data collection, integration, co-ordination, public involvement, information sharing, and decision-making are performed. The term IT includes the wide range of communication devices, networks, linkages, satellites, sensors, computer hardware, and software applications that facilitate the

collection, storage, manipulation, processing, and generation of information. Evolution of IT has been substantial in recent years, especially as costs come down technologies are becoming more accessible to a larger number of people. For example, communication satellites, one of the more costly IT innovations were at one time almost exclusively government projects; however, in 1997, 69% of the launches were by private companies for commercial purposes (O'Meara, 2001). As one simple example, this demonstrates how more users are gaining access to even the most sophisticated technologies.

IT provides opportunities to various groups, organizations, and stakeholders to participate more directly in the watershed management process, especially smaller groups that would not typically be able to afford the expenses involved in collecting information. Evidently, the role of smaller groups and organisations has substantially grown in previous years in their ability to contribute and participate in the watershed management process. The appeal of information technology is its ability to support integration, co-ordination, collaboration, public involvement, and information sharing efforts. To ensure IT is successfully implemented within an agency or organisation and as importantly, between organizations, there are a number of prerequisites.

Based on a study of community-based organisations, Kellogg (1999) provides a framework to assess the obstacles and opportunities for successful adoption of information technologies, identifying technological, organisational, and personal prerequisites (Illustrated in Table 2.16) (Kellogg, 1999, p.451).

TABLE 2.16: PREREQUISITE CONDITIONS SUPPORTING SUCCESSFUL ADOPTION OF IT

TECHNICAL PREREQUISITES	
Equipment	• Adequate computer equipment • Resources for maintenance and upgrades to equipment and software • Electronic data retrieval and data preparation capacity
Data	• Data availability • Adequate data standards
ORGANISATIONAL PREREQUISITES	
Culture	• Support from leaders in organisation/internal catalyst • Perceived relative advantage to organisation • Adequate planning and co-ordination
Information Management	• Organisational support for staff skill development • Presence of a staff GIS specialist • In-house database development capabilities • Effective use of information
PERSONAL PREREQUISITES	
Computer Orientation and Skills	• Existing staff computer skills • Supportive communication behaviour among staff • Perceived individual relative advantage
Substantive Knowledge	• Expertise in substantive field • Knowledge of data sources

Source: (Kellogg, 1999, p.451)

Obviously, for the successful integration of IT, there are certain technical prerequisites that are required, such as hardware and data. However, many groups have inadequate budgets to support such expenses and depending on the availability of government grants, competition may be rather heavy. For smaller groups, this requires greater planning of future organisational needs as well as forming strategic partnerships that maximize use of available resources. Recognising the large volumes of data required for watershed management, Hale, et al., remark that it is not realistic to expect any single organisation to be entirely responsible for the necessary information. Instead, it is important that organisations involved with information generation be prepared to share and integrate data among many users, moving toward common standards, directories, and data descriptions (Hale, et al., 2000, p.154). In their review of the Environmental Monitoring and Assessment Program and the Chesapeake Bay Program, Hale, et al., note

that people's perceptions of data and information can pose one of the greatest challenges, often lagging behind the speed of evolving technologies and preventing the potential of data sharing and integration from being realised (Hale, et al., 2000, p.154). Availability of quality data suffers similar challenges as establishing hardware, including the costs of acquiring it and the expertise to handle it adequately. With the proliferation of IT networks, securing quality data is becoming increasingly possible, providing there is adequate hardware to access larger networks. Stronger networks and partnerships will assist in this area with respect to data accessibility as well as greater attention to data standards. Organisational prerequisites include the staff structure and agency function, both of which affect the success of technical leadership and project implementation. Personal prerequisites include many of the soft skills that are required to give the process direction and ensure project implementation. As illustrated in Table 2.17, there are several steps proposed by the USEPA for the successful implementation of information management systems (USEPA, 1997, p.1).

TABLE 2.17: RECOMMENDED MILESTONES AND GUIDING POLICIES FOR INFORMATION SYSTEMS

Step 1. Set up an Information Management Design and Implementation Team
• Establish clear goals, tasks, and schedules as well as a mechanisms for communicating • Inventory skills and knowledge of the team and bring in other expertise as needed • Inventory existing information systems to be linked to watershed planning • Identify potential users of the information system
Step 2. Survey Watershed Planning Partners
• For each group of users, identify primary responsibilities related to watershed planning/management • Document relevant existing databases, maps, and geographic records and their formats • Identify data gaps • Distinguish GIS and non-GIS mapping, data management, and analytical functions • Identify current obstacles to developing an information system and potential solutions • Identify potential sources of funding and staff support • Identify current or planned projects that could impact implementation of an information system
Step 3. Prioritise Data Needed
• Prioritise data need • Create a schedule for developing or acquiring data
Step 4. Integrate/Relate Existing Data and Develop New Data
• Develop and formalise data transfer standards and protocols

TABLE 2.17: RECOMMENDED MILESTONES AND GUIDING POLICIES FOR INFORMATION SYSTEMS

• Develop and formalise a plan for transferring, relating, integrating, and updating data • Evaluate data sources (including quality and compatibility) • Choose key database relational fields for geographic analysis • Determine how database relational fields will be linked to GIS hydrology and land coverage • Determine how frequently new GIS coverages will be created after core watershed planning coverages are completed • Determine how frequently watershed planning databases will be updated • Develop criteria for integrating and relating data (based on the above findings) • Develop options that meet the criteria as well as the strengths, weaknesses, and cost of each option • Get feedback on which option is preferred and fundable.
Step 5. Evaluate Hardware and Software Configurations • Identify existing plans for reconfiguring hardware and software that may impact information system design • Determine the priority and sequence of basin planning hardware and software applications • Identify existing hardware and software and how they can best be incorporated into the watershed planning information system • Evaluate the compatibility of operating systems (i.e. transferring data between windows and Unix) • Determine need for exchanging and accessing data (including network speed) • Develop criteria for configuring the hardware/software/network • Develop options that meet the criteria (adequate, good, very good) as well as the strengths, weaknesses, and cost of each option • Get appropriate feedback on which option is preferred
Step 6. Evaluate Organisational Design, Staffing, and Support Issues • Based on preferred hardware/software and database management models, outline information management responsibilities • Identify staffing needs (including hiring, reassigning, and training staff) • Outline staffing options as well as the strengths, weaknesses, and cost of each option • Get appropriate feedback on which option is preferred and fundable
Step 7. Develop a Short- and Long-Range Implementation Plan • Based on Steps 2-6, develop a multi-phased, 5-year plan, including: staffing (including training), hardware, software, application development, data development, conversion, and integration, and network/communication • Include realistic funding for each component

Source: (USEPA's, 1997)

Technology as a part of the process is growing rapidly, a trend likely to continue, if not accelerate in its role with environmental management. Thomas Schmidt, representing the Regional Municipality of Waterloo speaking at the second Annual Grand River Water Forum, predicts technology in environmental decision-making will grow rapidly over the next ten years. As computer costs decrease, computing power and capacity increase, custom application development becomes easier, ability to co-ordinate

and warehouse date across networks improves, and real-time monitoring capabilities become a reality. Consequences of this will include increased direct costs to maintain infrastructure and to operate complex systems; burdens associated with staff training and upgrading including costs and lost labour hours. However, improved system understanding, decision-making, and management should result, leading to improved water quality and system reliability, and overall, technology advances will make implementation and development easier (Schmidt, 2002).

Similarly, the Food and Agriculture organization (FAO) of the United Nations calls the role of information technology in Watershed Management a "double-edged sword", a reference to both the positives and negatives offered by the implementation of information technology. Where computers can be expensive, time consuming, and resource intensive in areas where resources are already limited and scarce, they note that information technology can also improve coordination, save capital resources, and improve watershed management planning (Food and Agriculture Organization of the United Nations, 1996, p.ix). In conclusion, both the FAO and Schmidt note that in order to not only cope with the challenges inherent to keeping pace with the trend of technology, but also to realize its full opportunity and potential, investment in research and development must increase, an open dialog with staff concerning their needs and abilities must be maintained, planning and development of technology must be flexible and adaptive, and strategic management must be both near and far sighted (Food and Agriculture Organization of the United Nations, 1996, p.x; Schmidt, 2002).

Craglia and Signoretta in a review of information strategies in the United Kingdom found that there is a considerable amount of institutional, organisational, and

technological change within the public organisations that collect information. In their conclusion, they note that while technology developments continue to present many new opportunities for environmental management, efforts must also focus on developing information policies and strategies for sharing, integration, and knowledge building for effective use of the technology (Craglia & Signoretta, 2000, p.8-9).

2.2.5.1 GIS AND REMOTE SENSING

GIS as a tool has gained tremendous popularity since its advent in the 1960's. There are many examples of where and how GIS is being integrated successfully by management organizations. Zoning and land use issues such as environment, transport, and economic development planning are the leading areas where the use of GIS is frequently implemented (Ceccatio & Snickars, 2000). Yet, in many uses of GIS, the primary application remains as a tool used to complete relatively mundane tasks, valued for its ability in managing large volumes of information and manipulating data efficiently.

One example of the strength of a GIS is in the area of non-point source pollution, a common challenge facing many watersheds. Since there are so many non-point sources of pollution including agriculture, residential/urban areas, and storm water, non-point pollution is difficult to isolate and analyse. Increasing nitrogen levels, one of the most common forms of non-point source pollution, can be a result of multiple factors within a watershed. Streams, unique in their own characteristics, differ in response to such factors, making assessment and treatment difficult. In research focusing on nitrogen levels using a GIS, Basnyat, et al., look into how a relationship can be established among nitrate concentrations in water emanating from agriculture and urban areas that are in

contact with riparian forests (Basnyat, et al., 2000, p.66). This was done by classifying land use types from LANDSAT and SPOT satellite images and using aerial photographs to identify source types based on data collected from the stream. Complex ecological models were then run on the GIS to delineate buffer zones and to define nitrate-contributing zones that were linked as either land use or land cover type based on the classification. As a twist to the usual mundane tasks, this example demonstrates how GIS can be used to manage large volumes of information effectively, and manipulate it using complex ecological models to examine water quality variables (Basnyat, et al., 2000).

Ceccatio and Snickars (2000) investigate the application of GIS in land use planning as an auxiliary tool in decision-making based on an example of GIS applications from a residential renewal program in Sweden. In this unique example, GIS is used to involve the community without requiring users to be proficient with GIS, or to be experts in a scientific area, and effectively captures their qualitative input into the project (p.924). From the onset, this was perceived as a possible means of targeting the areas of greatest need and allocating resources accordingly, based on the values and knowledge of the community. GIS for this approach was used in a similar fashion as an expert system (expert systems will be discussed in detail in the next section). It was used as a forum for storing and discussing issues and information relevant to the decision-making process. Essentially, the idea was to integrate the knowledge and perceptions of the community into the GIS in an open forum (i.e. Open Forum GIS) (p.926). An evaluation of how GIS was used to represent qualitative and quantitative information is shown in Table 2.18.

TABLE 2.18: SUMMARY OF QUALITATIVE AND QUANTITATIVE STRENGTHS AND WEAKNESSES OF GIS

	STRENGTH	WEAKNESS
Quantitative	• Relatively easy access to data • Generally accessible as official aggregated statistics • Effective at visualisation • Helpful in making inferences of future impacts based on decisions • Possible to make measurements through analysis • Identification of possible 'hot spots', areas with high concentrations and highlight distinctions • Provides a useful basis for discussing linkages	• Data may represent an incomplete picture • Even a complete database may not reveal all system behaviours • Data accuracy, blurred and fuzzy data inferences can lead to fallacies • Data collection error can cause unpredictable and unnoticed results • Quantifying, categorizing, and representing usually means usually means simplification or reduction of data. I.e. Not truly representative
Qualitative	• Maps show real activity space • Data represents values, community perceptions, and social norms • Stronger community support for results • Qualitative information sheds light on relationships within the system, especially less intuitive linkages • Opportunity for community input • Different sorts of patterns emerge from the data	• The acquisition of qualitative data might be expensive • The degree of generalization is low • Risk of creating stereotypes of behaviour and attitude among the different groups of the interviewed population • Perception is a bias, different from reality

Source: Adapted from (Ceccatio & Snickars, 2000, p.932 and 934)

GIS still has tremendous potential to evolve, as open-forum GIS and the utilisation of the Internet are excellent forums for bringing together a broad ranging group of contributors to advance the use and application of GIS. How the Internet and World Wide Web are reshaping the way people use and share information, analyse data, and make decisions, will be explored in detail in a later section. Like all other information-related technologies, GIS is evolving at a steady rate. Watershed organizations that are faced with keeping up-to-date with the state-of-the-art in GIS are faced with formidable challenges with respect to costs and expertise. Initiative for new uses rests on the shoulders of practitioners and their willingness to make it happen

(Ceccatio & Snickars, 2000, p.935). This is with regard to the technical aspects of the GIS as well as the organisational and personal prerequisites that were identified in Table 2.19.

2.2.5.2 Modelling, Simulation, and Prediction

Modelling has been a popular tool for managers for some time but has gained increasing popularity because of approaches to management that adopt a complex systems perspective. Many practitioners and researchers have come to realise that their systems are nested in a hierarchy of processes and interrelationships, continually changing and evolving. As a problem-solving tool, models have been used to assist in this area, using prediction and simulation for some time. Earlier models employed mechanical, mathematical equations that required a number of strong assumptions, including that systems were closed and that the system had a tendency to move toward equilibrium. Current trends are leading practitioners to evaluate their assumptions, treating ecosystems as open systems of continual change. Recognising the natural tendencies of an open system requires models that recognise the spontaneity of the system throughout its history. This leads to the admission that an ecosystem, in its nested hierarchy, will behave in ways beyond the useful scale and scope of a mathematical model, thus requiring a model that will take into consideration its linkages and relationships (Allen, 1992).

Simulation presents opportunities to explore scenarios and predict decision implications. Bishop and Gimblett review the use of autonomous agents in establishing land use and recreation policy and have documented use of such tools. Autonomous agents represent user groups of a system, based on a set of governing heuristics that determine their behaviour. Although imprecise, after running several iterations of the

agents within a pre-programmed environment, a pattern of the behaviour and interaction of the agent begins to emerge. From this, it is proposed that the effect of a management decision can be seen from the influence it has on the change of behaviour of the autonomous agents interacting with each other and with the simulated environment (Bishop & Gimblett, 2000). Each agent has its own ability to sense, make decisions, collect information, and move within the environment. Using the example of a recreation trail, Bishop and Gimblett (2000) created agents that represented the primary trail users for a sensitive region that was experiencing a growth in the volume of visitors and interaction as a result of the area's natural appeal (Bishop & Gimblett, 2000, p.427-29). Based on the rules, new information is processed and the agent's behaviour changes as a result. While the behaviour is not useful for prediction, it is certainly a testing ground for decision and policy implications (Bishop & Gimblett, 2000, p.427). From their iterations of the simulation, they found it was possible to maintain visitor satisfaction levels with some enhanced management options that ensure minimal impact on the trail. Similarly to these simulation experiments, Deadman (1999) suggests that an additional advantage simulation has to provide policy and decision makers is in the investigation of inter-relationships of systems such as a watershed to the human activities within them (p.171). For example, the Freshwater Integrated Resource Management with Agents (FIRMA) project, launched in 1999, aims to improve water resource planning by using agent-based modelling to integrate physical, hydrological, social, and economic aspects of a watershed for resource management. Using five contrasting regions in Europe to test this new tool, the project will develop a generic model for integrated assessments by

representing customers, suppliers, and government in their interaction relating to water treatment, scarcity, and planning (FIRMA, 2003).

Advances in information technology may include important opportunities in areas such as open-forum modelling. Such technology could connect a broad base of users to contribute information to the model and test countless possibilities in an infinite number of iterations. With recent advances in computer hardware and application development, smaller and smaller groups are able to consider implementing modelling activities. Steps to information modelling and simulation include:

1. List the model objectives
    a. Characterize the end user
    b. What decisions will be made
    c. How accurate do the output requirements need to be
    d. How much funding is available for the effort
    e. What data are available
    f. What expertise is available
    g. What applicable models already exist for the system under consideration?
    h. What computer hardware is available
    i. What software capabilities are available?
    j. What costs and benefits is incurred in hardware and software use?
    k. How much time can each participant provide to the effort?
    l. What periods are available for inter-team co-ordination?
2. Identify sub models and sub-objectives
    a. What scale?
    b. Linear Objects?
    c. Mobile objects
    d. Create data define relationships
    e. Cellular automata interactions
    f. Time frame
3. Construct and validate sub-models
4. Assemble the sub-models into the complete model and validate
5. Attempt to address the questions identified in step 1
6. Examine the general behaviour of the model; identify behaviours of interest.
7. Conduct sensitivity analyses; identify the structure and parameters that are causal for the behaviours of interest; validate to see causal structures and parameters

(Westervelt, 2001, p83)

Mackinson and Nottestand argue the importance of integrating data sources and the usefulness of using modelling to do so. For them, stakeholders who are directly affected by the actions of management organizations have greater acceptance of such organisations if they are involved in the process. This usually results in stronger partnerships, information sharing, mutual respect, better decisions, and co-management (Mackinson & Nottestand, 1998, p.488).

2.2.5.3 Expert Systems/Environmental Information Systems

Another set of tools that are proving to be useful to practitioners to investigate ecosystems lies within the convergence and integration of existing technologies and techniques used in concert, such as an integrative computer-based system. Expert systems are a popular example of such an integrated system; referring to a type of computer set-up including hardware and software that is designed to mimic the knowledge and decision-making abilities of an expert in a particular field. An inference engine, built on reason, heuristics, and rules of thumb, can query the knowledge base as instructed by the user, and return results to the user based on the predefined parameters. Such information systems can vary a great deal in scope and objective, but where they have been employed, they have been used in several areas. Table 2.19 provides a breakdown of how expert systems are primarily used, with a description and example, as defined by Warwick, et al (1993).

TABLE 2.19: ROLES FOR EXPERT SYSTEMS

EXPERT SYSTEM ROLE	DESCRIPTION	EXAMPLE
INTERPRETATION	Inferring a situation from its description	Determination of a crop growth stage
PRESCRIPTION	Finding solution to a known problem	Prescription of nutrients to correct a deficit which is causing a reduction in a plant's growth rate
DESIGN AND CONFIGURATION	Selection of actions or components and their interconnections to achieve a pre-determined specification	Selection of a chemical mix, from stock available, to control pests, diseases or combination of both
PLANNING	Determine an entire course of actions before their initiation and implementation	Planning the development of a site after mineral extraction
MONITORING AND CONTROL	Continuous interpretation of signals with expected values and governing of overall system behaviour	Controlling a greenhouse environment
DIAGNOSIS AND REPAIR	Fault detection with a repair of remedy suggestion	Identification of a crop growth rate problem and subsequent corrective action
INSTRUCTION	Education about a subject field or domain area	Education of a manager about a new subject area

Source: (Warwick, Mumford, & Norton, 1993)

Where ecosystem-based approaches to management include scientific, social, legal, political, and technical matters, and there is a myriad of information sources with varying levels of quality and accessibility, such integrated computers systems offer intriguing opportunities to watershed management practitioners (Coulson, et al., 1999, p57). To this day, what continues to hold the most promise is the ability for computers, using the vast amounts of data now available through the intricate communication networks, to mimic expert reasoning, prioritise, and provide direction to decision-makers (Sullivan, 1990). An Environmental Information Management System provides additional analytical tools to practitioners to evaluate their information more efficiently, which saves time, money, and resources in the long run, supporting informed decision-making for watershed management (Fraser & Hodgson, 1995). This has been a turning

point for computers as they are now being designed for knowledge to be something that could be built or contrived out of information (Durkin, 1994). In this form, computers as knowledge-base systems are modelled to have artificial intelligence, so that they can mimic human reasoning, preference, and priorities (Hopgood, 1993). Knowledge-based systems include expert, rule-based, blackboard, and similar systems. Within the knowledge base are stored various rules and facts relevant to the context of the knowledge based system, which can include complex relationships, descriptions, and sequences (Hopgood, 1993). The inference engine can be structured in one of two ways: (1) data-driven (forward-chaining), or (2) goal-driven (backward-chaining) (Hopgood, 1993). A data-driven inference engine attempts to derive as many facts about a query as possible from the knowledge base, while a goal-driven inference engine attempts to resolve few solutions, focusing on a specific problem (Hopgood, 1993).

An expert system is a knowledge base designed to provide expertise in a specific area, mimicking the knowledge and recommendations of an actual human expert in the field. All of these systems depend on logic statements and heuristics within the search query to find the solutions of best fit. With this said, it is important to remember that knowledge based systems are limited to the information and logic that has been programmed into them, and their findings still require interpretation and correction. In fact, the most common and appropriate use for expert systems remains as an assistant for human experts in a support role (Durkin, 1994). In this capacity, they are able to make routine tasks more efficient, make complex tasks more manageable, and generally make expert knowledge more readily available (Durkin, 1994). Such systems can be integrated

to improve the function and provide support for other applications useful in management context such as GIS, remote sensing, and analysis software (Hopgood, 1993).

Successful function of integrated computer-based systems requires certain elements. While there has been some significant advancement in the world of mini-computers since Fraser and Hodgson (1995), their proposed phases of implementation for an information system still provide a useful framework for consideration. They identify three critical phases: the first phase is concerned with the primary activities of data collection and interpretation; second, information must be integrated and prepared for use; and, in the third phase, the system should test the decisions that are made and facilitate policy development (Fraser & Hodgson, 1995).

Where expert systems are able to perform in a wide variety of roles, their strength lies in their ability to quickly analyse or synthesise vast amounts of information, not in their ability to provide expert advice. Fuzzy logic has enhanced the abilities of expert systems incorporating the using relationships to determine probable affinity in areas that are overlapping or unclear. Ideally, a knowledge base attains the level of integration discussed in the earlier section, successfully providing access to data, information, and knowledge from a range of fields in a useable format. An important fact that must be recognised as a basic, inherent assumption of an ecosystem approach is that a knowledge base is incomplete and evolving (Coulson, et al., 1999, p.60). The Knowledge System Environment (KSE), as presented by Coulson, et al., is an advanced integrated-computer system, designed to specifically address complex ecosystem management problems (Coulson, et al., 1999, p.63). As a system, the KSE is designed to bring order to the information as well as to plan and provide decision support where bounded algorithm

solutions were less successful. Like an information tool, the KSE is only as useful as the information/data that is available and the capacity of the experts who use it. Unfortunately, again like any technology, there is a tendency to rely on such a technology.

2.2.5.4 INTERNET/WWW

The Internet is the network of computers that users are able to connect to using communication devices. The World Wide Web is one of many networking applications that makes use of the connectivity of the Internet and encourages interaction between users. The Internet has been fundamental in the advances of networking organizations and people together, giving practitioners easier access to information and people for collaboration. Governments and the private sector are able to educate, inform, model, debate, and collect information easily and broadly. For the future, IT such as the Internet will foster new patterns of watershed management (O'Meara, 2001). As with any technology, there are concerns about the abuse of the Internet. Specifically, whether or not it will contribute to the concentration or distribution of power; that is, whether or not such technologies will encourage or discourage a broader base of participation (Grieco, 2000). The concern here is whether or not such innovative technologies will actually be used to push the managerial approach to new frontiers or whether it will simply be used to administer the same style of management and governance. Further, there are concerns about the "digital divide" – the social relationship between class structure and access to IT, and whether or not this will further reinforce barriers between classes (Grieco, 2000). New emerging social behaviours and urban patterns will require attention and monitoring so watershed management can adjust accordingly. Regardless, the advances and opportunities offered by the Internet and by the World Wide Web complement the goals

of watershed management well. Where watershed management approaches stress the need to integrate physical and biological factors, but also political and socio-economic factors – there is a need to have linkages between them all. The Internet seems to serve these purposes well. While technology is not a cure-all for the challenges facing environmental management, it certainly has a great deal to offer in application. For information management, as has been demonstrated in earlier sections, information quality and quantity are only so important. Eventually, how much of it is shared effectively and used to analyse the problem is the most important factor. As Voinov and Costanza (1999) indicate, the web is open, interactive, fast, spatially distributed, hierarchical, and flexible. All of these characteristics lend themselves perfectly to the conceptual priorities of watershed management.

Voinov and Costanza support the sentiment that the next logical development for the web and the Internet is to foster deeper collaboration (Voinov & Costanza, 1999, p.244). The successful integration of new group-ware, point-2-point technologies, collaborative technologies, and group support systems, are examples of how collaboration efforts may develop. It is currently anticipated that collaborative technologies are the most revolutionary change in user interfaces in the computer industry since Windows 95. Collaborative technologies are expected to be applied in greater frequency in business process redesign, case analysis, education and learning, gaming and training, information system development, policy formulation, process quality assessment, process modelling, product development, project design and evaluation, resource allocation, strategy planning and creation (Jones & De Vreede, 2000).

Such technologies increase the speed of communicating and debating on issues between groups, automate certain tasks such as archiving or minute-taking, retain memory of dialog, and a number of mediums for users to interact over conventional time and space barriers. While there is no replacement for face-to-face encounters, such applications accelerate and facilitate the process when meetings are not possible or for the time between meetings. Jones and de Vreede found that in a group session to develop an environmental strategy for Malawi, participants felt more ownership of the process and more empowered in the process, especially since it was so easy to contribute (Jones & De Vreede, 2000). In addition, they found that the technique of employing such technologies across the web overcame some of the paradoxes involved with increasing public participation, without sacrificing some of the meeting functionality (p.216). Voinov and Costanza noted that the web creates a means of sharing information with the public, facilitating discussions and meditations, a means of involving stakeholders, an excellent means of gathering new information, and a means for collaborative management (Voinov & Costanza, 1999, p.243-244). Similarly, Ceccatio and Snickars conclude Internet GIS is an excellent means of fostering public participation and interaction between researchers, policymakers, and the general public alike (Ceccatio & Snickars, 2000, p.243). Corrigan and Joyce remark that new information and communication technologies provide alternative mediums for governments to have a relationships with the public; however, this is offered with the provision that these communication technologies are accompanied by an entirely new, open, and transparent relationship with the public (Corrigan & Joyce, 2000, p.1778).

An additional area where the Internet has significant implications is with other information technologies, such as the convergence of Internet and GIS applications. As a term, Internet GIS refers to the host of GIS applications designed to run on the Internet, either using the World Wide Web or any other networking application. Internet GIS and web-based GIS applications are reshaping the way people use GIS, share information, analyse data, and make decisions. According to Peng, the Internet is affecting GIS in three major areas: (1) GIS data access; (2) spatial information dissemination; and, (3) GIS processing (Peng, 1999, p.117). Across the Internet, users are able to access groups, share information, and disseminate results easily. The Internet will directly facilitate interactivity within and between departments. As Internet GIS develops, the challenge will be in selecting which approach. Table 2.20 illustrates the assessment framework for approaches to the development of Internet GIS as developed by Peng.

TABLE 2.20: EVALUATIVE FRAMEWORK OF INTERNET GIS

	CGI- based	Plug-ins	Java Applets	ActiveX Controls
Performance				
Client	Excellent	Good	Good	Good
Server	Poor to Good	Good	Excellent	Excellent
Networking	Poor	Good	Good	Good
Overall	Fair	Good	Good to Excellent	Good to Excellent
Interactivity				
User Interface	Poor	Good	Excellent	Excellent
Function support	Fair	Good	Excellent	Excellent
Local data support	No	Yes	No	Yes
Portability	Excellent	Poor	Good	Fair
Safety	Excellent	Fair	Good	Fair

Source: (Peng, 1999)

The web holds great promise for data management purposes also as web-based data management applications are becoming more available and easier to use, helping to improve the efficiency and effectiveness of information networks. Based on the development of a new web-based data management application at Northeast Ohio

Regional Sewer District, Blanc, Eberle, and Osthues reported that the new web-Based infrastructure provides these main advantages:

- Minimised cost and maintenance – server side applications are easy to update and maintain compared to client side or local computer applications
- Highest Possible Speed – Data processing occurs at location and then sends web pages rather than sending data, processing, and posting. Less congestion for the network and more data is available using 3 tier system (Database + Application Server/Web Server + Client Web Browser)
- Remote Access – Servers can be accessed anywhere if desired
- High Security and Data Integrity – Data is located in its own secure tier, so neither users nor applications can corrupt it
- Scalability – Applications can be added and taken away, new data sets can be added, interface is easy to change and update
- Integration Flexibility – data standards and easy web interface can be integrated with new or existing systems easily.
- Standardised data management and reporting practices;
- Secure, enterprise wide access to historical data for process and equipment troubleshooting
- Fully automated internal performance reports
- Full administrative control and oversight

Source: (Blanc, Eberle, & Osthues, 2003)

Such advances have also become a source of frustration. Quantity of information provided by the Internet although impressive is no substitute for quality. In many ways, the Internet has added to the complexity of information management rather than reduced the challenges, causing government organizations new work in areas of publication and communication management. Those responsible for information management will be called upon to develop numerous new web applications and provide technical support, manage seemingly endless volumes of information, and departments will be required to cover growing overhead costs for hardware, software, training, and malignancy. Challenges face the technology itself also, as Weikum noted. If the web is prove its worth as a reliable and dependable technology, response time must become predictable

and guaranteed; services must be continuously available; and search capabilities must evolve past superficial levels and penetrate deep information (Weikum, 2001, p.3,).

2.3 SOME IMPORTANT WATERSHED MANAGEMENT EXAMPLES

This section presents two examples of organizations with effective information management. In both instances, information management has had an interesting and important role. First, the Credit Valley Conservation Authority and the Credit Valley demonstrate the Conservation Authority model in Ontario and the importance of establishing a coordinated approach to information management across an organization. Next, the Patuxent watershed demonstrates how a partnership approach is an effective means of improving information management capacity through its involvement with the wider Chesapeake Bay program.

2.3.1 CREDIT VALLEY CONSERVATION:

The Credit River is a medium size watershed, covering 1000 square kilometres in Southern Ontario on the west side of Toronto, with its water flowing into Lake Ontario. The river is about 90 km in length with the width of the watershed spanning 15 km of shoreline along Lake Ontario. Areas of significance include the Niagara Escarpment in the central part of the watershed, and on the western portion of the Oak Ridges Moraine stretches along the watershed. Popular for its fishing, natural areas, proximity to Toronto, Hamilton, and Mississauga, urban sprawl and population growth have been major challenges for the watershed (Credit Valley Conservation, 2003a, 2003b). Approximately 600,000 people live in the watershed, 87% of which live in the lower 1/3 of the watershed (Credit Valley Conservation, 2003b). Also, it is expected that by 2020, approximately 40% of the watershed will be urbanised, a 25-30% change over 30 years

(Credit Valley Conservation, 2003b). Land uses in the watershed range from highly urbanised areas such as Mississauga centre to rural agricultural land uses.

Five tributary rivers flow into the Credit, including Black/Silver Creek, West Credit, Shaw's Creek, East Credit, and Caledon Creek. These rivers contribute up to 690,000 cubic metres of water daily, 65% of which comes from groundwater. The CVC originally formed to regulate flow along the Credit River and eventually come to oversee environmental and watershed management. It has had a profound impact on the local watershed. Credit Valley Conservation (CVC) is the organisation that is responsible for watershed management of the Credit River and its surrounding area.

The governing body of the CVC consists of 10 local municipalities including the cities of Brampton, Mississauga, Township of Amaranth, and East Garafraxa, and the Towns of Caledon, Erin, Halton Hills, Mono, Oakville, and Orangeville. CVC is one of 36 Conservation Authorities (CA) in Ontario, empowered under the Conservation Authorities Act, (R.S.O., 1990 c.27), responsible for co-ordinating watershed management. For the last 50 years, the CVC has managed the local watershed to reduce drought and damage caused by flooding and improves local water quality. Recently, as with all of the Conservation Authorities in Ontario, efforts have shifted to address ensuring sustainable and healthy economic and community development. As a part of this, the CVC has dedicated more time and resources to watershed management. This includes managing water quality and quantity, co-ordinating development, monitoring pollution and change, maintaining forests and wetlands, all on a watershed scale. When the CVC was created in 1954, the communities along the Credit faced extensive flood damage, low water flow, polluted water, open sewage, industrial discharge, and sediment

runoff. Additionally, the CVC is often involved in developing or reviewing environmental planning for local communities or partners. The Credit River, located in a region of Southern Ontario subject to intense population growth, urban development, and industrial activity, was all but destroyed before the creation of the CVC in the mid 1950's. Urban development in the region had led to deforestation and urban sprawl in region; agricultural practices in the north of the watershed combined with industrial activity in the south had led to very high pollution levels. In general, water supply was unpredictable and water quality was poor. Since the creation of the CVC, water flow has been regulated, source and non-point source pollution have been reduced through various remediation programs, agricultural practices have improved, a large proportion of waste effluent has been prevented from entering the watercourse, and fish species once thought lost are returning. As the activities and core business activities have gradually expanded to address environmental stresses, the health of the river has been returning: "There is as much forest cover in the watershed now as there was 100 years ago and Atlantic Salmon, which have not been seen in the river in 150 years, are now returning" (Credit Valley Conservation, 2003a). According to the literature provided by the CVC, their work is guided by three basic principles:

- A long-term management perspective;
- A strategy of prevention, rather than reaction;
- A holistic look at management decisions and actions

(Credit Valley Conservation, 2003a)

These guiding principles provide direction for the CVC in their watershed management activities, summarised in Table 2.21.

TABLE 2.21: CVC WATERSHED MANAGEMENT ACTIVITIES		
Water Quality Strategy	**1999 - 2004**	• The first two-year phase of this five-year project will identify present and future water quality issues within the entire watershed. • Issues might include industrial discharge, road runoff, sewage treatment, new developments, and pollution sources. • Strategy will develop an equitable means of managing the quality of water entering the river from all watershed communities.
Water Budget	**1999-Present**	• Tries to account for what is coming into and what is leaving the watershed. • Helps a practitioner identify management limits and provide essential information when considering requests for water taking. • In the past, water use has been conducted without a representative understanding of watershed water quantity limits. • Development of a Framework for Sustainable Management on a Watershed Basis (2000 – 2004) - the CVC and GRCA in a partnership project with Ontario government are developing an implementation plan to address water taking and land use changes as a part of the water budget.
Ecological Land Classification (ELC)	**Completed**	• First completed Ecological Land Classification in southern Ontario, the ELC helps identify land use change. • For watershed management practitioners, this information feeds into the set of knowledge that builds an understanding of water quality and quantity change. • Classification indicates that urbanisation in the Credit watershed increased from 15% in 1988 to 21% by 1996.
Flood Damage Reduction Program	**On-going**	• The FDRP update study entails reviewing the original work for the 22 flood damage centres (1985) located throughout the watershed and updating them based on land use changes and new technology.
Stewardship Strategy	**On-going**	• This CVC program is working to promote a variety of stewardship initiatives with watershed landowners that, collectively, own more than 93% of the land within the watershed. • The projects are selected on a priority basis to address specific needs identified by other research within the watershed. • Projects are usually carried out in partnership with individual landowners and community groups and include shoreline naturalization, tree planting, stream rehabilitation work, projects to control erosion, fencing to keep livestock out of water bodies and so on.
Watershed Monitoring Program	**1999-Present**	• Monitor the impact of change caused by residential, commercial, industrial, and natural activities • Program will assist CVC in understanding and communicating change to community members as well as assist long-term management planning.
Subwatershed Studies	**1999-Present**	• Watershed divided into 20 subwatershed • Studies research subwatershed characterization, resource issues and are used to set subwatershed goals and objectives • Based on system stresses, management scenarios are developed and provide direction for subwatershed management as well as watershed management as a whole.
		Source:(Credit Valley Conservation, 2003a)

Watershed Management and the Role of Information Management:

Many of the watershed management activities of the CVC draw upon information management as a resource. Using the CVC as an example, the following section provides a sense of how information management supports efforts across a watershed management organisation.

Water Quality Management

CVC is working with members to develop a water quality strategy (1999-2004): the Strategy is designed to provide a series of management goals that the CVC and its member municipalities can use to protect and enhance water quality conditions within the Credit River and its tributaries (Credit Valley Conservation, 2001). The strategy intends to:

- Assess existing water quality information, including chemical, physical, biological and microbiological data
- Identify existing and potential water quality stresses from land use
- Establish water quality objectives
- Develop a water quality assessment tool
- Identify alternative management scenarios
- Test alternative management scenarios
- Compare results with objectives
- Prepare a water quality strategy
- Implement strategy

(Credit Valley Conservation, 2001)

This strategy has 30 draft parameters of concern, which a computer-aided modelling tool uses to predict changes for the watershed over time. Information for these parameters is prepared within the CVC and is collected both by internal staff and from external agencies. Based on these predictions, various management scenarios are identified and evaluated for their overall effectiveness. Drawing heavily on information management resources, the effectiveness of this tool is limited to the quality and quantity of information available, the technology available to run the model, and the expertise on hand to interpret the results.

Water Budget

A regional scale water budget has been initiated by the CVC for the watershed. The water budget will involve the creation of a hydrostratigraphic model for the watershed that will be incorporated into a finite element 3-D computer model. The model will be calibrated against baseflow data that will be collected on an ongoing basis using stream gauge stations for all subwatersheds. The model will use continuous stream gauge data and should enable the identification of significant recharge areas, allowing for more accurate land use management policies to be developed, monitoring land use and climatic change, and assist with sustainable water allocation and permit-to-take-water (Credit Valley Conservation, 2001). Such a model requires continuous data to be collected and input, requiring a long-term investment in information collection and management by the CVC including both time, financial, and staff resources.

As the CVC is an area of high urban, industrial, and commercial development, the local demand for water is very high. Finding a means to maintain water quality and quantity issues given the finite supply of fresh water is critical. In collaboration with Ministry of the Environment (MOE) and the GRCA, an approach to water budgeting and water use allocation is being investigated. The *"Framework for Sustainable Management on a Watershed Basis"* will draw on much of the information gathered from the monitoring and subwatershed planning processes, as information will be gathered that will illustrate local water supply and water demand. Primarily, this framework will consider water taking and use versus water supply and predicted availability, providing a set of policy tools that support decision-making that will sustainable allocate the water resources. For Ontario, this progressive approach has not yet been tried in any other

watershed and will require a large volume of information to support such decision-making.

Ecological Land Classification

With land use change and urbanisation pressures on the Credit River Valley such a paramount challenge, ecological land classification provides a means of tracking land use change (Credit Valley Conservation, 2001). This is a systematic way to classify land use, based on ecological significance, which can be used to compare to later iterations of the same process. This is important for identifying land use areas that are changing that may have a dramatic impact on either water quality or water quantity. Classification requires up-to-date land use data and information experts who are capable of assessing land use.

Flood Damage Reduction Program:

As with all Conservation Authorities, one of the CVC's primary concerns is floodplain management. Efforts include regulations and policies intended to protect communities from floodplain hazards and to maintain a healthy watershed. Floodplain management in Ontario falls under provincial legislation and the CVC is the lead implementing agency for floodplain policies within the Credit River watershed (Credit Valley Conservation, 2001). CVC's primary approach to floodplain management is land use planning, a preventative approach that requires knowledge of the watershed's floodplain, soil, surface and ground water conditions, natural features, and urban development plans. Floodplain objectives are met through a combination of Land use planning and regulation of development; flood proofing and acquisition; and, flood forecasting, all of which require input and access to information management resources.

The intricate network of data collection and processing tools required for flood prediction need to be linked through information management.

Stewardship Strategy:

The CVC plays an important role in supporting watershed stewardship in the region. Such opportunities allow the CVC to work in partnership with municipalities, provincial organizations, interest groups and academic institutions in environmental restoration practices (Credit Valley Conservation, 2001). In this role, CVC co-ordinates relevant information and provides technical assistance to stewardship partners, facilitating more effective watershed stewardship. Primarily, this involves managing, collecting, and sharing information amongst stewardship partners.

Watershed Monitoring Program:

CVC has been expanding the scope and use of its monitoring as it affects watershed management. Monitoring provides feedback to the watershed management process, allowing practitioners to refine their management activities to address local changes in the watershed. Working with CVC partner communities, the objectives of CVC's monitoring efforts include:

- Characterize watershed conditions for specific areas;
- Improve management techniques and approaches;
- Collect and analyse information for the purpose of assessing watershed health;
- Anticipate future stresses on the watershed;
- Determine specific areas of concern and the effectiveness of management activities; and,
- Maintain an up-to-date database of detailed information on watershed conditions for watershed decision-making (Credit Valley Conservation, 2003a).

Since 1999, the Integrated Water Monitoring Program (IWMP) has represented a significant portion of CVC's monitoring efforts (Credit Valley Conservation, 2001). This program uses a suite of indicators to measure water quality, quantity, and biological

diversity/health for the Credit Valley watershed. This program operates in partnership with the Provincial Water Quality Monitoring Network (PWQMN) and the Provincial Groundwater Monitoring Network (PGWMN), adding to the data sources and expanding the utility of the monitoring program to include drought response, provincial water policy development, modelling, and land use planning (Credit Valley Conservation, 2001).

So far, the IWMP has yielded a relational database that will be used to store, organize, retrieve, and link monitoring information to a Geographic Information System (GIS) for CVC staff, communities, and watershed partners. Data included on the watershed include climate, baseflow/groundwater movement, flow regimes, forest cover, wetlands & riparian areas, stream flow, channel shape, water chemistry, benthic macro invertebrates, urban population/land use, and fish species. This process will continue to yield a substantial amount of information that will grow and develop over time, which requires a well-conceived, dynamic database design that could respond to such changes (Credit Valley Conservation, 2001).

Subwatershed Planning

The Credit River Valley Watershed has been divided into 20 subwatersheds. For each subwatershed, a plan is being developed; intended to provide information about the distinct subsystems that can be brought together and help manage the watershed as a whole. For each subwatershed, a three-phase study is planned. Phase 1, Subwatershed Characterization, will identify resources and specific management issues for the area, used to set subwatershed management goals and objectives. Phase 2, Prediction and Impact Analysis, will identify and predict probable impacts on the watershed; Phase 3, Implementation, will identify the possible management scenarios and suggest the most

appropriate management direction. The information gathered from subwatershed planning will support management of ground water, long-term planning, aggregate extraction, land-use planning, monitoring, water allocation and budgeting, high and low water conditions, fisheries management, land stewardship, and managing the watershed as a whole (Credit Valley Conservation, 2001). As a part of watershed management, subwatershed management provides a nested approach to understanding the system and management. Planning and protection of the CVC watershed is intended to protect water quantity and quality, natural areas, flooding, and encourage urban development. In addition, subwatershed planning will feed into the urban planning process, which involves reviewing land use proposals, guiding municipal development, official plans, official plan amendments, monitoring and planning studies, site plans, zoning bylaws, and development plans.

In review of the watershed management approaches of the CVC, information management plays a vital role in each of the Conservation Authority management activities. This role may change from either support of the activity to being the very objective of the CA's efforts. The Credit River Valley watershed faces significant management issues in the years to come and the CVC has designed a clear strategy in an attempt to maintain the river's health and integrity. With respect to information management, it is interesting to observe that each management step seems to be integrally linked to previous or concurrent management efforts, building on layers of management programs and projects, integrating information. The next section will introduce another case, in the Patuxent Watershed, a subwatershed of the Chesapeake Bay Basin.

2.3.2 *CHESAPEAKE BAY AND THE PATUXENT WATERSHED*

The Chesapeake Bay is the largest estuary in the United States, including Delaware, Maryland, New York, Pennsylvania, Virginia, West Virginia, and the District of Columbia (Chesapeake Bay, 2003). 322 kilometres in length, and fed by 48 rivers and 100 smaller tributaries, fresh water flowing down the Chesapeake slowly mixes with water flowing up from the Atlantic, creating a range from fresh water at the top of the watershed to salt water at its mouth (Chesapeake Bay, 2003). People have been making a home in the Chesapeake Bay since 8000 BC, when early natives inhabited the region using the Bay as their primary food source. Europeans who came to the area in the 1600's quickly released the Bay's richness in resources and began to settle shaping the Bay as it is today (Chesapeake Bay, 2003).

The Patuxent, one of the watersheds of the Chesapeake Bay system, is approximately 2334 square km in size and located within the State of Maryland and covers 7 counties (Chesapeake Bay, 2003). Flowing 177 kilometres, the Patuxent travels through a diverse mix of land uses, including a relatively high percentage of forest (50%), cropland (22% + 8% Pasture), and only moderate urban land use (20%) (National Watershed Network, 2003). The Patuxent's mix of land uses reflects similar percentages to the larger Chesapeake Basin and it is often referred to as a microcosm for the sake of watershed management modelling (Chesapeake Bay, 2003). Like so many rivers, the Patuxent has sustained the settlement and growth of communities within its watershed, providing a means of travel, water supply for irrigation of crops, drinking water, recreation opportunities, natural habitat, and supply of food. With human settlement, the many natural amenities and geographic proximity to large urban areas (Washington,

D.C.) brought rapid urbanisation. This combined with inadequate sewage treatment, pollution arising from atmospheric deposition, nitrogen, and phosphorous pollution resulting from non-point source pollution, sediment from rural and agricultural practices, residential and commercial activities, and natural erosion. (National Watershed Network, 2003). This has resulted in poor water quality, diminishing ground water resources, habitat and wildlife destruction, and overall degradation of the ecosystem (Chesapeake Bay, 2003). In particular, suspended sediment, bacteria, excess nutrients, and toxic materials pose the most significant threats to both surface and ground water (Garrison, 2001). Efforts to control these impacts include enforcement and implementation of better watershed management practices, achieved in part by the Chesapeake Bay Program and the Patuxent River Policy Plan. With respect to Information Management, as a part of the Chesapeake Bay Program, the Chesapeake Information Management System (CIMS) is a central warehouse of data, information, meta-data, software, and models aimed at improving information management within all of the watersheds and subwatershed of the Chesapeake (Chesapeake Bay, 2003). CIMS aims to involve all parties with interests in the Chesapeake basin and includes an online database for water quality, water modeling, GIS coverages, living resources (fisheries, benthic, plankton, bay grasses, point sources, river flow, and toxics (Chesapeake Bay, 2003). A wide range of data access and analysis tools are provided, as standards for gathering information, meta-data, and terms for use and sharing. CIMS has gone a long way in raising public awareness of environmental issues facing the Chesapeake and its watersheds and has led the development of information management for watersheds like the Patuxent.

The Patuxent River is one of the major tributary watersheds of the Chesapeake Bay Estuary, a region that has been guided by the Chesapeake Bay Program since 1983, which includes heavy involvement in CIMS. In principle, many of the problems facing the Chesapeake Bay are not new to the region nor are they uncommon to the field of watershed management. People have had a tremendous impact on watershed processes such as the transfer of sediment: erosion throughout the watershed provides the supply of sediment for beaches and coastline. This process has been severely altered by water control structures, conflicting land use, clear-cutting, and seawalls (Chesapeake Bay, 2003). The Bay Program represents a major environmental management partnership, led by Maryland, Pennsylvania, and Virginia; the District of Columbia; the Chesapeake Bay Commission; the U.S. Environmental Protection Agency, and participating advisory groups. In June 2000, the third Chesapeake Bay agreement was signed, leading the management efforts of this multi-jurisdictional program into the year 2010. Developed by local government leaders, researchers, public, and conservation groups, this new agreement will build on past efforts, but is intended to improve water quality sufficiently that it can be sustained long into the future (New & Heron, 2000). To achieve high water quality standards by 2010 and avoid stringent enforcement regulations in 2011, the agreement required commitments that would ensure the implementation of management efforts that reduce nutrient and phosphorous loads, increase nutrient reduction goals, and establish sediment reduction goals, including a host of other management efforts (New & Heron, 2000). The agreement outlines 93 commitments including protection and restoration goals central to improving the Bay's water quality.

Building on the Chesapeake Bay initiative, the Patuxent River Policy Plan provides guidance to counties within the State of Maryland for managing the Patuxent watershed, focusing on land management, developed in cooperation with the Patuxent River Commission, the seven watershed counties, and the state of Maryland in 1984. In the face of the challenges facing the watershed, it was recognized that the local decision-makers needed to have a common direction for shared objectives for improving the river's health and integrity. Led by the Patuxent River Commission, 20 goals that were used as the basis of the Patuxent River Policy Plan were devised to provide water quality treatment and improved land management, which led to the protection of primary management areas (as established by the plan), established stream buffers, and prescribed land management sensitive to watershed processes (Chesapeake Bay Commission, 2003). In 1997, an addendum to the Patuxent River Policy Plan was adopted to ensure its long-term effectiveness.

The Patuxent River Commission and the Chesapeake Bay program support information through CIMS and through additional projects such as watershed planning system, which is a tool for integrated management of land use and non-point pollution within the watershed. Drawing on GIS themes from CIMS, land uses layers are combined with a non-point source model, which draws upon an inventory of non-point sources, and combines it with a growth management simulation model, which combines current demand with future demands (Weller, et al., 2002). This tool is helping to identify rural parts of the watershed that may be need of agricultural controls, given growth predictions and is aiding in experts in the identification and protection of source protection planning and decision-making.

The Patuxent River Commission has 34 members, who are ultimately responsible for ensuring the Policy Plan is implemented. Members are from all three levels of government, business, development, environment and conservation groups, citizens, researchers, and farmers. Responsibilities include reviewing policies, proposals, and projects that may affect the watershed and serving as a forum for watershed issues, as well as initiating their own watershed projects. The Patuxent River demonstrates how different levels of government in co-operation with local stakeholders can come together, co-ordinate their information management efforts to more effectively manage their watershed.

2.4 CHAPTER SUMMARY

This literature review has served to help develop the various elements of information management, as they relate to ecosystem-based approaches to watershed management. From the literature, a number of challenges were identified, and in most cases, various mechanisms or tools were presented for coping with such challenges. These information management tools and mechanisms vary from scale and scope of a project, and depend largely on the objectives of the management process. Interestingly, various aspects of information management seem to overlap other aspects at times, and thus information technologies are causing some management practices to evolve. In reviewing the information management efforts to achieve the goals of ecosystem-based watershed management, it becomes clear that there are many elements to information management and many roles it can have form from one organization to another. A means of evaluating how the various information management elements fit together would help organizations establish an effective information management core.

Building on the sections identified here including information planning and design; data management, processing, and analysis; information sharing and coordination; and, information management technology, interviews will be conducted to learn from practitioners first hand how these elements actually function. Internal and external considerations will be used as an additional category to investigate information management, as there seem to be a number of organizational, political, and cultural factors that can influence information management.

CHAPTER THREE - METHODS

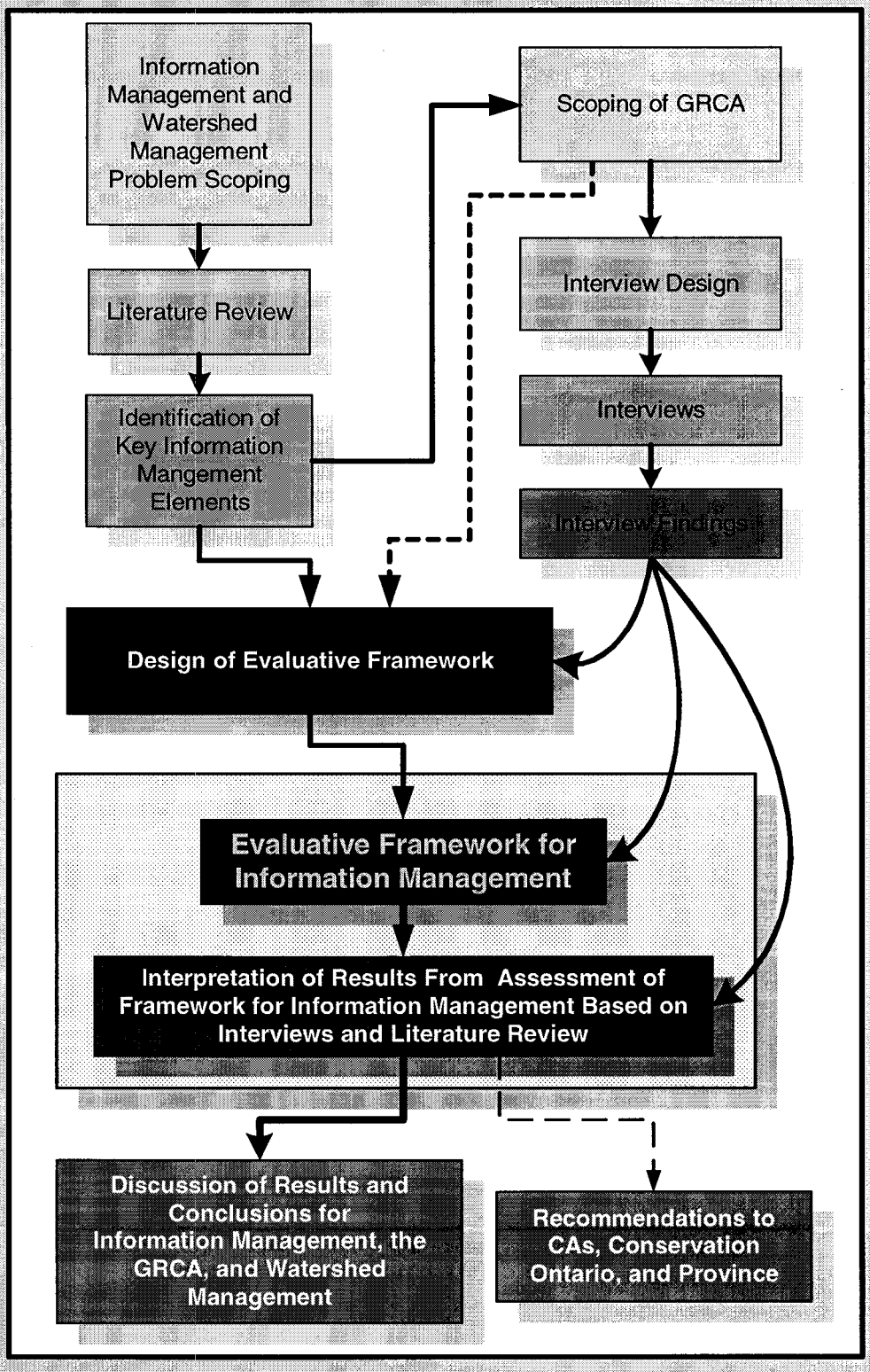
3.1 INTRODUCTION

This Chapter will introduce the methods used in this research project, including the development and application of the evaluative framework for information management. Following a brief description outlining the general study process, the reader will be led through the process, providing a sense of the approach used for this research. Interviews and personal accounts of practitioners are used as a means to assess the literature and further refine the findings through primary case-study work.

3.2 STUDY PROCESS

The study process for this research, including the literature review, interviews, the case study, development of the information management framework, and application of the framework are illustrated in Figure 3.1. Beginning with a thorough review of the relevant literature, this research used synthesis as a primary means to formulate the significant barriers as well as the key elements of effective information management. For the case study, the Grand River Conservation Authority, interviews were conducted as a means of validating the appropriateness of the framework and literature review. Using the knowledge gained from the interview process, adjustments were then made to the framework.

FIGURE 3.1: RESEARCH STUDY PROCESS



A case study method was selected to investigate information management and to support the development of an evaluative framework as it widely considered an effective method for describing, explaining, and analyzing organizational structure, which is appropriate for investigating organizational information management (Babbie, 1999). Yin (1984) observed a case study is a preferred research strategy for social sciences and for organizational and management related studies as it allows for the investigation of the "how" and "why". Yin noted, "the case study allows an investigation to retain the holistic and meaningful characteristics of real life events – such as organizational and managerial processes..." (p.14). Creswell (1998) defines the case study as an exploration of a "bounded system" over time through detailed multiple sources of information, where the case can illustrate issues or uniqueness through the study. A case study involves the widest array of data collection, including the use of documents, archival records, interviews, direct observation, and participant observation (Creswell, 1999). As Yin documented, a case study is an empirical inquiry in real life context, the phenomenon and context are not fully understood, and multiple sources are used. Results from the research of a case will provide a description of the case, will allow themes to be identified, and support assertions regarding the field of study. The next section discusses how case study and related research supported the desired research objectives

3.3 DEVELOPMENT OF THE INFORMATION MANAGEMENT FRAMEWORK

One of the primary objectives of this research is to develop a framework for evaluating information management practices of watershed management organizations. The framework is intended to be user-friendly and comprehensive in its approach. While the framework is not meant to be a guide to information management, it does serve as a

means of evaluating practices by identifying a comprehensive set of elements that are central to information management. The following sub-sections will provide a detailed account of how the framework was developed as well as a review of the key elements and why they are significant.

3.3.1 PROBLEM SCOPING

Initial problem scoping involved a broad survey of the literature, attending conferences, and contacting the GRCA. Through this step, the current state of research, methods, and practices related to information management for watershed management organizations was explored. While the literature review was useful for identifying the broad scope of the problem, direct consultation with practitioners in the field was required. Attending conferences and meetings related to the subject matter was quickly found to be the most useful avenue. This included attending the following conferences: Science and Management of Protected Areas Association (SAMPAA) (May 14-19, 2000); Canadian Association of Geographers (CAG) (May 31-June 3, 2000; May 29 – June 3, 2001); Canadian Association of Geographers, ONTario division (CAGONT) (October 22-23, 1999; November 4, 2000); Ontario Water Resources Association (OWRA) (June 6-8, 2001); GRCA general meetings (December 2002 and Spring 2003); and, the GRCA Water Forum (2001 & 2002). From these conferences, it was possible to see not only where researchers and practitioners were focusing, but to engage with them directly. In particular, the SAMPAA conference included an interpretative tour of the Grand River Watershed and GRCA, led by Professor Gordon Nelson of the University of Waterloo. At the OWRA conferences, practitioners from the GRCA led and participated

in many discussions, presenting the issues that faced the agency; and, at the GRCA Water Forum, discussion and presentations were led by the GRCA and focussed on the watershed. This provided a context where the issues facing the GRCA were highlighted in relation to each other. Finally, at GRCA meetings, the operational and strategic planning of the association was discussed at length. This provided an opportunity to document the actual activities with GRCA practitioners. This step assisted in refining the literature review as some additional points from the literature were revisited. In addition, this was an important step for adding practical insight to the framework and for identifying individuals for interviews.

Based on the preliminary literature review summarised above and the problem scoping process at the GRCA, the following information management considerations were identified as being fundamental in supporting an organisation's watershed management efforts: Information Planning and Design; Data Management, Processing, and Analysis; Information Sharing and Co-ordination; Information Management Technology; and Internal and External Considerations (shown in Table 3.1). By reviewing the preliminary research, these broad headings were identified and used during the literature review to flush out the key considerations for each of the elements of information management as well as serving the development of the evaluative framework directly and in the design of the interview questions.

TABLE 3.1: KEY CONSIDERATIONS FOR VARIOUS ELEMENTS OF INFORMATION MANAGEMENT

ELEMENT	*CONSIDERATIONS*
Information Planning and Design	• Problem identification • Data priorities (Organisational goals and values) • Approach to Watershed Management • History of Watershed • Management Units and Scale • Organisational Budget and Resources • Project Partners • Environmental Conditions and Characterization
Data Management, Processing, and Analysis	• Data Collection Resources • Existing Data Sources • Local/Traditional/Existing Knowledge • Data Quality, Quantity, and Integrity • Integration (Biophysical and Socio-economic & Scientific versus Traditional or Local knowledge) • Formatting and Data Standards • Meta-Data • Technology Needs and Capabilities • Database Management • Archives and Storage • Interpretation and Data Analysis • Forecasting and Scenario Building • Expertise
Information Sharing and Co-ordination	• Key stakeholders and players • Dissemination and Intellectual Property • Accessibility • Networks and User Groups • Public Participation • Technology • Utilisation and User Interfaces • Stakeholder Involvement • External Organisations/Inter-Agency Co-operation
Information Management Technology	• Technology • Expertise • Cost • Technology development • Knowledge-base/Information-base systems • Information Accessibility
Internal and External Considerations	• Monitoring • Reporting • Information development (Reporting of changing information needs) • Next Steps • Environmental conditions and issues • Organisational Culture • Political and public pressures • Money

Source: Adapted from Denning & Grieco, 2001; English, et al., 1999; Hooper, et al., 1999; Mclain & Lee, 1996; Orna, 1999; Slocombe, 1998a, 2001; Slocombe, Bavington, & Brown, 2000; Slocombe & Sharpe, 1995; Timmerman, Ottens, & Ward, 2000; Webler & Tuler, 1999

3.3.2 *LESSONS LEARNED FROM THE LITERATURE*

A thorough literature review was used to formulate a clear picture of the role and critical elements of information management for watershed management. A wide range of sources were used from multiple disciplines including geography, environmental studies, computer science, systems engineering, organisational behaviour, strategic planning, business, psychology, sociology, watershed management, land use planning, as well as a number of government sources. The variety of sources also represented a broad range of academic rigor, from peer-reviewed journals to edited books, personal accounts and descriptions, books, pamphlets, web sites, and presentations. Literature references that focused on operational and strategic elements, as opposed to tactical elements were used, as the scope of the research was to focus on the conceptual process of information management, as opposed to the details of implementation (Carayannis, 2001; Dixon, 1993; Probst, et al., 2000). Conceptual strategy was preferred to maintain the relevance and applicability of the framework for other watersheds, rather than trying to prescribe implementation steps, which would be limited in utility to the circumstances of a single watershed. Continuing from the problem scoping process, the literature was reviewed and organized based on the preliminary elements and considerations that had been identified (see in Table 3.1); common themes were then synthesised and categorised as specific information elements (discussed in section 3.3.3). These elements were combined and expanded upon to form the evaluative framework.

3.3.3 SPECIFIC FRAMEWORK ELEMENTS AND COMPONENTS

The key elements of information management as determined through the literature review are combined in Figure 3.2 to make up the evaluative framework for information management. Starting with the elements in the literature review, the framework was constructed by incorporating findings from the literature with direction from the problem scoping exercise, especially the group meeting at the GRCA, and builds on the rational decision-making model. The framework ties the five main elements identified through the literature review as strategic, practical steps for information management, linking them to the concept of adaptive watershed management. In choosing the rational decision making model and the concept of adaptive watershed management to build on, the grouping produced is intended to closely resemble the flow of information throughout the watershed management cycle as well as the problem solving approach of a watershed management organization such as the GRCA. As a staring point for an evaluative framework for information management, by adapting the steps of the rational decision making model, a suitable structure for the framework was created: (a) *define the problem* (Information Planning); (b) *identify decision criteria and allocate weights to the criteria* (Data Gathering, Pre-Processing and Management); (c) *develop alternatives* (Data Processing and Analysis); (d) *evaluate the alternatives* (Process Tracking); and, (e) *implementation and monitoring* (Review and Evaluation). Each of these elements for the evaluative framework for information management is described in detail below.

Information Planning

Information planning is the formative step in the process and directly reflects the organisational culture and practices of an agency. It is during the planning stage when

the objectives, priorities, direction, and approach are decided. In the past, information management could have some significant shortcomings in this area, especially if information management occurred in a reactive manner to managerial activities without adequate strategic planning. It is at this stage that the information management process needs to directly connect with the organisation and watershed management planning processes (Probst, et al., 2000). Drawing on an adaptive approach to management, the process is continually evolving and improving (Finger & Brand, 1999; Sparrow, 1998). This allows for co-ordination of activities and ensuring that the information activities support the planned watershed management activities. Planning is based on the needs of the organization and on input from across the organization, as well as considering external factors (Dixon, 1993, 1994, 1999; Orna, 1999).

Data Gathering, Pre-Processing, and Management

Often viewed as a purely mechanical part of the process, this is the step in which data and information are brought together, co-ordinated, improved, stored in a usable format, and made available for use, including the integration of different data types (Easterby-Smith, et al., 1999; USEPA's, 1997). The key to this element is making information accessible for processing and analysis. While this element is certainly highly technical in nature, it often requires a degree of diplomacy for the sake of partnership building. A key step for this element is to establish information networks, linking information from different organizations together across inter and intra-agency boundaries (Dixon, 1993, 1994, 1999; Orna, 1999).

Data Processing and Analysis

This element usually produces the primary deliverable of the information management process. Data and information manipulation and analysis provide knowledge and improved understanding that support decision-making. As practitioners depend on the quality and timeliness of this knowledge, this element highly depends on the effectiveness of the previous elements for its success. Otherwise, the understanding gained may not adequately support practitioners in their management activities. Processing and Analysis by qualified experts, practitioners, and decision-makers alike is important for the validity and confidence in information management. This phase produces value-added information to support decision-making and management activities.

Process Tracking

This element covers all of the activities related to assessing the process, relative to the planning, reality of implementation, and changes. Without process tracking, there would be no way to tell if the knowledge acquired was useful or representative, or if knowledge was required. Process tracking activities should identify changes in the system and will provide an indication of new information needs. Most frequently neglected, even by organizations with well-developed information management, this addresses not only technical development, but also cultural, organisational, internal, and external changes (Dixon, 1994; Orna, 1999).

Review and Evaluation

This element covers all of the activities related to improving information management by reviewing, reporting, and evaluating the process and the information

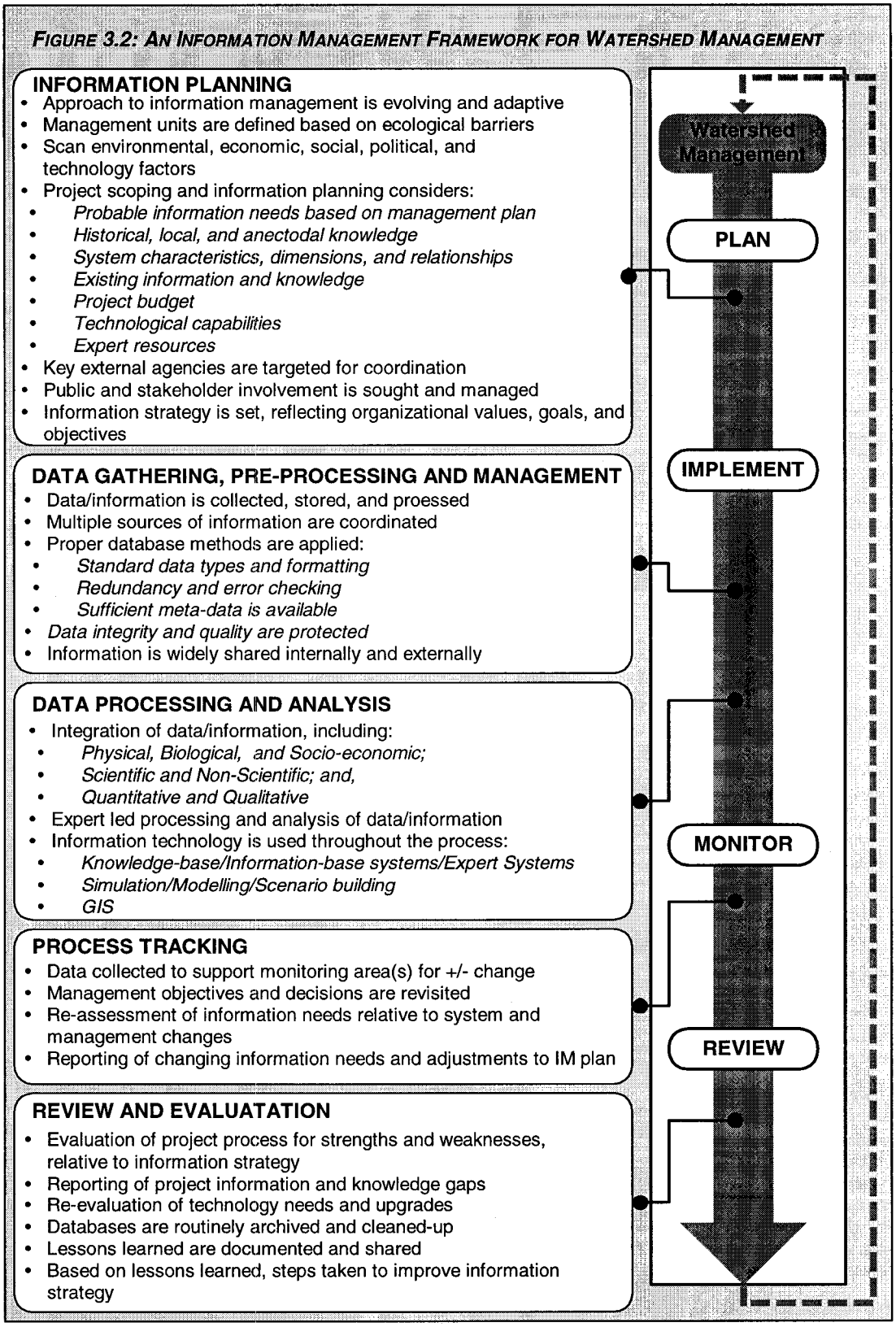
produced (Dixon, 1994; Finger & Brand, 1999; Sparrow, 1998). Continuous improvement based on the reflection of experiences and anticipated new conditions is the only way to ensure that information management process remains effective, producing representative and useful knowledge based on new needs and systems changes.

3.3.4 Case Study Selection

Selection of the GRCA as the primary case study considered a number of factors. First, the watershed itself is representative of watersheds in Ontario: The region has a history similar to many major rivers, where people were first attracted by the flow of the river for rural and agricultural development, followed later by the heavy industrialisation common to Southern Ontario. Today, this mix of land uses creates a complex set of issues that face watershed management practitioners.

Secondly, in Southern Ontario, Conservation Authorities are the public agency that defines their jurisdictional management activities by watershed boundaries (i.e. watersheds are their defined management unit). Conservation Authorities have been responsible at a regional level of management for watersheds since the 1940's and 1950's, collecting over 50 years of management experience (Shrubsole, 1996). Their primary role is to co-ordinate the activities of local municipal governments as well as to act as the primary agency for implementing provincial water policy for Southern Ontario. Widely considered a significant success, this model has been studied by other jurisdictions from around the world for its innovation and effectiveness (Conservation Ontario, 2001, 2002a, 2002b; Shrubsole, 1996).

FIGURE 3.2: AN INFORMATION MANAGEMENT FRAMEWORK FOR WATERSHED MANAGEMENT



More specifically, the GRCA was considered ideal as a case study for this research because it is a leader among Conservation Authorities and watershed management organizations alike with respect to information management. Among all of the conservation authorities, the GRCA clearly emerges as a leader in information management for watershed and flood management practices (Conservation Ontario, 2001, p.6). Early in its history, there was commitment to improve the understanding of the Grand River watershed to reduce flood damage and improve water quality, which included long-term commitment of resources to develop information management (Francis, 1996, 1999; Grand River Conservation Authority, 1998e; Slocombe & Sharpe, 1996). This commitment ensured sustained growth of what has become a premier example of information management for watershed organisations. While this point is demonstrated in more detail in Chapter Four (Case Studies), the purpose of this research is to provide a means to evaluate the conceptual process of information management. In studying one of the leading role models, the results should yield examples of best management practices that will have broad-based appeal and transferability. Based on Yin's suggested research structure for case studies (1984), since the GRCA has been widely recognized for being innovative in the area of information management, selecting only one case study for this initial exploration of an evaluative framework for information management will be useful in focusing the research efforts at this time (p.42). Additionally, while studying the GRCA provides an excellent example of best practices for watershed information management, it will also provide useful feedback to the GRCA itself in an area that is under continual development (Grand River Conservation Authority, 1997d, 1998d, 1998e, 2002a, 2002b). For these reasons, the

GRCA was selected as the primary case for developing the information management framework.

3.4 INTERVIEW PROCESS

Once the major elements of information management were identified through the literature and the framework was compiled, interviews were used to refine the framework and to explore the practical implementation of the major elements of information management. Information gathered through a review of the relevant literature will assist in designing, organizing, and interpreting the results of the interviews with respect to recent initiatives and current activities of the respective watershed organizations. Interviews will be used to investigate the findings from the literature review process.

Interviews were conducted at two different times, two different ways, and for two different purposes with respect to this research. During the first step, following the annual general meeting of the GRCA on December 18, 2002, an invitation was sent out to the staff inviting them to participate in a discussion about information management activities and how they relate to its core business of watershed management. Five staff members participated, representing various work groups from the GRCA including Information and Technology Management, Resource Planning, Communications, Engineering, and Hydrology. A summary of the discussion, including the list of questions used to facilitate the discussion is outlined in Chapter Four, table 4.5. As a scoping exercise, this discussion generated a set of the key elements, as identified by the GRCA that are central to information management. Additionally, for each key element, this exercise served to generate a list of core requirements necessary for the success of each element (documented in Chapter Four: Case Studies and Chapter Five: Discussion

& Results). This step proved to be instrumental in tying the literature together for the framework as it relates to watershed management, as well as serving as a guide for designing the next step, that is the formal interview stage.

Formal individual interviews were considered fundamental to this research as an opportunity to seek out more detail for the framework and to evaluate the actual practices of the GRCA. Interviews were conducted with key individuals who had been targeted during the project scoping and background research. In total, 26 people were targeted and solicited for interviews, based on their role within the GRCA or familiarity with information management as it relates to Conservation Authorities activities. Of these, 16 interviews were conducted. Once again, the problem scoping exercise conducted at the GRCA was useful reconnaissance for structuring the interviews, selecting interviewees, and validating themes that had been identified in the literature review.

Using a qualitative interviewing technique, interviews were semi-structured, based on a systematic interview protocol, using prepared interview questions that allowed for some degree of variability and exploration. Building on the notion of Rubin and Rubin (1995), the notion being that the qualitative interview approach was iterative, evolving based on analysing information as it was gathered, synthesis, learning, and adapting the interviews, focusing more on specific themes as they become more apparent (Rubin and Rubin, 1995, in Babbie, 1999). Similarly, this technique resembles the approach put forward by Creswell whereby the researcher designs and redesigns the research, questions, techniques, and results as the researcher formulates the findings during the research (Creswell, 1998). Working in a relaxed, open discussion environment, questions focussed on the key elements of information management, critical

factors required for success, and a broader discussion regarding trends, anticipated information management directions, and lessons learned, but respondents were given freedom to contribute where they felt they had the most to offer. A list of those interviewed and the questions that were used as an interview guide are provided in Appendix 2. The interviews were documented to stimulate later synthesis and organization for common themes that are discussed in detail in the results and discussion, Chapter Five.

3.5 Application of Information Management Framework

Based on the interviews and case study of the GRCA, the framework was then applied to illustrate how it could be used and what types of information could be gained from it. In addition, this application of the framework serves to focus the discussion and yield some recommendations relative to the GRCA, other CAs, and watershed management practitioners in Ontario. The resulting discussion of the application of the framework addresses considerations and limitations of how the framework can be applied in different situations (e.g. things a smaller, rural CA needs to keep in mind versus a larger CA). This is important as a smaller CA would not have the same resources available and due to the expensive nature of information management, not all aspects can be scaled to any size of watershed agency.

3.6 Summary

This Chapter outlined the general process of the methods that were used for this research. Central to the research is the synthesis of the varied experiences reported in

case studies within the literature. The next Chapter will characterize the primary case for this research, the Grand River Conservation Authority, which will be used to further evaluate and refine the framework and lessons learned for information management. Results and discussion surrounding the application and use of the framework are found in Chapter Five.

CHAPTER FOUR – THE GRAND RIVER CASE

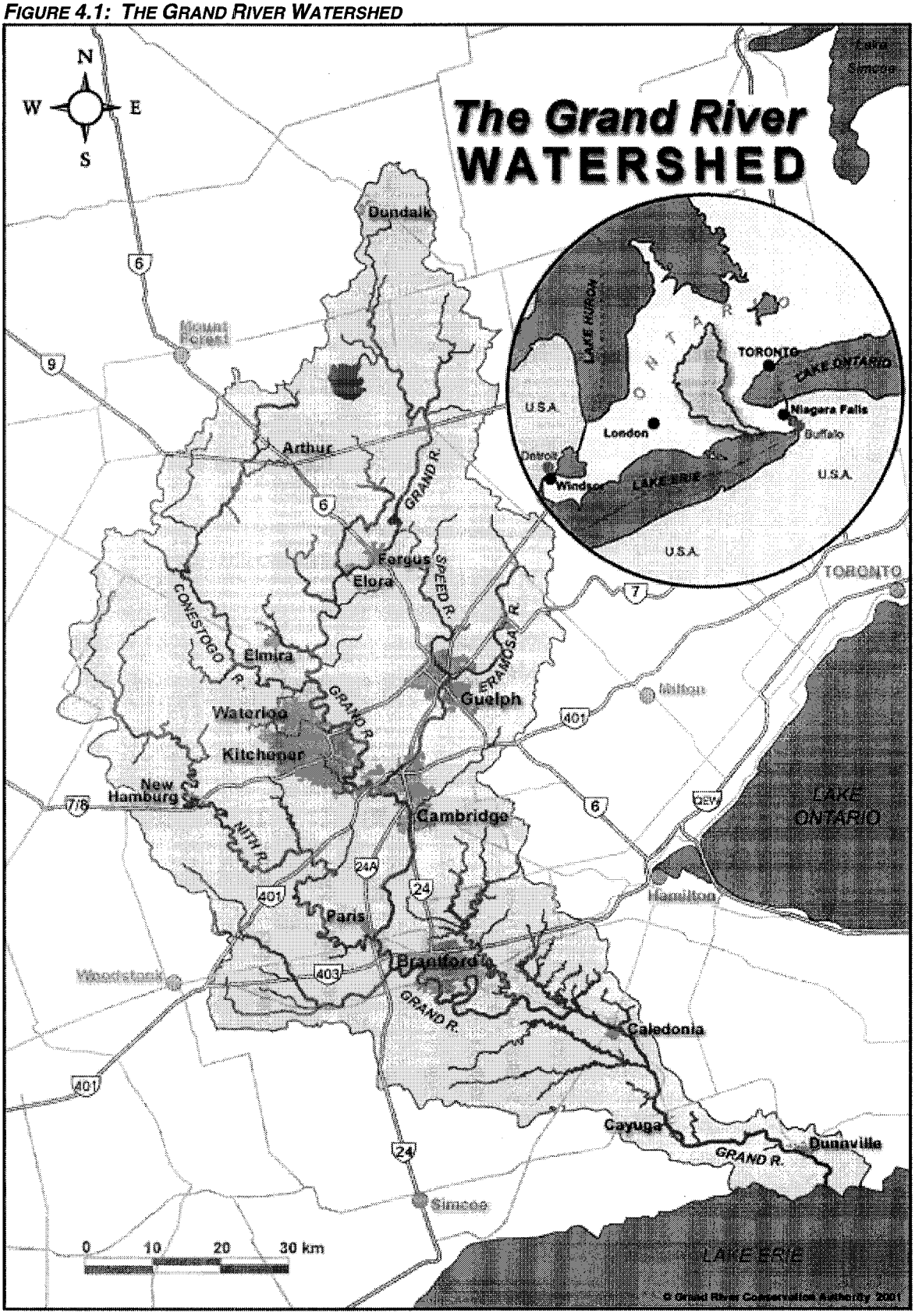
4.1 INTRODUCTION

This Chapter introduces the case study for this research, the Grand River watershed. As the primary case study, the Grand River watershed is representative of a watershed that is on the forefront of effective, adaptive approaches to environmental management, even among Ontario's 32 conservation authorities. This Chapter will illustrate how the GRCA has evolved, how it functions, and the role it plays in environmental management. The watershed and GRCA are both characterized, building a case for how the GRCA conducts information management in support of watershed management. This includes the role of the conservation authority, participants in the watershed management process, existing policies, structures, relationships, and practices of the GRCA, and environmental information management by the GRCA. From this, a more thorough understanding of the nature of information management, as well as the barriers facing practitioners surrounding information management is achieved. This characterization of the watershed leads to the next Chapter where the framework is applied to the Grand River Conservation Authority and discussed.

4.2 GENERAL CHARACTERIZATION OF THE GRAND RIVER

The Grand River watershed is the largest watershed in the Great Lakes Basin, totalling 6,965 km, (Grand River Conservation Authority, 2002a). The river and its major tributaries (the Conestogo, Nith, Speed, and Eramosa Rivers) span over 300 kilometres from Dundalk to Dunnville (on Lake Erie). Illustrated in Figure 4.1, the Grand River is home to a human population of 750,000

FIGURE 4.1: THE GRAND RIVER WATERSHED



people living in 34 upper and lower tier municipalities (Francis, 2000; Grand River Conservation Authority, 1983, 1997d, 1998d, 2002a; Poll, 1979; Shultz, Saenz, & Hyman, 1998; Van Osch & Nelson, 2000).

The river has nurtured the growth of a thriving culture and economy with the long establishment of villages and cities along the river and its tributaries. Alongside the development of this human settlement, challenges have also evolved that threaten the natural integrity of the watershed. Mounting pressures from the growing population and climate change are causing changes to the watershed faster than the system can adapt. Urban sprawl, flood control, pollution, water supply, water quality, water capacity, exploitive land use, water availability, contamination, loss of biodiversity, economic change decline of agriculture, manufacturing and industrial downsizing, growth of the knowledge sector, growth pressures from the GTA, agricultural practices, and industrial activity all impact on the Grand River watershed (Conservation Ontario, 2003; Francis, 2000; Grand River Conservation Authority, 1983, 1997d, 1998d, 2002a; Poll, 1979; Shultz, et al., 1998; Van Osch & Nelson, 2000). This section will provide a clearer picture of the characteristics of the Grand River Watershed, leading up to a discussion of how management practices have evolved.

4.2.1 Physical Characteristics of the Grand River Watershed

The Grand River watershed comprises soft sedimentary formations consisting of limestone, shale, and sandstone that overlie Precambrian bedrock. Much of the shape and form of the watershed is attributed to the impact of the Wisconsinan glacial ice age approximately 15,000 years ago on these bedrock formations. This period was

responsible for carving a new drainage pattern for the region and formed many soil characteristics and land form features, including moraines, eskers, and drumlin fields (Grand River Conservation Authority, 1998e, p.2-1). As the last glaciers receded, the headwaters of the Grand emerged at Dundalk, a swampy lowland area with clay soils, leftover from glacial till that provide relatively poor natural drainage (Grand River Conservation Authority, 1983, p.1.1; Grand River Conservation Authority, 1998e, p.2-1; Poll, 1979, p.7). In the central part of the watershed, in a region of rugged farm terrain the Conestogo, Speed, and Eramosa tributaries join the Grand. And in the lower half the Nith River joins in a relatively flat part of the river, slowing and meandering through the watershed (Grand River Conservation Authority, 1983, p.1.1; Grand River Conservation Authority, 1998e, p.2-2).

Climate has had a noticeable impact on the river and precipitation varies in the region, causing extremes with respect to both high and low water levels. A dry month will cause noticeably lower flows in the Grand and its tributaries, whereas a month of rainy weather can raise the river levels to the point of flooding (Grand River Conservation Authority, 1983, p.7; Grand River Conservation Authority, 1998e, p.2-2, p6-2). The variation in the climate, and especially the precipitation levels, greatly influences the type of crops that can be grown in the watershed (Van Osch & Nelson, 2000, p.1). Often climate variation can be extreme resulting in too little or too much water, which can be troublesome for farmers. Partly due to the climate variation, 29 different eco-regions are supported, with varying terrain, soil, flora and fauna including 50 rare plant species, extensive wetlands, breeding birds, and several rare and endangered species (Grand River Conservation Authority, 1998e, p.2-2). With about 15% of the

watershed remaining forested, the predominant forest type in the south is the relatively rare Carolinian forest type, whereas the north is mostly a mixed forest, more typical of the region (Van Osch & Nelson, 2000, p.1).

4.2.2 HUMAN SETTLEMENT AND DEVELOPMENT OF THE GRAND WATERSHED

The River has been occupied by human settlement for approximately 12,000 years, over which time various groups have made their home along the rivers banks (Van Osch & Nelson, 2000). Prehistoric native settlements, thought to be the first inhabitants of the area have been found dating back 9,000 years, and are linked to the primitive hunting groups that may have crossed the Bering Sea during the last ice age (Dunham, 1947; Grand River Conservation Authority, 1998e, p.3-1). These primitive settlers were eventually displaced by Eastern woodland tribes known as Attiwarondaks or the "Neutrals", drawn to the area for its suitable agricultural land and supply of wild game and fish. These settlers were eventually driven from the region by war with the Iroquois, leaving the region unoccupied again for another hundred years (Grand River Conservation Authority, 1998e, p.3-1).

During the colonisation of Upper Canada, six major parcels of land totalling 1427.96 square kilometres in the southern reaches of the watershed were awarded to Joseph Brant in 1798 who settled in the area with Iroquois loyalists (Dunham, 1947; Grand River Conservation Authority, 1998e, p.3-1). Throughout the 1800's, the river was valued as a means of transportation, water supply, and waterpower, serving as incentives for growth and settlement in the region, driving urban and agricultural growth (Dunham, 1947; Grand River Conservation Authority, 1983, p.1.3). Land clearing activities and the natural transportation network provided by the river supported a viable

lumber industry, including grist and sawmills, which met the needs of local settlers. The river also provided drinking water supply and a waste disposal system for river communities, an incompatible mix for the era's water treatment capabilities, which eventually lead to water quality problems. Guelph, Galt, Preston, Hespeler, Paris, and Brantford grew rapidly in proximity to the river as it provided water, power, and mills.

The introduction of steam power during the 19th century allowed cities away from the river, such as Kitchener, to develop industry and manufacturing opportunities (Grand River Conservation Authority, 1998e, p.3-3). Transportation networks like the Welland canal and the railroad encouraged further development, especially the railroad that changed the space-time relationship with surrounding cities such as Toronto substantially (Grand River Conservation Authority, 1998e, p.3-4). In the second half of the 19th Century, logs from the north of the watershed were floated downstream and sent by rail to supply Toronto's growth (Grand River Conservation Authority, 1998e, p.3-4). Unfortunately, the clearing of these forests greatly affected the flows of the Grand River. The headwaters of the river lost much of the traditional water storage capacity of their swampy forestland. Settlers were suddenly faced with new, self-made problems of flooding which caused property damage, loss of livestock, polluted water, and unpredictable water supply year round (Grand River Conservation Authority, 1998e, p.3-5). Summer flows were no longer augmented by seepage from the wetlands, heavy rains were no longer restrained causing flooding downstream, less water storage resulted insufficient water flow in the summer time for water-power, mills, and removal of waste (Grand River Conservation Authority, 1998e, p.3-5).

While the region prospered during the 19th and early 20th Century with industrial development, logging, and agriculture, the region was bound for dramatic change. Serious problems were affecting the communities within the watershed, brought on by the sudden and disruptive nature of development in the region.

4.3 WATERSHED CHALLENGES

The Grand River is a watershed under considerable human pressure. Located in Southern Ontario, the river runs through regions of rural land use as well as dense urban populations. When the interim report on the Grand River watershed was drafted in 1983, data indicated that as much as 78% of the land was used for agriculture, 3% was developed for urban uses, 17% was classified as wooded, and the remaining 2% was idle land (Grand River Conservation Authority, 1983, p1.3). Today, the densest population is found in the urban centres in the middle of the watershed, while the north and south remain largely agricultural or natural. In 1999, total income for the watershed was over $14.2 billion and the contribution of the Grand River watershed to Canada's gross domestic product was larger than that of several provinces, and is comparable to that of Nova Scotia (Grand River Conservation Authority, 1998e, 2002a).

Throughout the 1990's, approximately 81% of the population was living on 7% of the land, while the remaining 17% lived across the 93% of the watershed that was considered rural or agricultural (Grand River Conservation Authority, 1997d, p.4). While human activity has caused the river to be less predictable, human settlement and dependence on the river require the watershed conditions to be more constant than ever before (Grand River Conservation Authority, 1983). Water supply is a fundamentally important resource to the communities within the watershed as Waterloo is the largest

community in Canada that is primarily dependent on ground water for its municipal water supply (Robinson & Benninger, 1984). Water is also drawn directly from the river for irrigation and recreation, municipal, industrial, rural, domestic, and livestock purposes for total estimated withdrawals of 520,000 cubic metres per day, as a yearly average (Grand River Conservation Authority, 1998e, p.7-3). The largest concern is with the river's capacity to meet the water needs of a growing population (Grand River Conservation Authority, 1983, p.2.6-2.7; Grand River Conservation Authority, 1997d, p.14; Poll, 1979, p.32-36). The total capacity of the watershed, both in terms of ground water and surface water is not fully known and is certainly dependent upon factors that make it difficult to predict (i.e. variations in the hydrological cycle) (Grand River Conservation Authority, 1997d, p.17-18).

Flooding has a long history in the watershed. Flooding is well controlled throughout most of the year, but there continues to be significant flood damage due to the high-density development that lies within higher-risk flood zones. Severe storms and combinations of conditions (e.g. high water, heavy storm, ice jams, spring run off) can still cause significant damage (e.g. serious floods such as the one in May 1974 caused upwards of six million dollars damage) (Grand River Conservation Authority, 1998e, p.6-22; Poll, 1979, p.31). A significant limiting factor on river capacity is the associated cost of treating discharge water before returning it to the system. While measures that are more conservative for conserving and promoting efficient use of water are certainly needed, the sustainability of current water-taking levels needs to be thoroughly investigated (Grand River Conservation Authority, 1997d, p.16). The rapid urbanisation of the area causes water-quality problems such as low dissolved oxygen, excessive

nutrients, high phosphorus levels, bacteria growth, suspended solids, toxic substances, and various trace contaminants (Grand River Conservation Authority, 1997d, p.19; Grand River Conservation Authority, 1998e, p.8-1; Poll, 1979, p.34). Upper portions of the watershed, near the source of the river, demonstrate the highest water quality with declining quality as it moves downstream, reflecting the various inputs from the urban environment human activity (Grand River Conservation Authority, 1983, p.2.5; Grand River Conservation Authority, 1998e, p.8-1). Unfortunately, the area is badly fragmented by urban and agricultural areas. Of the original forests, only 17% remain wooded and this continues to be a problem (Grand River Conservation Authority, 1983, p.2.7). Related deforestation and agricultural practices have had an impact on soil degradation, soil erosion, and ultimately water quality.

Much of the Grand River at one time supported a rich and diverse fish habitat, along the many varied ecosystems of the river. Today, the river is recognised as having a world class fly fishery (Van Osch & Nelson, 2000, p.2). With the urbanisation of the watershed, the habitat has been popularly seen as a viable sport fishery. Today, the 50 species of fish that are still supported by the waters of the grand are threatened by low dissolved oxygen levels, water turbidity, vegetation clearing, sedimentation, agricultural runoff, increasing water temperatures, water contaminants (e.g. ammonia/chlorine toxicity), invasive species, and habitat limitations (e.g. water control structure) (Grand River Conservation Authority, 1983, 1997d).

The region is rich with historical, geographical, archaeological, and cultural significance, giving it character and appeal not commonly or easily acquired (Grand River Conservation Authority, 1983). Yet the charming quality and historic significance

is under constant threat, largely resulting from limited areas to develop, lack of maintenance, natural wear, population growth, and dwindling public interest in such features (Grand River Conservation Authority, 1997d). Many features are in fact considered nationally significant, cherished as a part of early Canadian settlement heritage, earning the grand distinction of as a Canadian Heritage River. Forecasts for economic growth for the region are high, which will result in continued pressure on the watershed and land use conflict. Population alone is expected to grow by 24% by 2011 and 37% by 2021, most of which will occur right in the middle of the watershed (Grand River Conservation Authority, 1983, 1997d). Maintaining a balance between growth, nature, and climate change will require accurate and precise information to support decision-making and planning.

4.4 WATERSHED MANAGEMENT AND THE GRCA

Flooding, fluctuating water levels, poor water quality, water supply shortages, poor water quality, severe flooding, and general degradation of the environment because of watershed development meant increasing hardships for residents across the watershed (Grand River Conservation Authority, 1983, 1997d, 1998e). Like most of the other watersheds in south central Ontario, many factors threaten environmental degradation of the Grand. Table 4.1 summarises some of the most significant challenges.

Increasing awareness of the impact human activity was having on the watershed led to a number of early initiatives aimed at managing water quality issues, such as the Public Health Act (1880), and the Municipal Waterworks Act (1882). However, very little was done to preserve the system's integrity and health, as well as to ensure the livelihood of the inhabitants within the watershed (Grand River Conservation Authority,

1998e, p.4-1). Efforts for many years focused on single issues, which were of pressing concern. For example, the Ontario Hydro-Electric Power Commission was created in 1907 to deal with the supply of hydroelectric power to the municipalities. After a particularly damaging and expensive period of floods, the Grand River Improvement Association, consisting of representatives of flood-prone municipalities, was formed in 1912 (Grand River Conservation Authority, 1998e, p.4-1).

TABLE 4.1: CHALLENGES FACING THE GRAND RIVER WATERSHED

ISSUES	UNCERTAINTIES
Climate	• What are the implications of a changing climate for the watershed system as a whole?
Urban Sprawl	• What level of business and urban development can the system sustain without negatively affecting the natural system? • What is the capacity of the watershed to support industrial and business growth?
Population Growth	• Does the watershed have the capacity to meet growing municipal demands without compromising water quality and supply issues? • What is the river's capacity to deal with increased waste and wastewater discharge?
Habitat Loss and Species Loss	• What is threatening various habitats and species? • How are invasive species affecting the system?
Water Quality	• What are the sources of pollution? • What is the system threshold for residential, industrial, and agricultural pollution to ensure adequate water quality?
Water Supply	• Considering system dynamics such as climate, how will increasing human water demands be met without compromising the health of the natural system?
Recreation and Sport Fishery	• How should the impacts of human activity, limited water supply, and poor water quality on recreation and sport fishery areas be managed? • What are the impacts of recreational activity on the watershed?
Heritage and Culture	• How should cultural and heritage resources be preserved under development pressures,. lack of maintenance and lack of interest?

Source: (Conservation Ontario, 2001, p.12) (Grand River Conservation Authority, 1997d, p.10-34)

Since settlement began in the watershed, issues facing the watershed and its communities have for the most part been dealt with in isolation from each other, rather than dealing with the relationships between the various issues and their impacts on the system (Grand

River Conservation Authority, 1998e, p.1-2). This proved to be a problematic approach when so many issues had implications across watershed.

During the early part of the 20th Century, struggles with floods motivated community members to begin organizing a response to deal with the problems that had been caused by the natural resource use and industrial and economic growth in the region (Van Osch & Nelson, 2000, p.2). Following the largest flood to hit the region, in 1929 a government inquiry was ordered to investigate the recurring issues facing the riverside communities. The Finlayson Report, completed in 1932, recommended substantial changes across the watershed including water control structures to alleviate water supply and water quality issues (e.g. low water levels failed to remove human waste pollution) that were causing health hazards (Boyd, Smith, & Veale, 1999, p.26; Grand River Conservation Authority, 1998e, p.4-1). As a result, the Grand River Conservation Commission (GRCC) Act was passed in 1932, marking the beginnings of organized watershed management and conservation work for the region (Grand River Conservation Authority, 1977). This allowed municipalities in partnership with the federal and provincial governments to co-ordinate and implement water control measures such as the Shand Dam (completed in 1942), Luther Dam (completed in 1952), and Conestogo Reservoir (completed in 1957)(Grand River Conservation Authority, 1998e). Conservation groups and the provincial and federal governments recognised that the area would need a permanent management arrangement, tackling not only water issues, but also soil and forest degradation issues (Grand River Conservation Authority, 1998e, p.4-2). In support of these efforts and in recognition of needs elsewhere in the province, the Conservation Authorities Act was passed in 1946, providing the legislative structure to

support regional water management efforts with the technical and financial support of the provincial government. In 1948, the Grand Valley Conservation Authority (GVCA) was established, for the purpose of river valley development, reforestation, land use problems, and recreational areas, while the Grand River Conservation Commission maintained the construction and operation of multi-purpose reservoirs. In 1966, these two organizations were combined to form the Grand River Conservation Authority to reduce redundancy and co-ordinate efforts (Grand River Conservation Authority, 1977, 1983, 1998e). Under the Conservation Authorities Act, Section 20, the goals of the GRCA are clearly stated.

Since 1966, the Grand River Conservation Authority (GRCA) has been the only agency with a specific mandate of managing the watershed and co-ordinating management efforts (Grand River Conservation Authority, 1998e, 2002a). However, cross-jurisdictional boundaries and legislation limit the GRCA's powers (Francis, 2000). In addition to the GRCA's staff, the authority is led by a 26-member board of directors that is elected directly by the 34 municipalities represented by the GRCA. The Board members meet for both general meetings and for operations meetings such as administration, finance and personnel, and planning and operations on a bi-monthly basis (Boyd, et al., 1999; Grand River Conservation Authority, 2002a). In the beginning, GRCA efforts largely centred on flood control, because of losses suffered by areas such as Galt in 1947 (Grand River Conservation Authority, 1997d, p.6-23). Efforts to mitigate water supply, prevent soil erosion, and restore water quality for both surface and ground water followed shortly after (Grand River Conservation Authority, 1983, p.1.5-1.6). Management efforts eventually broadened to incorporate both water and land use management, including flood plain regulation, tourism and recreation area development,

natural area protection, habitat restoration, pollution control, and watershed conservation (Shrubsole, 1996, p.319). As was discussed in Chapter Two, many organizations have different roles and responsibilities for watershed management in Ontario. The GRCA is the public agency that provides the means for the municipalities within the watershed to work together in a co-ordinated and effective manner for mutual benefit and the wise management of the environment (Francis, 2000; Grand River Conservation Authority, 1997d, 1998d, 2002a).

4.4.1 THE MODERN GRCA

The last two decades have seen some tremendous changes in management approaches for the Grand River. An inquiry led by W.H. Palmer, commissioned to investigate the Authority's dysfunction regarding the flood of 1976, concluded that the authority itself should be disbanded and that the Ministry of Environment and Ministry of Natural Resources should take over all watershed management responsibilities (Palmer, Church, & Winegard, 1978). The review was quite specific that while the efforts of the staff of the GRCA were "beyond reproach" (p.134), the Authority was not capable of competently managing the river resources and providing adequate protection for the communities along its banks. Since this time, the GRCA has modified its approach and continually adapted its management practices. While it has taken many years, designation as a Canadian Heritage River in 1994, recipient of the Theiss River Prize award in 2000, and most importantly making some progress with both water quality and quantity issues demonstrates the effectiveness of the organisation (Grand River Conservation Authority, 2002a). When the Grand River was designated a Canadian Heritage River, environmental consciousness and commitment were raised through

stimulating stewardship activities within the community (Francis, 2000). A significant part of this success has been the Grand Strategy released in 1994, clearly defining the approach to watershed management and laying direction for the Grand River.

In the Grand Strategy, the river is seen to have an enduring value; the well being of the watershed depends on knowledge and stewardship; rivers are life supporting; and, rivers are indicative of society (Grand River Conservation Authority, 1994, p.11). The vision statement formally adopts an integrated watershed management approach. Since management efforts began on the river, the emphasis had been on flood control, water supply, and water quality. A co-ordination committee for management was not formally implemented until 1994 to support a more holistic approach to watershed management, focusing on natural area protection, sustainable resource use, landscape rehabilitation, hazard management, and growth strategies for urban and rural areas (Boyd, et al., 1999; Grand River Conservation Authority, 1998e, 2002a). The strategy partnerships include representatives from provincial and municipal governments, various watershed or community organizations, First Nations, educational institutions, community interest groups and the public and private sectors, totalling approximately 300 participants in the process (Grand River Conservation Authority, 1998e, p.4-4). The purpose of the Grand Strategy is to bring the numerous parties within the watershed together, to co-ordinate their efforts and their visions for the river to ensure that issues at all scales are addressed in the most effective, productive fashion. As such, the GRCA is committed to the Grand Strategy and ensures:

- A joint Work Plan identifying specific tasks and priority actions for 1997 and 1998;
- Expanded forums for dealing with issues, sharing expertise and information;

- Actively pursue partnerships and co-operative efforts by all levels of government, institutions, businesses, community organisations and landowners in solving watershed problems;
- An annual report card;
- Co-ordinate the preparation of an annual state of the watershed report on the health of watershed resources, the effectiveness of the years activities, and priorities for action;
- A maintained and accessible database;
- Provide opportunities for watershed stakeholders to actively participate in a shared approach towards solving watershed problems which build on the Grand Strategy Process;
- Provide administrative and technical support required to ensure ongoing participation and interest;
- Organise and maintain, with other partners, an accessible and current information base; and,
- Carry out priority actions for which the GRCA is deemed responsible.

(Grand River Conservation Authority, 1997d, p.9; Grand River Conservation Authority, 1998e, p.4-5)

For this vision to be realised the challenges facing the watershed must be addressed; however, the challenges and probably the appropriate management responses, affect the entire watershed as a system. Therefore, an understanding of the system dynamics within the watershed is essential if the community is to see the vision become a reality. As the GRCA is so intimately involved in the management of the water and land within the watershed, it is imperative that the GRCA work with other organizations, groups, and public and private sectors that are also concerned with the region (Grand River Conservation Authority, 1983, p.1.6; Poll, 1979, p.7-8). This is important as the GRCA is in an excellent position to be the facilitating body for managing co-ordination among the various groups and has much to gain by being the lead organisation (Grand River Conservation Authority, 1983, p.4.1).

Twenty-six members representing 22 municipal councils for 34 upper and lower-tier municipalities govern the GRCA. Each member is appointed to a committee, the Planning and Operations or the Administration, Finance, and Personnel Committee, which meet once a month to review, endorse, modify, or table recommendations (Grand

River Conservation Authority, 2002a). The Chairman acts to ensure the directions agreed to by the committees are carried out by the GRCA's staff, working within the two main divisions of the Authority: Resource Management and the Administration and Operations sections (Grand River Conservation Authority, 2002a). Under the Resource Management division, Engineering & Conservation Services, Watershed Resources Planning, Watershed Resources Environment, and Communications are addressed. Under the Administration and Operations division, Corporate Services, Property and Business Development, Information Systems, Conservation Area Operations, and Central Services are covered. Table 4.2 provides a summary of the specific activities covered by each section. Collectively, this structure has worked together to greatly improve the management effectiveness of the GRCA, which has resulted in the achievements and recognition the authority has received, in contrast to the criticism it received during the 1970's.

With flood and erosion control efforts, the emphasis is on damage prevention and water control, and reducing losses that result from flood damage (Grand River Conservation Authority, 1998d, p.14). On average, annual flood damages are estimated at $1,482,413, and as such, one of the primary goals of the GRCA is to reduce flood damage (Grand River Conservation Authority, 2002a; Poll, 1979). These efforts include a flood control system (including 7 major dams, 4 major dykes, 4 flood channels), continuous river and weather monitoring and warning system, a computerized flood forecasting model, emergency planning, review of land use planning documents for flood hazards, flood plan mapping, and construction regulations.

TABLE 4.2: A SUMMARY OF GRCA ACTIVITIES BY SECTION

GRCA SECTION	SUMMARY OF ACTIVITY
Member Committees and Senior Administration	
Planning & Operations Committee	• Approves permits granted for applications made under fill, construction and alterations to waterways regulations • Approves tenders for goods and services required to accomplish the works approved in the annual budget • Advises and prepares recommendations to the GRCA in the area of watershed management and planning, conservation area development and operation, public relations and marketing.
Administration, Finance and Personnel Committee	• Advises on general administration • Advises on financial planning and management • Advises on personnel policy, compensation, and contractual negotiations.
Audit Committee	• Ensures the financial accountability of the committees
Chief Administrative Officer	• Chief of Staff • Guided by the members approved committee directives.
Vice CAO: Planning & Operations	• Chairs the Planning and Operations committee • Co-ordinates with the CAO • Co-ordinates with the 34 upper and lower tier municipalities with respect to planning and operations of the GRCA
Vice CAO: Finance and Personnel	• Chairs the Finance and Personnel committee • Co-ordinates with the CAO • Co-ordinates with the 34 upper and lower tier municipalities with respect to Finance and Personnel
Source: (Grand River Conservation Authority, 2002a)	

Additionally, reforestation of headwaters and wetland protection has worked well. Now much of the work must focus on continued floodplain regulation and maintaining or improving floodplain control structures (Grand River Conservation Authority, 1997d, 2002a; Poll, 1979). Since the GRCA has existed, structural, non-structural, and institutional arrangements have improved and matured to reduce flood risk, however, flood preparedness can continue to improve further (Boyd, et al., 1999, p.45). There are 34 water control structures operated by the GRCA throughout the watershed. These structures range from simple overflow weirs to large multi-purpose dams and reservoirs (Grand River Conservation Authority, 1998e, 2002a). To improve on these management

schemes, improved understanding of flooding conditions and monitoring would be invaluable. Much of this would also build on the existing flood forecasting and warning efforts, which include monitoring river conditions, operating reservoirs, and relaying timely flood warning information to the municipal flood co-ordinator through the flood warning system (Boyd, et al., 1999; Grand River Conservation Authority, 1998e). Management of water supply, capacity, and quality requires added tools and process mechanisms to adequately consider the combined impacts of urban development, agricultural industrialisation, human activity, and direct management activities most effectively (Grand River Conservation Authority, 1997d, p.19).

Efforts with respect to water quality are very much related to water supply and capacity, as it relates to flow augmentation. The GRCA operates four continuous water monitoring stations, conducts water quality modelling, provides technical support for storm water management, supplies information to municipalities for decision-making, and ensures best management practices are followed with respect to water quality (Grand River Conservation Authority, 1998d, p.18). Water management planning efforts for the watershed have been evolving since the days of the Finlayson report and the GRCA has been learning lessons from other organizations that have been at it much longer. As such, the GRCA has worked to co-ordinate water issues through effective water management planning and has implemented many monitoring, pricing, economic, policy, and conservation mechanisms to improve on these (Grand River Conservation Authority, 1998e; Robinson & Benninger, 1984, p.27-30).

The GRCA's involvement in protecting natural areas such as woodlands, wetlands, and habitat corridors is focusing more on community involvement and

partnerships with municipalities and groups with similar long-term aims (Grand River Conservation Authority, 1998d, p.16). This includes managing natural areas, encouraging responsible stewardship among landowners, restoring lands to sustainable conditions, providing recreational and natural interpretation opportunities, protecting cultural heritage, developing frameworks for natural area protection, land use planning, and providing information for decision-makers to assist with land use decisions. All of these efforts are aimed at improving the quality and health of the watershed. Improved planning and management aimed at co-ordinated land use would yield sustainable practices.

As a region grows, much is left to the management authority to cope with the added needs, a scenario that is not only reactive, but also vulnerable to failure. An understanding of precisely what is required and how the watershed can sustain human activity must be investigated (Grand River Conservation Authority, 1997d, p.10-11). Improved information co-ordination could assist business with land use development planning by reducing costs and help the environment by reducing impact. For this to occur, representatives from various sectors need to be a part of the strategic process, linking development with the environment (p.12-13). While the GRCA has been the primary watershed organisation responsible for sustaining the river's health through effective watershed management, government streamlining and shuffling bureaucracy has hindered these efforts. In addition, some human activities are only now becoming better understood, such as ozone depletion, air pollution, persistent chemicals, and urban sprawl. Population growth predictions of up to 30% for the region in just the next 15 years pose further complications on the existing burdens (Grand River Conservation

Authority, 1998e, 2002a; Poll, 1979). Many of the problems are closely interrelated and have overlapping causes and effects, requiring a co-ordinated and appropriate management response.

4.4.2 INFORMATION MANAGEMENT EFFORTS BY THE GRCA

A significant component of these improved management approaches is the recognition of the importance of managing and sharing information. Understanding of the Grand River watershed depends on a relatively comprehensive data set of a range of factors (Slocombe & Sharpe, 1996, p.6). The GRCA has been able to much improve its information management capabilities. In 1995, the GRCA in an effort to reduce long-term costs, establish functional interdependence with internal and external agencies, improve the level of service, address competitive pressure, introduced and has since maintained a fully functioning GIS along with all of the monitoring and data collection it was already maintaining (Grand River Conservation Authority, 1995). With the aid of a GIS, the GRCA has been able to improve levels of co-ordination among watershed partners, reduce internal redundancy, better analyse watershed pressures, and cut data costs (Grand River Conservation Authority, 1995, 2002a). An integral component of constructing the GIS was the compiling of data layers, themes, and geospatial data for the watershed (Grand River Conservation Authority, 1996a). While this is a never-ending process, the initial process of establishing a base set of data was critical to the success of the process. Themes include: satellite imagery, Ontario Base Maps, topographic, flood, agricultural, hazard, digital elevation, catchments, land use, hydrological, water quality and water level data (Grand River Conservation Authority, 1995, 1996a, 1996b, 1997a,

1997b, 1997c, 1998a, 1998b, 1998c, 1999). Building the database for the GRCA presented some important opportunities to network with groups that have existing data sets. Simply through negotiating data licensing agreements, networks of communication were established between the GRCA and other organizations, such as municipalities and MNDM (Grand River Conservation Authority, 1997b).

To ensure the success of the GIS implementation, GIS staff focused on communicating the potential of the GIS, demonstrating its capabilities, and holding GIS symposiums for people, both internal and external to the GRCA (Grand River Conservation Authority, 1996b, 1997b). Naturally, education and training were a significant portion of these efforts aimed at providing GRCA staff members with the means to utilise the GIS tool set (Grand River Conservation Authority, 1997b, 1998c). This also provided an opportunity for GIS staff to become intimately familiar with the type of problems various work groups within the GRCA were working to solve. Further, training ensured higher quality GIS analysis and database maintenance, which improved the level of decision-making based on GIS. Also, the training helped the proliferation of the GIS itself, as planning future projects tend to be better aligned with the capabilities and needs of the GIS (Grand River Conservation Authority, 1998c).

GIS staff have regularly overseen technology upgrades to ensure users have uninterrupted access, realising the full potential of the GIS (Grand River Conservation Authority, 1997b, p.5; Grand River Conservation Authority, 1997c, 1998a). In 2000, the GRCA implemented a new architecture for all of its GIS operations. As the existing system had been used over the years, demand had grown, technology had aged, and demands for integration and co-ordination had increased, ultimately requiring a complete

system upgrade (Grand River Conservation Authority, 1998a, 1999, 2002a). The GIS renewal included new peripheral devices and required changing UNIX ArcView users over to a Windows NT environment, as well as a database switch to MS SQL. GIS is fairly well adopted, with over 30% of the staff well versed in ArcView GIS and a few additional staff members trained on ArcInfo GIS for their data maintenance, standard map production, complex spatial analysis, and spatial data management (Grand River Conservation Authority, 2002a). Users can access their geospatial data through a central data file server and GIS applications reside on an application server, making the system very easy to access, update, and maintain. Such a system provides maximum scalability and fosters an environment where geospatial data can be fully integrated. GIS is a key element in the GRCA's arsenal of information management practices. GIS has prompted significant information management practices within the GRCA. Data has been organized and data integration has been a priority. GIS training has exposed many staff members to the potential of information technology and helped to co-ordinate their activities within both the GRCA and external organizations. Data sharing and dissemination have fostered database growth and strengthened relationships between organizations, private contractors, and the public, not to mention raising the profile of the GRCA's activities in general (Grand River Conservation Authority, 1998a, 1998b, 1999).

Information management continues to be an area where management practices can be further explored and experimented with so that information management efforts can be fully optimized, as some shortcomings and weaknesses continue to be identified. In one working session put on by the Heritage Resources Centre (University of Waterloo), local heritage organisations, universities, Parks Canada, Provincial

Government, GRCA, and the Heritage Canada Foundation, were invited to participate and complete a questionnaire based on experiences with watershed management and heritage conservation along the Grand River. The questionnaire was designed to assess the effects of the government funding reductions and downloading from 1993-1998 and to evaluate whether or not the GRCA was meeting its community needs and goals. The survey was intended to identify what elements of the GRCA were working effectively and what needed attention, ultimately helping to achieve success through effective planning, managing, and decision-making (Heritage Resources Centre, 1998, p.4-7). In the area of information management, several questions were asked of the participants as to what they thought worked or did not work. In answering a question about the challenges and needs with regard to information, respondents offered that improved information management was one of the largest information needs. As a suggestion, several respondents recommended an "information clearing house" as a solution for sharing and managing information more effectively amongst watershed partners, allowing for easy consolidation and co-ordination of watershed data. This would also ease the frustration of people trying to access information, and perhaps make diverse sets of information more accessible for political decision-making (Heritage Resources Centre, 1998, p.12). With respect to computer, technical issues, and technical support, respondents agreed that computers were both underused and failed to meet expectations in terms of their needs. Software programs, time, and expert personnel were needed to update or maintain the system (Heritage Resources Centre, 1998, p.14).

The working group was also asked about challenges and access to experts, experience, and skill sets and their role in the information management process. It was

agreed that more expertise is needed. Additionally, people with specialized knowledge in specific fields, working in a trans-disciplinary setting, and financial restraints were also identified as significant barriers. Furthermore, improved networks between watershed partners, participants, and especially local knowledge should be developed. Two people said that a network was needed which would permit local groups to develop relationships with other groups (Heritage Resources Centre, 1998, p.14). Responses to the final question, about the needs and challenges facing linkages and communication with political decision-makers, indicated that a lack of linkages among decision-makers was seen as a major challenge. Some specific reasons for difficulties in maintaining linkages were cited, including: Difficulty keeping politicians involved, in that after the last election, linkages disappeared; downloading of various government functions is making it more difficult to keep politicians interested in heritage; new governmental priorities; and that monitoring takes a great deal of time and energy (Heritage Resources Centre, 1998, p.16). Table 4.3 provides a summary of some of the general recommendations that came out of the "What Works?" session.

TABLE 4.3: RECOMMENDATIONS FOR INFORMATION MANAGEMENT FROM "WHAT WORKS?"

AREA	RECOMMENDATION
1. Government	• Raise priority given to heritage conservation at various levels of government. • Strengthen organizations through improving resources and funding so they may better help themselves. • Co-ordinate activities and efforts between levels of government.
2. Co-ordination	• Co-ordination of information (Specifically data, inventories, ideas, legislation, previous experience with similar projects, publications, skilled individuals, ways of getting money). • Improve access to information. • Improve sharing and co-ordination of information. • Provide an information-clearing house to help co-ordinate knowledge.
3. Networking	• Establish and maintain networks for exchange of information. • Share technical expertise, skills, and knowledge. • Contact similar organisations and maintain relationship.

Source: (Heritage Resources Centre, 1998, p.18).

In a review of the Grand River Basin Water Management Study, 1972-1982, a number of lessons integral for effective information management and understanding needed for management program areas and decision-making were also identified:

- Clear and understandable goals and objectives;
- Public participation in determined study objectives and involvement in the formation, evaluation and selection of the final management plan;
- Strong leadership at the political and staff level;
- Representation of all parties affected by the plan and its implementation on the Grand River Implementation Committee and Technical Committee;
- Strong linkages to existing programs, including local and regional land use planning processes, water quality and flow monitoring programs, and similar programs to optimize use of available information and minimise duplication of effort;
- Adequate expertise for multiple objective planning and evaluation procedures, especially in economic, social, and environmental areas;
- Good tools to do the job;
- Consideration of a wide range of alternatives to solve observed problems;
- Adequate resources of time and money for planning and implementation;
- Local participation.

Source: (Conservation Ontario, 2003)

Similarly, in *The State of the Watershed Report* for 1997 – 1998, the next steps that were identified as priorities for the watershed included several points that were closely related to information management practices for the GRCA. These include increasing integration, establishing information priorities, encouraging involvement in the process of building an understanding of the watershed by both municipalities and the community, and pursuing more collaborative arrangements (Grand River Conservation Authority, 1997d, p.35).

Currently the GRCA invests approximately $5 million in watershed management and monitoring programs, or 25% of their annual budget, which in turn generates $4 million in revenue that is returned to the operating budget (Grand River Conservation Authority, 2002a). The bulk of this work provides the information for resource

management and watershed stewardship. Evidently, there are many challenges facing the watershed, perhaps some of the toughest challenges yet. In response, the GRCA has sought to improve its approach to environmental management, utilising different levels of planning, co-operation, participation, research, and management. In working to improve its efforts, the GRCA has identified several steps necessary to address watershed management challenges, most of which emphasise improved watershed planning and environmental information to some extent (Grand River Conservation Authority, 1997d, 1998d).

With respect to watershed planning, the GRCA acts as a co-ordinator for the various groups involved in planning to pool resources and direct planning efforts for the most effective results. This emphasises the completion of integrated sub-watershed management plans such as water quality management plans, waste water treatments, urban storm water quality improvements, rural water quality improvements, sub-watershed plans, fisheries management plans and forestry/habitat plans for all of the tributaries and streams that are a part of the Grand River Municipalities (Grand River Conservation Authority, 1998d, p.10). Environmental Information management for the GRCA entails collecting and developing information for watershed planning and decision support, especially at the municipal planning level, where the GRCA is the co-ordinating source of information for the watershed (Grand River Conservation Authority, 1998d, p.20). Ultimately, information management is an important element of all areas of the GRCA's efforts, playing a role in water quality monitoring, flood reduction, watershed planning, watershed monitoring, public awareness and education, as well as natural area protection. To co-ordinate all of these efforts, the GRCA maintains an electronic real-

time data collection and modelling system and utilises GIS technology as a means of analysing data.

The database is useful for maintaining, sharing, collecting, and co-ordinating information types and data. In addition, the GRCA maintains a web site that provides a great deal of information and is used at times to collect information. To complement the information technology, the GRCA maintains expertise in hydrology, hydraulics, watershed planning, geomorphology, forest management, terrestrial, and aquatic biology, storm water management, and rural land management. In total, information is collected from floodplain mapping, hazard mapping of unstable slopes, water quality characteristics from 22 stream flow gauges, 14 rainfall and temperature gauges, 12 snow courses, gauges at watershed flood control structures, 28 water quality stations in co-operation with ME, TABS Weatherwatch for continuous weather information, fish habitat assessments and spawning surveys, a computerized camping and recreation database, and the Internet site (Grand River Conservation Authority, 1997d, 1998e, 2002a; Van Osch & Nelson, 2000). In total, the GRCA has access to a significant amount of scientific information related to the health and activity of the watershed. However, with new technologies and new theories emerging, and the region changing as rapidly as it is, using the information effectively is difficult.

4.5 A Discussion of Current Management Efforts

On December 18, 2002, following the Annual Resource Management Meeting held by the GRCA, an informal discussion with practitioners was conducted for approximately 2 hours. The focus of the discussion was on the status and future direction

being taken by the GRCA with respect to information management as well as issues facing the organisation. Table 4.4 provides a summary of the working session that was effectively used as a scoping exercise for information management practices at the GRCA:

TABLE 4.4: SUMMARY OF INFORMATION MANAGEMENT SCOPING AT GRCA
What are the information management elements at the GRCA?
• Within watershed management, there are different roles for individuals: Producers vs. consumers. Some use different types of a data have different needs and considerations. Information Services works to co-ordinate these roles and responsibilities within the organisation • Warehouse for integrating data is very effective and efficient. Sources include Grand River Simulation Model, Dissolved Oxygen Model (air, water, bio/land, vegetation, streambed), Provincial Water Quality Monitoring Network, Real Time Water Monitoring Network, NRVIS, and water quality database (water quality studies). Information generated from programs also feeds into warehouse • Standard approach to meta-data also allows historical data to be more accurately applied and interpreted. Also, necessary for identifying gaps in existing data • To resolve the problems surrounding making data known about and understood and to ensure it is used properly, efforts are underway to improve the Metadata. The Metadata Repository will identify when the data was collected, how it is stored, what limitations or errors, coverages, gaps, etc. Extensive Metadata is now being collected and circulated within house (GRCA). Historically, data has been separated into GIS and tabular form. Metadata will allow for the integration of different types of data – integration that is more reliable. • Data is prioritised based on decision making gaps and relies on sound leadership and effective corporate culture
How are gaps in understanding addressed?
• Review of data to see if it still adequately meets the needs. Those reviewing data for gaps need a clear sense of corporate strategy and direction. • Strategic plans at management levels and then filter priorities down for proper implementation. This maintains core levels of knowledge and provides proper direction • Water quality issues are so tangible since Walkerton; there has been a change in priorities, which changes the information needs of the organisation. In deciding on information priorities, attempt to foresee what needs are, predicting what the next issues will be. Process for predicting, guessing, and forecasting sets the goals for the organisation. Strong relationships with external organizations and public are essential for influencing the organisations own reality (e.g. Public education, partnership building)
Why has the GRCA been so successful relative to other Conservation Authorities with respect to information management:
• Complexity of issues facing GRCA causes innovation and creativity • Due to different demands on the watershed, the leadership at the GRCA is forced to pull together and find common ground. As a result, the data reflects this effort • Infrastructure: Technology needs to be adequate and appropriate – not necessarily forefront, but capabilities need to be in step with industry standards. Can be as simple as using the latest version of windows. • Data maintenance is key – needs regular updating and maintenance • Documentation, management, training, and open culture facilitate support for all roles and foster co-operation • Dynamic culture helps CA to adapt and respond to needs. In addition, culture encourages

TABLE 4.4: SUMMARY OF INFORMATION MANAGEMENT SCOPING AT GRCA

ideas and experimenting.
- Leadership, strategic planning, and vision are key ingredients and have been done very well at GRCA
- Clearly identify the issues and implementation plan, gaining full support from staff to make sure things happen
- GRCA is responsive to the market. Major part of the business is information management (99%) vs. (1%) and the GRCA has shifted priorities accordingly
- High quality staff dedicated to jobs and organisation
- Actual decision-making is relatively flat. Decisions are spread across culture of organisation.
- Technical committee provides forum for addressing challenges. Brainstorming in committee has significant benefit, helping to identify what technology directions are needed in strategic plan.
- Means of refining the process are built in. Process continually evolves.

What challenges is the GRCA faced with respect to Information Management?

- Culture can create a stumbling block; can be that things are a little too unmanaged, too liberal, and have too few priorities
- Integration needs to be improved, but requires resources.
- Large amounts of data will always be lost, partly due to limited resources. There is an inherent weakness in losing data due to the volumes that can be collected.
- Process for data management and application management is needed
- Delivery of data is not always timely, especially when it is collected by external organisations.
- Resources are always a problem. Resources; lack of awareness, misuse or misunderstanding; or wrong format limits access to data. More than anything, resources restrict people and expertise. Source of sustainable funding is needed for longer-term corporate planning
- Human tendency to create silos of data is still a challenge
- Many players in the process complicate things. Everyone wants the limelight and feels threatened by others. In addition, they are heading in different directions and have different opinions. They are often all competitive for the same resources
- Co-ordination of databases – this needs to be accomplished. Until then, this is a major structural barrier
- Method for setting priorities is not systematic or transparent enough
- The level of expertise and knowledge that is stored in people's heads and is not transferable. While this knowledge will never exist in digital form, but is important to find other ways to share.
- Due to cost restraints, historical data will never be incorporated into a modern system.
- Technological advances keeps the wheel moving – adds to the pool of resource issues and planning
- Communication can always be improved.
- Better efficiency is critical – shortening the distance form creator to user. More empowerment of users with content management software applications

Participants: Phil Lenoir (Information Technology), Mark Anderson (Water Quality), Dave Schultz (Public Relations), Robin Van De Lande (Biologist), and Chris Powell (Resource Planning)

From this preliminary group interview session, it was clear that the GRCA is considerably further ahead in its information management than other Conservation Authorities. The organisation committed early to information management based on the

need for better understanding of the watershed dynamics, which was forced by flooding and drought problems associated with the river and those significant communities living along its banks. With a substantial tax base consisting of the various member municipalities (especially, Kitchener, Waterloo, Cambridge, Guelph, and Brantford) and the interests of a large urban population, the GRCA was able to use some adverse conditions to its advantage to develop strong information management practices and infrastructure. Other CAs with a more rural population and/or smaller tax base either had less need to develop information management or lacked the commitment or resources. These comments were used to refine the evaluative framework, focus the literature, and prepare the in-depth interview questions.

4.6 CHAPTER SUMMARY

This Chapter has profiled the watershed and management efforts for the Grand River watershed. The next Chapter will summarise the interview results and refine the information management framework through its application to the Grand River Conservation Authority, and discuss the themes that have emerged from the research around information management.

CHAPTER FIVE – DISCUSSION AND APPLICATION OF AN EVALUATIVE FRAMEWORK FOR INFORMATION MANAGEMENT

5.1 INTRODUCTION

This Chapter provides detailed discussion and analysis of the problems identified in Chapter One. It is based on the results of interviews conducted with practitioners from the Grand River Conservation Authority, Conservation Ontario, and Ontario Ministry of the Environment, Ministry of Natural Resources, and Ministry of Agriculture and Food. The results from the interviews are used to explore the evaluative framework for information management (as developed in Chapter Three), to apply the framework to the GRCA, and to provide recommendations regarding information management for watershed management practitioners in general. Chapter Six will then provide observations on the state of information management and where future research can further contribute to decision-making for watershed management. Limitations of this research will also be identified in the final Chapter.

5.2 INTERVIEW RESULTS

Using the interview methodology that was described in Chapter Three, interviews focusing on watershed management involving the GRCA, and the other major provincial organizations including the MNR, MOE, and Conservation Ontario were conducted. The semi-structured interviews (see Appendix 1 for Interview questions) were synthesized and categorized into six headings: *Watershed Management in Ontario and Information Management, Information Planning and Design; Data Management, Processing, and Analysis; Information Sharing and Coordination; Information Management Technology;*

and, *Internal and External Considerations*. These results provide the basis for the discussion for the rest of this Chapter. Interviews ended up being quite informal, resulting in good discussion during each of them. This Chapter attempts to capture the common themes and trends from all of the interview discussions.

5.2.1 Watershed Management in Ontario and Information Management:

There are many challenges currently facing watershed practitioners, both technical and theoretical. Staff from MNR, MOE, Conservation Ontario, and the Grand River identified that the approach to development, existing patterns of growth and water consumption will not be sustainable over the long-term. Land use planning is based on continued growth in every community at all levels of government rather than optimization and finding efficiencies at existing levels. From the start, this creates a scenario where planners are trying to use information to make a case for a mission that is already flawed. From the perspective of the staff members interviewed, these factors combined with inadequate staff resources, insufficient spatial data coverage, limited budgets to initiate projects, and lacking an approach to process tracking, represent a formidable problem. In general, information management efforts need to optimize data and information resources, make the information accessible, improve data collection efforts, and most of all, improve inter-agency co-operation and ensure adequate information priorities.

Jurisdictional boundaries remain a problem with respect to information management. Three staff members working with the GRCA as well as a senior manager with the provincial government commented that Conservation Authorities are constrained

by the provincial and federal policy framework, as significant gaps in the policy framework limiting CAs ability to do their work include discrepancies in the generic regulations that do not match the intention of the provincial policy statement. This creates more work in order to achieve co-ordination and tends to generate redundant data layers. Government has tendency to get distracted by bureaucracy. As a solution, an information manager with the MNR suggests strong internal political leadership and vision is needed to define clearly roles and relationships amongst organizations. This will require political will committed to properly undertaking watershed management. There are many agendas involved in watershed management. A MNR manager noted that complexity of relationships has caused watershed management to evolve into something that is unclear. Roles and responsibilities need to be clearly defined and revisited in "an effort to align all the constellations". The current situation seems to introduce too many unnecessary challenges and inefficiencies, causing both organizations and individuals to work independently of each other. A senior manager at the GRCA lamented that achieving *functional interdependency* among organisation staff is difficult as human nature and organisational nature is to work independently rather than together. A range of staff from the GRCA, Conservation Ontario and Provincial Government resolved that provincial leadership should help this, by providing coordination, as would increased project and information reporting aimed at increasing communication.

Being able to identify the value of information to others and make it accessible is not an automatic process. Senior staff at MNR and the GRCA propose that information reporting helps achieve co-operation and co-ordination in watershed management regardless of scale or size of watershed agency or scope of management issues as it helps

establish project and program linkages and opportunities for information sharing. Finding a balance between the priorities of watershed management and the priorities of funding partners are often a challenge for Conservation Authorities. A senior provincial staff member questions the point where the goals of watershed management become compromised in favour of the goals of a primary funding partner like a municipality. Finally, a range of staff members from the GRCA and Conservation Ontario identify getting the right message about information management out to staff and management as a challenge as there is a lack of recognition for two main reasons: 1) ignorance i.e. "never did it that way"; and, 2) lack of resources. Climate change, artificial recharge of groundwater, low water/drought conditions, water taking permits, preservation of natural systems, loss of wetland and forest cover, flooding, water quality/water capacity, sub-watershed planning, and effluent management among a host of other issues all pose challenges to watershed management practitioners at the CA level. Information Management is a key challenge for watershed practitioners: getting the right data, generating the right information, and doing the right things with it are all underestimated.

For information management within the GRCA, size is the biggest challenge. Size of the watershed increases the cost of the data significantly, as both the volume of data and required technology capacity are expensive. Staff from MNR, MOE, and the GRCA indicated any service offered with data is more work, dissemination of knowledge is a larger task, more data agreements are required, priorities for data differ across the watershed, and differing Intellectual Property (IP) copyright issues arise from municipality to municipally. Added to this, maintaining knowledge and information in an environment of shifting priorities, job migration, and out-sourcing of work to

consultants are all challenges that compound an already difficult task. Any combination of these factors can result in information loss from the organisation and reduce knowledge transfer to other practitioners, as well as the usefulness of the information for its intended purpose.

A senior GRCA manager stated that the challenge of watershed management as it relates to information management is also managing people, not managing resources, or information. Changing behaviour, managing behaviour, and influencing decisions is the primary activity of watershed management. Natural resources and the environment are seldom given real value, affecting public perception and decision-making. Creating a sense of value around the environment so there is adequate support in the form of changed behaviour, rather than creating a need for regulatory processes, which are not as effective, has been a barrier and remains a primary objective of most organizations, and therefore is the primary area information management supports watershed management. Practitioners are left with the challenge of providing the public and decision-makers with sufficient knowledge in order for them to understand the value of resources, so information management ends up serving as a marketing or educational tool.

Information Management has helped to provide organizations with appropriate knowledge at many levels in order to help facilitate decisions at all levels (federal, to provincial, to local site level). The goal of information management is to provide timely, reliable information so that consistent decisions can be made. However, information management is actually changing how watershed management is done at all levels – it is even redefining watersheds. As new surface water flow maps are created with more precise and accurate data, watershed boundaries are being modified to reflect actual

watershed flows more accurately. Additionally, technology allows for timelier reporting on information, facilitates cost effective process tracking in time, and has dramatically improved ability to provide access to information faster and make it available to practitioners. GIS has evolved to support decisions, which has helped information management to evolve as a continuum within sections and ministries. Staff from MNR, Conservation Ontario, and the GRCA working with GIS suggest that, as a tool of information management, GIS has been evolving as a process and expanding the perspective and awareness of other information management elements through establishing awareness of information management practices with other staff members and senior management. GIS development has fostered GIS expertise in many CAs, which raised the bar for Information Management practices.

Information Management is a core activity of the GRCA as it is essential for maintaining credibility when working with municipalities, the province, or the public, and it is key to understanding water quality and quantity. While there are varied capabilities among the CA network, and the GRCA's is a rare experience due to its resources, developed expertise, and infrastructure, a senior information manager at the GRCA suggests there remains a need to identify the importance of doing information management at all scales of capacity remains. This will reduce the fuzziness around existing data sets; streamline costs, and support analysis, decision-making, monitoring, and reporting. It is easy for staff to underestimate or be misinformed regarding the role information management can play in improving business services. Staff from Conservation Ontario believe this is the result of many senior managers who have either not been exposed to technology or information practices, or in some cases, are over-

confident in existing processes that have been used over the past two decades. Recent legislation that requires integration of information for planning purposes such as the Nutrient Management Act and Safe Drinking Water Act and the proposed work around Source Water Protection guidelines will help, as will OGDE and WRIP, to force change among the CA network. Additionally, projects such as these have helped improve relationships between CAs and provincial Ministries by bringing more money to partnership projects and helping establish new personal relationships.

Several GRCA senior staff commented on how information management has reduced the time it takes to access and update information, thus improving the knowledge transfer rate. Less time is spent on searching for data that may or may not be the most current available. For an end user such as a planner, information management has improved confidence levels with respect to their data, as they are able to spend more time working with it rather than searching for it. Additionally, Information Management provides efficient support for decision-making. Desktop GIS is an example of making information available to end-users more readily. To make this level of information available, there is a huge front-end investment of resources in projects and programs. For example, ground water studies require significant initial investment, but if better data were available, more project money could be allocated to analysis, modelling, monitoring, and reporting. Information Management also helps reduce the time required in the field by planners. While field visits are an essential core component, if there is confidence in the data or information, fewer site visits are required.

Through the interviews, a number of conditions considered prerequisite for effective information management were identified. Staff at Conservation Ontario

working on information management stated that at the base level, each of the following elements needs to be a part of the information management framework for an organisation: a) System design; b) collection of information/data; c) data storage; d) analysis and interpretation; and, e) reporting. Adequate resources in terms of staff are also fundamental to the process. Senior managers from all organizations commented that committing to develop necessary infrastructure is a challenge, but must also be a priority. Staff, who often see their budgets cut in other areas, view large investments in IT with scepticism, especially when many do not see direct results. In addition, large investments often deliver the infrastructure to house data and information, but the data must already exist. Often staff do not see this connection and blame Information & IT staff for poor data quality, rather than questioning fieldwork investment – the business area still needs to provide the data. Decision-makers need to invest not only in infrastructure, but also in the data so users can see the benefits. The most important objective of information management is to serve and represent the business service needs of the organisation. To achieve this effectively, three staff members from the GRCA stated the case that Information Services staff need to be internalized in core business areas and projects.

Provincially, there needs to be openness, political buy in, financial support, and technical capacity. In addition, all organisations need to be open and willing to share their watershed information. Corporate commitment to spend time, money and allocate resources is essential to establishing effective information management. The reality of information management is that it is a long haul. Short-term investments are not sufficient to establish and maintain necessary infrastructure. Good people drive effective information management and instil a healthy culture and attitude. Patience is an essential

attribute for an organisational culture to have relative to Information Management as many elements of the process take time to develop and refine. An information manager from the GRCA and MNR both identified the recipe for successful information management as "Orgware" + Software + Hardware. The Province is very good at focusing on software and hardware but often forgets the importance of the organisational culture and attitude. Often a single individual can have as important role in implementing effective information management as all of the technology combined. A champion of information management is one of the most important conditions.

With respect to the CA network, their current form and function is a result of the cuts that were made over the last eight years. Currently, a leaner structure for the GRCA has been beneficial, but it has taken time to redefine internal roles. The MNR is becoming a larger partner again as some of the spoiled relationships over difficult years are being forgotten and more money is returning to the table (i.e. special project and program money has increased since Walkerton). A wide range of staff members from MNR, MOE, Conservation Ontario, and the GRCA identified three critical pieces for implementing effective information as (1) People (ensuring their expectations are realistic and have commitment to the process); (2) Information (structured appropriately, to meet needs); and, (3) Technology. The People piece is critical to getting things done as are inter- and intra-organisational politics for influencing information management one way or another. In order to maintain commitment, it is important to give people regular progress updates and "quick wins". Strong leadership is needed to provide direction to attain skills, acquire resources, and ensure implementation. Leadership has to be focussed and well connected to the various partners to ensure a broader commitment to

information management. In addition, the size of organisation needs to be appropriate so that there are sufficient resources to meet demands and still support base level information management practices. This ensures there are adequate connections and informal opportunities for communication between IT departments and core business services. The GRCA spends a lot of time working with people, especially maintaining strong relationships with municipalities (e.g. annual report in local paper, relationships with local media including radio and television.).

Staff from Conservation Ontario remember an important lesson from Walkerton, in that you cannot assume there are not any issues or pressures. It is important to maintain understanding of a system so that when situations like Walkerton spring up, there is a means of making decisions. Because of this, it is important to build and maintain an information system that is sustainable once political attention has moved away. Cost-effective information systems are essential for surviving the waxing and waning of public and political interest and the changing funding support that comes with it. Within the organisation, information management is used to mitigate crises and stresses. Information is used to gain an understanding of crises by providing information that explains the situation, rationalises resource allocation and priorities, and provides direction for next steps. As a result, whenever there is a major event or crisis, resources for both watershed management and information management are usually increased (e.g. Walkerton and resulting programs and projects).

According to two senior managers at the GRCA, information management supports decision-making in day-to-day contexts (i.e. permit review) as well as longer-term corporate direction (i.e. corporate strategy process by providing information on

larger issues e.g. population growth and development). Dissemination of information is fundamental for validating the watershed management function of the GRCA and educating the public and decision-makers. The GRCA has been very good at information collection, data processing, maintenance, and warehousing. However, the GRCA has had some shortcomings with regard to resources allocated to analysing, interpreting, and reporting to ensure that information is feeding back into the process. For the rest of the CA network, information networks such as OGDE, LIO, and WRIP have brought CAs back to the partnership network table with provincial ministries such as the MNR. In this case, information management is encouraging inter-agency collaboration.

On the question of whether there was enough data/information available for decision-making, practitioners indicated that while there is never enough, the larger issue is whether existing information is being optimally put to use. That is, are the various parties that could use it utilising information and is the potential for new information and knowledge being harvested from data and information that already exists. Most decisions are ill prepared given the potential of existing and accessible information. Standard base mapping (1:10,000) quality is critical to improvement, as there are too many unknown conditions across the province, which cannot be compared effectively because of base map limitations. Data coverage at chosen scales needs to be optimized as currently there is variance in coverage resulting in skewed decision-making. Too often geospatial data is considered as an after-thought during project development. At the onset of projects, project teams need to consult with information specialists to see what geospatial data is needed from a larger corporate perspective.

While there are many sources of information including MNR, MOE, MNDM, federal government, municipalities, water chemistry labs, consultants, and at times the public, access to information can range from open, to very restricted, to none. Offering their support, staff from MNR, MOE, Conservation Ontario noted that a core objective of the Water Resources Information Project (WRIP) will be to identify key data sets and provide infrastructure to ensure data that is essential for watershed management is accessible and available, thus reducing the number of existing data gaps. In general, there is never a complete set of information for resource management as it is the nature of the problem. However, more information could be used in support of specific areas including in-field data collecting and ground truthing, source protection, water budgets, water quality, ambient water quality, ground water, drinking water, flood forecasting, and climate change. While flood forecasting represents the most sophisticated of current data collection capabilities, in order to cope with changing climate conditions and development pressures, a flood-monitoring network needs to be revisited. Existing data sources need to be leveraged for more information. This will probably require more work on data standards to make the data compatible. Information is getting better and has been improved by the Natural Resources and Values Information System (NRVIS) and OGDE – however, objectives still need to focus on making existing data more accessible optimal. In addition, more custom queries need to be built, and information needs to be provided, offering faster access to commonly used combinations of data. Two information managers from the GRCA suggested that this will make better use of existing data and help identify gaps, as well as improve accessibility. In addition, efforts will include direction from Information Services on new projects during the design phase,

providing an opportunity to analyse database design, enforce meta-data standards, and address data quality will be provided. On the other side of this problem, there can be too much data and information. It is necessary to find a way to balance between too much and too little information. With too much in some areas, it becomes difficult for decision-makers to *"see the forest for the trees"*. This is why refinement and synthesis of information is so important to the management process. In many cases, there is enough information, depending on the questions being asked, and limitations of the data are recognised. For example, pesticide monitoring is only done at the mouth of the Grand (federal site) and is only recorded periodically; therefore, sample timing is not representative of watershed conditions. Two data experts identified that more sites and more sampling would be required to ask questions that are increasingly specific about the entire watershed.

Throughout the interviews, there were several key challenges identified that might be barriers to effective information management. Adequate access to information is a barrier for several reasons: The technical capacity is not in place; adequate staff resources are not available, or, institutional barriers are in the way like data-sharing agreements. Overcoming these barriers and ensuring that information is readily available needs to be a goal of Information Management. In achieving the above goal, standard approaches to data sharing including both data standards and meta-data standards will need to be addressed. This has proven to be a challenge in terms of finding common ground among the different organizations. With respect to finding common ground, redefining roles and responsibilities is a formidable challenge that needs to be addressed or will otherwise continue to bog down information management practices. Data-intense projects

especially require better co-ordination, as currently there are many duplicate efforts and similar scales. OMAF, MOE, MNR, MMAH, and MNDM have shared jurisdictions and overlapping responsibilities with respect to water – Several representatives from MOE, MNR, and the GRCA identified that this needs to be streamlined and defined clearly. MOE especially has been lagging with regard to information management since the downsizing during the 1990's, when they lost the bulk of their staff and skilled people in this area. Three senior managers from MOE and MNR stated that work needs to focus on the internal fractures that MOE continues to demonstrate. While the CAs are a major success story as a cost-effective watershed management agency, their roles also need to be re-examined as imbalances between the have and have-not CAs are not improving. According to a staff member from MOE and Conservation Ontario, where services are no longer offered by the province, some CAs are attempting to provide replacement services; however, not all CAs are picking up these services, so there is beginning to be a variance in programming and services offered from region to region.

Unfortunately, information management is still considered new, and is therefore not recognised as a central business activity and there remains resistance to adopting it. Sufficient and sustainable funding is a challenge for CAs large and small. With respect to Information Management, maintaining investment means maintaining workload efforts, sufficient staffing, sound infrastructure, and good data. It would seem that some sort of cost/benefit understanding needs to be gained before switching efforts randomly. In an environment where there are so many issues, it is important to know which ones need attention first, based on a systematic assessment. So long as funding is a concern, politics will continue to be a challenge for the GRCA. The GRCA invests a lot of time

maintaining strong relationships with board members to make certain they understand the business of the GRCA, ensuring that the politicians can effectively represent their constituents. As a part of this equation, Municipalities are a powerful third player (e.g. Waterloo provides 60% of funding for GRCA). This critical role affects the politics of organisation. Two staff members from the GRCA expressed concern that depending on services downloaded from the province to the municipalities, directions of the CA, and tax base changes, support for GRCA activities can swing substantially. The potentially wavering political support and continuous concern over funding is a conundrum for CAs. Currently the lack of clarity around roles is causing confusion between organizations and resulting in local priorities of municipalities overriding watershed priorities.

Variance between CAs needs to be addressed. Many CAs just recently added computer network capabilities, while others are developing desktop GIS and document management applications. Senior information managers from MNR and Conservation Ontario expressed concern for smaller CAs, where intellectual property and data restrictions mean the allocation of more resources, already stretched thin in an attempt to be compliant. Efforts need to be taken to ensure adequate services and programs are offered evenly across Ontario. At the same time, CAs need to be prepared to make mistakes and learn from their approach. They should not expect too much from information management (i.e. information management is not a silver bullet); rather, information management needs to be nurtured over time (e.g. migration to ArcSDE required 6 months of dedication by senior staff member). Practitioners and the public cannot expect too much from Information Management, as it is not alone, going to improve the conditions of the watershed; it can only support those working on such goals.

When people have too much blind faith in information, they forget that it is an artificial version of reality, and place too much faith in it.

5.2.2 Information Planning and Design

Through the literature, it was apparent that planning had a wide role in the success and effectiveness of information management. Interviews investigated the nature of planning for the organisation and how information management was linked to the wider corporate planning practices for watershed management. According to senior management at the MNR, within the provincial government, priorities are set through rational efforts with varying degrees of success; however, political pressures are a very strong driver and usually disrupt the planning system (e.g. Nutrient Management and Source Protection Planning). Political and business institutions and processes such as cabinet, elections, business planning, and visioning planning all have roles in settling goals and objectives for the organisation. Senior managers at the GRCA use a long-term vision and strategic planning to achieve goals identified on one, three, and five-year cycles. Strategic planning builds on internal scans that involve both SWOT (Strengths, Weaknesses, Opportunities, and Threats) and PEST (Political, Economic, Socio-cultural, and Technology Factors) analysis. The GRCA Board of Directors, Chief Administrative Officer, and Chair carry out goal setting. Staff have input through annual town hall meetings, retreats, Latornell, weekly section/department meetings (through their supervisors), and through committee meetings. While strategic planning documents are dynamic and are updated regularly, a more formal process for setting priorities within the plan is needed. Even with all of the planning and goal setting, the GRCA remains a very

reactive agency to the pressures of the day. GRCA staff members indicate that directives, either from the province or from member municipalities, regularly create new directions for the organisation. Different efforts for introducing priority setting have been tried, but nothing has been settled on.

The MNR is generally on a good path. The current process has been effective at planning and budgeting. Leadership has been proactive at times and very effective with respect to the development of large concepts such as Information & Information Technology (I & IT) clusters, NRVIS, LIO, Service Centre, Business Centre, and the Information Group. The I & IT cluster is not being openly recognised across the government at this point, but the planning and information priorities are systematically addressed. Information planning is done annually. It states broad objectives, is based on business planning for sections, and is rolled up to the I & IT cluster level. For individual programs and projects, updated strategy and objectives are needed, especially for the WRIP. This could be improved by having a more formal reporting relationship across the cluster ministries and a requirement for cluster ministries to participate. Information Management planning is tied to the corporate planning process. Business planning within sections and branches stems from public announcements, legislation, campaign material, and cabinet instruction. From there, senior management attempt to co-ordinate different directives with existing programs and policy, while considering information management needs and capabilities. Specific long-term information management planning is prepared by the I & IT cluster to support these efforts and reports are made to senior management.

Unfortunately, according to an information manager at the MNR, information management is still viewed with scepticism and viewed as a black hole for resources. A lot tends to go in, but many staff never see the direct benefits of the investment. As such, decision-makers outside of the I & IT cluster do not always have strong information priorities and have not worked to ensure data and information is co-ordinated. Planning must be careful to consider where it is appropriate to spend money - On volumes of data or on flexible infrastructure, ensuring careful prioritization of resources. Additionally, planning currently overlooks existing data and data gaps. Planning too often starts with the perspective that information needs are known. Through the Oak Ridges Moraine process, it was made evident that new information needs were very different from what was originally perceived. Interviews were conducted with various partners to identify needs and sources of data by MNR, which ultimately changed the information strategy significantly. Both needs and gaps were identified. More interviews should be completed for major programs and project initiatives to avoid different organizations duplicating data or missing obvious data gaps. Currently there is a lack of the big picture on the target environment. A staff member from MNR believes that stronger data and information reporting from all data rich sections would facilitate more effective information priority planning. A clearer list of priorities within and among water organizations is needed, which can be partially achieved with more commitment to the I & IT cluster concept.

There are efficiencies to be found in collaboration and co-ordination through co-business planning. Efforts are made to link information management planning, but there are deficiencies in the process. According to three MNR staff, because business planning

can be reactionary to the pressure points that arise throughout the year, there is a delay in the time to consult with the information management planning process. This is mostly because the information management process is less formalised and happens mostly between a few key staff and management within the organisation. Many informal meetings and chance encounters provide the bulk of information management strategy and planning. While a committee of senior management attempts to meet regularly to discuss information management needs and determine priorities and workload issues, a senior manager from the GRCA feels this committee needs to find ways to be more effective. Currently when new technology or information-related decisions are made the full implications of workload or resource demands are not fully known and become a larger burden than expected. For example, an effort to purchase new orthophotos in partnership with municipalities had much larger workload issues than was originally perceived.

Long-term planning for information management is tied to the corporate strategy. In addition, provincial projects provide strong incentives for CAs to plan for information management, such as WRIP and NRVIS. Meetings held in support of these projects help identify future information management goals and work through related challenges. A more systematic approach for long-term planning around information management needs is required including assessment of resource allocation and priorities. The specific information management plan for the GRCA is maintained by Information Services and co-ordinated through a management committee. The plan works towards broader GRCA objectives and supports core business wherever possible. According to a range of GRCA staff, for planning purposes, industry standard approaches to information planning are

employed. The focus has been on trying to identify where different users may be developing information that is a resource to other users as well – i.e. to co-ordinate information efforts e.g. Water Quality and Fisheries. Through this, Information Services is trying to raise cultural awareness around information management considerations. The nature of the business of watershed management is reactionary during many points of the year. Only so much planning can be done to prepare for information management needs. Four GRCA staff identified that in an effort to address information management shortcomings, the Information Services section of the GRCA tries to participate in section meetings and project meetings by embedding a representative who can help facilitate identification of information management/IT needs and opportunities for co-ordination with other parts of the organisation.

In general, recognition of other potential data-users is an important part of planning, especially from other ministries: MOE, OMAF, and MNDM, who might use the data. A permit to take water for example is only now beginning to record more geospatial data, which can be used by water allocation modellers. In addition, technology changes daily so staying ahead is difficult. A GRCA staff member commented that information development needs to be well thought out and component based (i.e. modular design) so those new elements can be interchanged and updated easily.

Those who are committed to information management planning help the organisation make significant gains, while someone who is not interested in information management, can create substantial barriers. To this end, information planning needs show incremental results to maintain the interest and support of those stakeholders affected. Maintaining adequate information management, funding, data, people

resources, and maintenance are all key ingredients. A range of staff members from MOE, MNR, and the GRCA commented that the critical part is not just collecting data, but making it valuable and accessible. Interpreting adds value to the data and meta-data helps to reduce islands of data and optimize data use throughout the organisation. It is important to ensure that Information Services is well linked to various business services of the organisation so that planning reflects actual needs. In an effort to achieve this, practitioners will embed staff in different sections to open lines of communication, e.g. two practitioner positions in the Resource side that are primarily Information Modellers bring understanding of information structures, and limitations to resource management area. Their culture of motivation, independence, and innovation at the GRCA has a tendency to have people work in isolation.

In response to this, IS has adapted its planning process by embedding individuals on project teams and section meetings to ensure that operational and tactical capabilities meet the business needs of the organisation. By participating in weekly team meetings, project leads can be consulted early in the process and Information Services can plan accordingly with project needs in mind for information management planning i.e. ensure appropriate data is collected, adequate technology is available, and necessary expertise is hired. Setting priorities remains the biggest problem for information planning. On a regular basis, multiple issues need to be addressed simultaneously, creating a need for a coherent and transparent process for priority setting. A staff member from the GRCA indicated some gains have been made through linkages to external research groups and academic institutions have helped to recognise where the process is evolving and where further work is needed. A senior GRCA manager commented on the open culture within

the GRCA and how it promotes interaction and is critical for fostering support for information management and keeping personnel goals aligned within the organisation.

While there are many opportunities throughout the planning process of a watershed management organisation, it was interesting to learn through the interviews that usually urgency drives needs, rather than formal information needs analysis at an organisational level. Formal efforts are made to identify needs, but most arise through chance discovery of gaps and are usually needed quickly. Ultimately, needs are assessed on a reactionary basis. However, in an example of planning on a larger scale, in an attempt to determine baseline needs and capacity, Conservation Ontario conducted 36 interviews and 4 workshops with the Conservation Authorities to identify baseline priorities and needs aimed at developing standards that would support WRIP. Information Management seems to evolve throughout the process, especially as technology evolves and new issues arise. New issues drive adaptive approaches to information management. New technologies continue to evolve planning methods by providing new capabilities and therefore new needs.

5.2.3 Data Management, Processing and Analysis

The provincial government and the GRCA alike both employ strict data management and processing policies. Based on the interview responses, there was unfortunately no systematic approach to analysis identified. For data management, there is no new data entered into a warehouse without modelling/meta-data/custodians assigned or tied to it, which means there is always a business area taking responsibility for the data, including long-term maintenance costs. Having a data warehouse allows many

opportunities for sharing and integrating data with either other organizations or the public. A senior information manager from the GRCA commented that now, opening the warehouse to the public or other organizations would have many positive impacts; it would also create some heavy workload issues around coping with additional data requests and assistance. While there have been efforts aimed at data maintenance, generally there is insufficient data maintenance being done. This seems to be a result of tedious data work not being seen as a priority or not having political appeal.

Data management issues are very complex in multiple agency environments. According to several GRCA staff, the GRCA has been able to establish a strong information management culture, teaching people the importance and benefits of data management. An important step is defining data management roles, especially ensuring that competent owners and custodians are identified. These issues become more problematic in a centralized database structure with the advantage of economies of scale. Instead, data-rich CAs have more interest in central repositories than ones that are simply updated regularly.

To ensure long-term access, a scaleable and flexible database design ensures long-term access to data. Using ESRI-based applications fosters long-term access, as its format has become the industry standard. In addition, a structured approach to data collecting and processing is maintained which keeps the data standardised. The OGDE may provide broader access to data also and improve the state of standards. In addition, I & IT provides assistance to data custodians to ensure it is maintained to the highest technical standards. This approach has proven to be very effective and well suited to small user environments. All data is organized and kept in databases and warehouses

such as OLIW and NRVIS, improving data integration and exchange, and co-ordination through the OGDE. These relatively young initiatives were initiated in the middle 1990's and need to be maintained and improved. Several staff from the GRCA, MOE, MNR, and Conservation Ontario indicated that ensuring that new data is collected with proper geospatial considerations and is co-ordinated with other users remains a challenge. A more streamlined process for communicating data proposals and intent to collect data needs to be thought out so more co-ordination can take place at early stages.

A lot of effort is made by Information Services at the GRCA to provide integration and co-ordination. They attempt to anticipate where linkages will be needed and prepare data accordingly. LIO (OLID & OLIW), NRVIS, and OGDE have all improved the level of data integration and co-ordination, however three GRCA staff members believe the data sharing approach needs to be further streamlined and opened up. In addition, a vast amount of data does not meet the GRCA's meta-data standards, so this information needs to be augmented. With the municipalities, the GRCA has identified the need to exchange data more frequently. At the GRCA, an information manager said the upgraded ArcSDE structure is an improved set-up for accessing different data sources and integrating different data types. Internally, all data is centralized within the GRCA, which has been an effective approach to forcing co-ordination and integration. Problems with multiple organizations need to be addressed. Adopting a standard data model across the CA network would be ideal for data management, however with so many different interests and capabilities; there is little chance of this happening in the short-term. Amongst the CAs, everyone has a different approach to information management and unique information management needs and

limitations. A uniform approach to meta-data should be adopted instead; so individual CAs can at least co-ordinate existing data sets. Based on the experience of three GRCA staff, data standards are set internally but need to be formalised among stakeholders. With the watershed community being so diverse, consensus may be difficult. Provincially, there is a systematic approach to data standards, enforced by the IT section. Internally published standards, which conform to industry standards, are used.

Time, resources, and technical capabilities all pose constraints on data management and analysis. Part of the solution to these lies in setting priorities. More needs to be done toward assigning a value of costs per decision based on information, so there is an understanding of what gaining more understanding actually costs. More resources are needed for in-house staffing and developing expertise to support maintenance, interpretation, and analysis of data. Less project and program money should be spent on consulting as it results in the expertise being developed off-site and therefore a loss of knowledge. While time and resources are limitations, so is desire. Data management and analysis tend to be jobs that are less preferred by staff due to their inherent monotony and tediousness, so morale can be a major issue.

With respect to knowledge management, there is virtually no identification of it either provincially or within the CAs. Specifically, at the GRCA the informal culture fosters a very relaxed approach to knowledge management and most knowledge is passed along through osmotic learning. However, an information manager indicated a meta-base for all data layers is being developed which will allow users to have deeper, context based information searches using a growing set of data descriptions.

Watershed management organisations within the province of Ontario seem to be aware of the need to make partnership linkages across information management mediums. There is a tendency away from "silo"-building with data, but more work is required to ensure ready access to data from multiple sources. Concerns were raised by two senior managers from MOE and MNR regarding the MOE ground water study is an example of how linkages with other organisation can be beneficial. Other organisations, such as the MNR could have an interest in producing base map data that may be useful for other purposes in addition to the study, making it an ideal candidate for a partnership, rather than simply contracting work out.

Within the CA network, individuals are key to making linkages with other organisations, either with the federal or provincial government. Efforts through data agreements, OGDE, and NRVIS have all helped to expand the number of partners linking with the GRCA. Data exchange agreements to support linkages with other organizations create a significant workload. A GRCA staff member agreed that more umbrella agreements are needed to foster easier exchange of data and information – sort of a free trade for data.

In terms of projects, the Province of Ontario is really lacking with respect to project standards. Contracts are regularly signed with no regard for how the information is delivered back to the province. Specific standards need to be developed for how projects should be delivered. While a centralized database has some obvious advantages with these goals in mind, it may pose other problems around access, licensing, and delegation of authority and responsibility. Additionally, centralized databases may not adequately serve local interests; their scale may be too coarse. A senior GRCA manager

agreed that the best scenario would be a combination of local and global working environments.

A significant part of improving data management is the adoption of meta-data. Meta-data in the province is much improved through efforts around NRVIS, but the implementation of metadata standards still does not meet industry standards. An information manager from the GRCA commented that OLID is a positive step and has been a very useful tool for practitioners by providing a search engine for existing meta-data. The GRCA strictly enforces maintaining meta-data in its data warehouse including an abstract, accuracy information, data, source, contributors, and limitations. A common complaint among CAs is the amount of time required to clean meta-data. A lot of time is spent adding meta-data from other sources in an effort to prepare it for the warehouse, especially meta-data from MNR since there is so much data provided by the MNR and that because a different, less thorough meta-data standard is used. Meta-data is so critical for proper application and interpretation of data and information, as well as taking so much time for supplementing existing meta-data second hand, that provincial leadership is needed to establish meta-data standards. A complaint shared by staff from MOE, MNR, and the GRCA is that sharing information without accurate or detailed meta-data verges on being unethical as it risks resource decisions being made on misinterpreted data, e.g., a planner making a decision on a parcel of land needs confidence in mapping information.

5.2.4 INFORMATION SHARING & COORDINATION

Based on the interviews, data sharing across the province was not achieving its potential. In most instances, data sharing agreements will bog down most users to the point that they will never get the data they seek. Even recently, provincial government district offices needed to pay for data, making some projects very expensive. Currently, other ministries need to pay large amounts of money for data, plus data cannot come back from other ministries into the warehouse – several staff members from the GRCA and MNR lamented this makes some data work redundant and adds unnecessary costs to many projects. Priorities are fundamentally out of touch with reality as the main concern should be getting data and sharing it with practitioners, businesses, and the public. This is especially true with baseline data, as insufficient base map infrastructure is a major impediment to many primary watershed management partners. There is also a general lack of co-ordination in the province between different scales of data. The resulting uncertainty as to whether or not the province or Conservation Authority is responsible, results in data redundancy. Staff from MNR, MOE, Conservation Ontario, and the GRCA expressed concerns that MNR is being pulled down and CAs are not being pulled up. The cause of this being that while the MNR attempts to support local data needs, local level decision-making requires large scale data where as the provincial interests are at a more coarse, medium to small scale. While there is a perception that large scale data is equated with higher quality, the provinces data needs are clearly different from those of CAs. If this Province is going to continue to support local data needs, there will be implications for MNR's resources and expenses.

Senior information managers from MOE and MNR agreed that supporting this, strong relationships with external organisations are needed and can only be achieved once there is trust between partner organisations and within organisations is needed for healthy working relationships. A barrier to this is the territoriality around information and protectionism that some organisations exhibit. Senior managers and politicians who fail to understand that information is in the public domain remain a barrier for most organisations across the province. A wide range of staff commented that, at times, there has been some abuse of data sharing policies at the CA level; the Ontario government has done more harm than good with respect to data sharing by creating more barriers through possessive data sharing agreements than are necessary. Senior staff from Conservation Ontario believe the current proliferation of data agreements is creating a sense of ownership of data among CAs, which will have longer-term implications for sharing policies around information management. Sharing agreements are resulting in CAs and their member municipalities putting a higher price tag on data and making them less likely to share their own data. This results in barriers to sharing due to either financial costs, or possessiveness, which is counter to high-level policy statements by both Conservation Ontario and the Provincial Government. Many other jurisdictions with fewer resources have found ways to make base map data available to their constituents without imposing such strict data-sharing agreements. Currently, infrastructure is in place or could easily be put in place, but there is not the political motivation to do so.

Data sharing within the GRCA is done through primarily ad hoc efforts and depends on who is involved. For external data sharing, strict access permissions based on licenses; specifying data integrity and use are required. Request forms for data are

available on the corporate web site and are processed manually. Supplying data or information is very labour intensive and the job of making information available consumes many labour hours. Information management staff from the GRCA believe improved provincial data standards would improve this process by reducing the amount of work required to standardise incoming data. Most data is openly shared with member municipalities depending on which data agreements are in place.

While knowledge sharing is primarily encouraged through broader technical reports and peer reviewed journals there is very little corporate strategic planning for knowledge sharing, especially with respect to sharing with other organizations. As far as strategic knowledge sharing is concerned, there is very little being done at the GRCA and virtually nothing is being done at other CAs. There are a number of opportunities for staff members to exchange knowledge although there is no formal knowledge-sharing plan. Opportunities include "show & tell" lunch meetings, yearly town hall meetings, board meetings, weekly section meetings, and the GRCA Water Forum. While a more sophisticated approach to knowledge management would be helpful, the relatively small size of CAs is conducive to informal knowledge sharing. Within provincial ministries, there appears to be a strong atmosphere of openness and trust, and among individuals from different ministries, relationships are very open. However, overall cultural personalities of different ministries do not foster an open relationship. To improve data sharing between organizations, two staff members from the GRCA agree common data standards and central databases are needed to resolve co-ordination issues, but most importantly, agreement among organizations on data sharing policies.

As a part of this, roles and responsibilities need to be considered, as indicated by a range of staff members from the GRCA, MNR, and MOE. Historical relationships with Conservation Authorities are slow to change. The Provincial perspective suggested that the CAs should not analyse or report on provincially collected data as they did not have the expertise and might create problems. Old relationships and feelings need to be broken down and where local expertise does not work, efforts should be made to create local expertise that supports analysis and reporting on data. Common understanding among the Conservation Authorities is needed. Information managers from the GRCA have proposed just such a discussion at a the Latornell Symposium, to discuss how the Conservation Authority network wants to co-ordinate its efforts and define its roles with respect to information management. Currently there is more dividing the Conservation Authorities with respect to information management than bringing them together. Commonalties need to be identified and lessons learned regarding best management practices need to be shared. In addition, meta-data standards are needed and they must be completed to a high industry standard. Efforts need to be aimed at reducing liability around data, and opening up the avenues for sharing. The OGDE should help reduce agreements and open up opportunities for organizations to share their data. In addition, this provides incentive for acting on the issue of meta-data and data standards

Stronger communication around information would help ensure co-ordination, strong information linkages, and reduce different organizations from collecting duplicate data. Limitations on data uses need to be removed. While there is a tendency toward data use right now, the licensing process to gain access is increasingly complex and is close to becoming a barrier to sharing. The most effective approach is partnership

programs and projects, which have been successful at the GRCA. While history and relationships can negatively affect current efforts, new working relationships need to be established. Ultimately, leadership from the province in consultation with major partners is needed

Currently there is very little done at the provincial level to involve the public directly in part of the information management process. Senior managers from MNR and Conservation Ontario agree there is large potential to share data with the public, especially the rural community. The costs of bringing in information could be high if it were of poor quality, but if it were good quality, then the benefits would be significant. For example, ground water studies were supported by farmers who had "come clean days" in local communities and would show up for community meetings to identify abandoned wells at no risk of assuming responsibility to do something about them. Farmers are strong land stewards and could be very effective at adding values and attributes to data, as demonstrated in the ground water example by adding well location and farm/field use. Farmers would also be very effective at adding value to the nutrient management data rather than being forced to do farm plans. If they were brought in as a partner, they would more likely contribute benefit to existing data sets. Future goals for sharing information with the public may resemble the "Surf your Watershed" application provided by the USEPA While river data and watershed conditions are shared with the public, very little information is collected from the public. Future web-based applications may support more data collection using some sort of volunteer program, but the investment to process publicly collected data is high. Web-based applications may include something like a "map your farm" application to help support farm plans in

support of proposed Nutrient Management Act requirements. This type of application would allow farmers to identify vulnerable areas on their land using data provided by the CA, but may also provide a means of updating land use plan information. At this point, the workload is too high and the cost of making public data useable is too high. Currently, most public involvement is in the way of survey tools or education tools, aimed at either gathering public opinion or informing the public. Web-based applications will be more useful at social marketing (i.e. Fostering public interest) rather than as a data collection tool.

5.2.6 Information Management Technology

Technical compatibility is a major starting point for co-operative approaches to information management. While coming to agreement on data standards would be ideal, ensuring agreement on meta-data standards is a minimum for inter-agency co-operation. In addition, having centralized databases could produce opportunities where staff members throughout the organisation and in external organisations such as CAs who are ultimately responsible for that data layer maintain different data layers. In 1992, GIS software was standardised in favour of ESRI products and related Information Technology has been selected to support this product line. At this time, a relatively risk-free decision has proven to be a wise move as ESRI has emerged as the industry standard, which is now well implemented within the Ministry of Natural Resources. Other Ministries failed to make similar decisions and their respective I & IT capabilities have lagged behind. A new version of NRVIS will allow users to map at their desk, using a central database without the direct need of a GIS technician.

Information managers at the GRCA indicated a high-end hardware infrastructure supports the Information Management process. Using the state-of-the–art, industry standard ESRI product line, desktop access to data is provided throughout the organization using ArcView GIS 3.3, supported by Windows 2000, MS SQL server, ArcSDE, MS access front end, and full MS Office Suite access.

With respect to other CAs, Conservation Ontario staff commented there is a broad spectrum of information technology capacity and capability, based on a range of needs from one CA to another and varying budgets. The document management database at the Upper Thames, which allows users to search and access all files related to a specified subject as well as the Desktop GIS at GRCA both represent state-of-the-art capabilities.

Information management technology supports decision-making for watershed management provincially by providing the infrastructure to house, manipulate, and produce vast amounts of high-quality information. However, there are some inconsistencies between the land cluster ministries in their information management infrastructure, as some ministries have invested heavily in alternative technologies, such as Spans desktop GIS, PCI/Geomatica, MapInfo, or Idrisi, which are creating some data sharing issues, especially when trying to exchange information/data with smaller Conservation Authorities. Information management technology provides GIS, which supports resources planning in assessing planning documents through use of ortho-imagery overlays. The purpose of technology is to provide access to data, information, and knowledge, as well as to reduce time for data users. Eighty percent of a planner's time used to be spent looking for information, but GIS has reduced the search time by providing access to a centralized repository. According to two senior GRCA managers,

generally information management technology has reduced data and information access time, but has created workload issues around maintaining data and infrastructure, requiring continued investment and commitment. Over reliance on technology is another common problem as there is an expectation that it will provide the perfect answer. Information management staff from MNR, Conservation Ontario, and the GRCA agreed that practitioners keep trying to build 'the perfect mouse trap', that is, over investing in infrastructure rather than maintain well-trained expertise who can interpret results. Staff from MNR and the GRCA felt overall, technology is easier to use as it is supported by in-house training and user-interfaces are becoming friendlier. However, applications could be sped up through more custom querries for the most frequent uses, such as themes that are regularly used by planners. New technology needs to focus on improving existing data accessibility and analysis through the development of query related tools. Cost of technology and in-house expertise remain the most significant technology problems as they pose heavy burden to budgets.

A senior MNR manager feels compatibility issues within the MNR seem to be conquered through effective long-term planning and selection of appropriate technology. Custom application development is the toughest task that remains ahead, which requires further investment. However, compatibility across ministries and with CAs still needs to be refined in support of the OGDE.

Within the GRCA, there are relatively few compatibility issues. However, within the CA network, there are many challenges ahead. Given existing resources and immediate needs, smaller CAs tends to focus on local issues rather than trying to be compatible with other organizations. Overcoming this will require provincial leadership

and support, ideally by providing a framework for compatibility, based on minimum standards and current needs.

New technology needs to focus on users and provide access that is more direct. Development of more mapping tools needs to focus on desktop access, user friendliness, and information access. For selecting new technologies, the Internet and online user community groups are a major source of information. For the GRCA, existing technology does meet needs, but expertise with different technology is low. A senior GRCA manager provided the example that currently web-based GIS mapping is under review, however while there is sufficient technology to host such services, Internet GIS mapping programming expertise is low. New technologies are identified based on needs, complaints, obvious symptoms, product reviews, and community advice. Priorities are set and a business case is written for the upgrades, which is reviewed and approved by a committee. For smaller CAs, there is a major lack of technology and expertise. Investment in both is required to bring smaller CAs up to speed, which could then follow the leadership of medium size CAs that have made positive gains in this area.

Aside from corporate web sites describing projects and program activities, there is very little information provided to the public in support of watershed management. At the GRCA and for most CAs, the current effort is to provide real time watershed conditions on the web site. Eventually, volunteer precipitation monitoring data could also be provided. Internet technologies can support much greater public access to the system and data could be shared with the public. A user accounts system could keep track of who is using what, but could still be done free. Mapping tools can also be supported by new GRCA IT infrastructure. There were a wide range of GRCA staff who

felt a more open policy about data sharing would help local landowners understand the role of the GRCA and their responsibilities as land stewards. Online access does pose some serious workload issues, needs to be assessed for what the ultimate objectives are, and be scoped accordingly.

5.2.7 Internal and External Considerations

Political motives and issues can get in the way of sound technical information management practices. Optics around provincial politics can influence priority setting either negatively or positively, depending on the most pressing issues facing politicians and the provincial ministries are affected. For example, the Walkerton crisis has seen a substantial increase in funding to programs that focus on developing understanding of threats to drinking water. While politics is commonly associated with the provincial government, municipalities were identified by senior managers from MNR and the GRCA as a major political player relative to Conservation Authorities. Since CAs depend so much on municipalities for their budget, they are seen as the primary client. Most of the sensitivity surrounds the reporting of information and decisions affecting particular Municipalities. A long history with MNR, MOE, and the provincial government has had an impact on operations of CAs. Different visions of services and programs affect how they operate, and what is funded. Most progress to resolve historical relationships is made within departments, sections, and districts on an operational level where individuals play a large role. There is a perception of downloading by the province on the part of the Municipalities. They are convinced that the government will eventually come around and the downloading trend will reverse.

Staff members from Conservation Ontario and MOE feel this creates an atmosphere of inactivity, failing to recognize that the government has probably changed in some ways for the long-term. While political pressure can drive information management ahead, during times when there is less public interest in information related to watershed management, information management can suffer

Efforts are taken to involve everyone in the information management process, but at times, management is too busy to be involved throughout the process. Within the information management process of the GRCA, there is an effort to include all of the internal sections. However, among most other Conservation Authorities, the feeling is that the GIS crowd comprises the primary players. Provincial organizations such as the Government and Municipalities should have a larger role in an ideal world, but limited resources and traditional working relationships discourage changes in relationships. Additionally, there can be resistance to participate if time is scarce or knowledge of information management is low by individual staff members – there can be a reluctance to participate especially if it requires being a data custodian, which increases workload responsibilities. At the GRCA, staff indicated they are always trying to enforce the corporate approach to data by increasing connection to each of the sections; an effort aimed at reducing the natural tendency for individuals to isolate their data. At many CAs, there is a tendency to include everyone, but at some level, in practices, it does not always happen because resources are so scarce. Often, minimal work will be maintained rather than ensuring everyone is represented if budgets are tight.

Overall, job transition is something that has been handled poorly and knowledge loss is significant. Unfortunately, too much expertise is currently lost. A senior manager

from the GRCA agreed greater effort is needed to ensure full-time staff receive more training opportunities including conferences and in-house training; however, sufficient salary resources remain the biggest obstacle to maintaining staff. For the most part, low resources are the most significant barriers to ensuring adequate job shadowing and knowledge sharing. While there is some succession planning, most knowledge sharing within the GRCA is handled through osmosis or events such as the Water Forum and with very little done in the way of planning. As with most Conservation Authorities, there is a tendency to deal with it when it happens, which has a significant impact when massive events such as the downsizing of 1996 happen – an event most CAs are still suffering from in terms of loss of expertise.

Considering the size of provincial ministries, internal boundaries do not pose too much of a barrier. Working relationships are established through working matrices, which embed necessary expertise and communication in different sections. As with most CAs, at the GRCA the hierarchical boundaries between staff are informal and relaxed. In fact, many CAs are too small for this even to be an issue. With respect to information management, GRCA staff boundaries serve as a means for setting priorities and ensuring the appropriate channels of communication. For the most part, the culture of the organisation is very open and people exchange information well amongst each other. There is a continual conscious effort to maintain this. Leadership in IT has a strong influence in setting the right culture and preventing individuals from becoming silos of data. For example, one GRCA staff member complained it is difficult to make your own database because it is forced to be co-ordinated with I & IT. However, by developing a database in collaboration with I & IT, they are able to support your

development technically and possibly contribute resources if the database fills a larger void within the organisation. Unfortunately, some individuals attempt to keep their information from being found by I & IT. The most significant barrier remains that of technology and those individuals who prefer to avoid it.

The path of information from creation to use is not always completed. However, the province and the GRCA have employed a similar approach where often the keeper of knowledge is a user and the collector of the information. By assigning *custodians*, users who are most likely to be concerned about the data quality are given the responsibility of maintaining it. There is still a tendency to expect staff working in GIS sections to be accountable for data, but this is slowly changing. While there are many opportunities and avenues for end users and collectors to communicate at the GRCA, this still does not happen as much as it should. There is a strong spirit of pride and innovation at the GRCA, which is partially fostered by a sense of independence. This independence can result in some breakdowns in communication. Some groups are virtually entirely data consumers, such as resource planners, who use far more information than they produce. As such, a GRCA senior manager identified there is an effort to bring the groups together and provide more information and interaction through as many means as possible, especially electronically. Across the organisation, data collectors are required to be data custodians for data layers as they are expected to be the ones most concerned about quality, integrity, and maintenance. However, there has been a need voiced several times for a more regimented approach to recording information electronically and ensuring it is made available to the rest of the organisation.

Obviously, many different factors can influence information management within an organisation, including culture, leadership, and modes of communication, other systems, and structures. With the MNR in 1997, not every desk even had a computer – in the past few years, everyone has had a computer, and in the next 5 years, staff will start getting access to central data libraries and inventories. Mapping using light versions of software will also be possible and will not require a GIS technician to be a part of the process directly. An information manager at MNR believes a central database will support all higher-level information management objectives by increasing access and usability of the data. A commitment to such an initiative will be the dependent variable, as such, a project requires long-term investment before it really begins to demonstrate its value. Such efforts have been tried in the past and commitment did not last long enough for the projects to be successful. Fortunately, lower technology costs and higher information management potential should help maintain interest in current efforts. Data models that can potentially make better use of existing information are also very promising, as efforts are underway to adopt and implement new capabilities, such as ArcHydra™ are promising for watershed management.

Major changes in organisational funding in 1995-1996 resulted in organisational restructuring and reprioritizing of services and programs that is still reflected by today's activities. The most significant changes to the organisation are the 1996 budget cuts by the provincial government. This sent the GRCA looking for new sources of income, which it found with the municipalities. Less provincial money meant less provincial involvement on the board, giving the new financial sponsors, the municipalities, and a larger voice on the board. The new composition of the CA board resulted in the

municipalities having a larger role in decision-making and priority setting. Since many of the municipalities carry out their own information management for their local regions, they put a lower priority on investing in information management at a watershed scale.

Generally, at the provincial level, there is a very good base budget for information management related infrastructure, but it does not translate to people. For example, the Ministry of Natural Resources, as the lead agency of the I & IT cluster, has all of the essential hardware, software, and data, but lacks sustainable funding to maintain core competencies in full-time staff. Data maintenance is usually undervalued. One strategic technique identified by an information manager at MNR for maintaining investment in older data sets is to assign a meaningful data value to it and then to slowly depreciate that value if updates or maintenance have not been made. This provides a meaningful way for project and program leads to recognise the priority of maintaining and updating their data sets. Unlike most CAs, within the GRCA, resource levels are satisfactory as far as technology and data are concerned. However, staff resources remain very lean since the 1996 cuts. It was speculated that most other CAs would complain that all resources levels would be low. Database training, Internet GIS expertise, internal communications and liaisons, and human resources were identified as areas with low resources. One advantage within the GRCA identified by a senior manager is its size, which enables it to achieve many resource goals without more investment i.e. adequate resources for many similar tasks, so capital investment has already been done, and organisational culture is maintained by a core group, even with turnover. Practitioners from MOE, MNR, Conservation Ontario, and the GRCA agreed the most sacred resource remains individuals in partner organisations who are supportive of the GRCA's efforts and

generally make life easier. Key individuals are critical to getting the important work of watershed management done when higher-level politics can be a barrier.

With the rapid development of information management, many organisations have been going though a lot of change and development. Other developments within an organisation can also have an impact on information management. Some of the most significant changes in information management come from other major projects and new technology, which have helped information management practices evolve. Lands for Life (1999) helped the ministry to expand its information management practices, opened its data sharing policy through partnerships, and resulted in the province facilitating public meetings using new data map products. A relatively new position, *Information Co-ordinator* has been created and used across the Ministry of Natural Resources. This position is intended to optimize resources around information management, ensure information and business needs are aligned and embedded in projects and programs. A current technology aim of the province is to improve Desktop GIS capabilities and centralize databases wherever possible. This should increase the access to data and information. With technology changing, the approach to information management has been changing. GIS has had such a deep and far-reaching impact on the business of environmental management that people have become familiar with information management technology and related practices.

Projects like WRIP have been important for starting to solidify standard approaches to information management across CAs and raising awareness of pertinent issues. Expectations have also changed. People believe more is possible than is feasible as it is very easy to oversell the technology. Across the Conservation Authority

movement, primary incentives of deadlines and funding, driven by the political priorities set by the province and municipalities, continue to focus on getting things done versus getting things right. Although the GRCA recognises the benefits of sharing knowledge of best management practices within the CA community (i.e. improving the effectiveness of the CA network), municipalities as the prime client recognise this knowledge as an asset and expect it to be used on a cost recovery basis. Additionally, there has traditionally been poor communication within the CA network, so there is no habit established for "spreading the word". In general, the GRCA is willing to take a risk and learn from its mistakes, by taking a leap of faith; some of the most fruitful lessons are learned through trail and error.

While this section has identified a number of areas where there were common findings around information management from the interviews, there were a few notable areas where respondents disagreed on information management. Of particular note, the merit and value of information technologies for connecting to the public and sharing information were questioned. While many agreed that this was a worthwhile direction for development, some staff from the GRCA, MNR, and MOE felt that it would consume more resources than it was worth. In addition, several staff members from the GRCA, MNR, and MOE disagreed about the role of politics and values in information management, and considered it a much more pragmatic process. Finally, while most respondents were supportive of the Conservation Authorities having a larger role in watershed management in the Province, including more responsibilities, some staff from the GRCA, MNR, and MOE identified weaknesses inherent in the Conservation Authority structure. Weaknesses included unsustainable resources and conflicting

municipal interests as reasons why Conservation Authorities are not a reliable to assume full watershed management responsibility. Overall, there was strong support for information management and Conservation Authorities to have a stronger role in watershed management from the Conservation Ontario, MOE, MNR, and GRCA staff interviewed.

5.3 REVISITING THE FRAMEWORK FOR INFORMATION MANAGEMENT

This section synthesises the interview discussion and relates the lessons learned to the evaluative framework for information management. Essentially, this section pulls out of the interviews the practical information steps identified and attempts to summarise how practitioners in strengths, weaknesses, and challenges facing information management for watershed management.

INFORMATION PLANNING

With respect to information planning MNR, MOE, Conservation Ontario, and the GRCA identify many of the same factors identified in the original framework as essential. Information planning represents the planning phase where practitioners must decide how their efforts and available resources will be allocated in the pursuit of a deeper understanding of the watershed. This begins with interpreting the goals and objectives of the organisation in terms of data and information priorities. Decisions affecting the nature of the entire process including costs, timelines, research techniques, management units, format, and quality issues should all be addressed during this phase. Ideally, such decisions will cause practitioners and organizations to consider their research needs, values, management approaches, anticipated system changes, on-going

work by other groups or organizations, historical events, system processes, long-term community needs, and existing information.

One item that was stressed more by practitioners than in the framework was in designing the process, all of the experts, practitioners, data producers, and data consumers need to have a stake in its development. Too often, there are high-level bureaucrats or managers present and an absence of adequate information management experts, scientists, and/or researchers. Any resulting information management approach fails to ensure optimal use of capacity, resources, and collaboration opportunities. Through the interviews, managers from MNR and Conservation Ontario agreed that having experts demonstrate technical capabilities and information needs improves the understanding of bureaucrats and is an important step in resolving this. Through this exercise, bureaucrats and managers can learn from the process and redefine their expectations.

DATA GATHERING, PRE-PROCESSING, AND MANAGEMENT

The interviews supported the data gathering, and pre-processing, and management element of the framework. Beginning with information gathering, efforts to collect data and information from sources may include new data or existing data internally or externally. Other important information considerations include scale, quantity, quality, research techniques, and data types. Types of data and information could consist of any or all of the following: Biophysical and socio-economic; scientific and non-scientific; or, quantitative and qualitative. As data and information are collected, pre-processing steps refine, transform, and manipulate the data into more manageable and useable formats.

However, pre-processing techniques raise data quality, error, and integration issues (i.e. integration of biophysical and socio-economic data and scientific and traditional or local knowledge), which make it important for data standards and meta-data to be considered and documented for future formatting, sharing, and analysis purposes. The need for adequate meta-data was stressed throughout the interviews by staff from all of the organizations involved. With respect to data storage, database management issues arise, including data integrity, security, and user accessibility. Obvious matters of archiving and storage capability arise, as well as usability and functionality of the data for specific software applications and information systems. So many senior information management staff from MNR, MOE, Conservation Ontario, and the GRCA commented that the infrastructure for processing and managing the data needs to be adequate, as does the expertise to handle it. Sound infrastructure needs to be well thought out based on current and probable future needs. This point about robust technology infrastructure needs to be addressed specifically in the framework.

Information sharing and, more generally, co-ordination and co-operation between organizations and interest groups are important and usually desirable; however, interaction between organizations and groups is inherently complex due to the nature of the relationships and history between the parties involved. Manipulation of data after collection and pre-processing adds value to the information, making it more desirable especially by external parties. However, for the controlling agency, the information represents a great deal of work and investment. In general, it can be difficult for organizations to recognise the altruistic value of sharing knowledge with other parties, but disseminating knowledge is an important part of gaining support for ideas, verifying

findings, and furthering the interpretation and learning process. In this phase of information management, there are a number of considerations including dissemination, accessibility, sharing networks, public participation, data utilisation, user interfaces, stakeholder involvement, and both interagency, and intra-agency co-operation.

DATA PROCESSING AND ANALYSIS

A range of staff from MNR, MOE, Conservation Ontario, and the GRCA supported the data processing and analysis element of the framework. Once information has been gathered and adequately prepared, manipulation and analysis is possible, which involves interpretation and examination of the data and information. Technology offers many powerful tools in the areas of manipulation, analysis, and visualisation in aiding experts working with the data. While technology does provide many advantages, it can also be easily misused or used ineffectively. Ultimately, expertise behind the technology is critical; ensuring data manipulation and analysis is meaningful, avoiding any misinterpretation. This being the case, there is no replacement for having competent staff to work with the information. Processing and analysis provide an opportunity to refine, improve, and learn from the data and information. Staff from MNR and the GRCA agreed this step is instrumental in optimizing data and information efforts so far leveraging potential knowledge based on investment in information management to date. One additional item to identify in the framework is that the data/information used for processing/analysis is both timely and appropriate. In addition, with respect to how it fits within the watershed management iteration, data processing and analysis needs to also

occur using information generating through monitoring, and should be reflected in the framework.

PROCESS TRACKING

Process tracking was identified by staff from MNR, MOE, Conservation Ontario, and the GRCA as an underachieved part of information management currently in the province of Ontario. As watersheds are systems under constant change and pressure, monitoring and process tracking are a vital part of the information management cycle. Identifying change, new threats, and pressures, helps identify new information needs and new management direction. Unfortunately, process tracking is usually a cost intensive aspect of information management and sometimes shows little reward. A range of staff from MNR, the GRCA, and Conservation Ontario felt a strategic approach to monitoring and process tracking should make use of partnership opportunities and aim to have a representative monitoring network based on needs and threats rather than a comprehensive grid, which may result in over-investment.

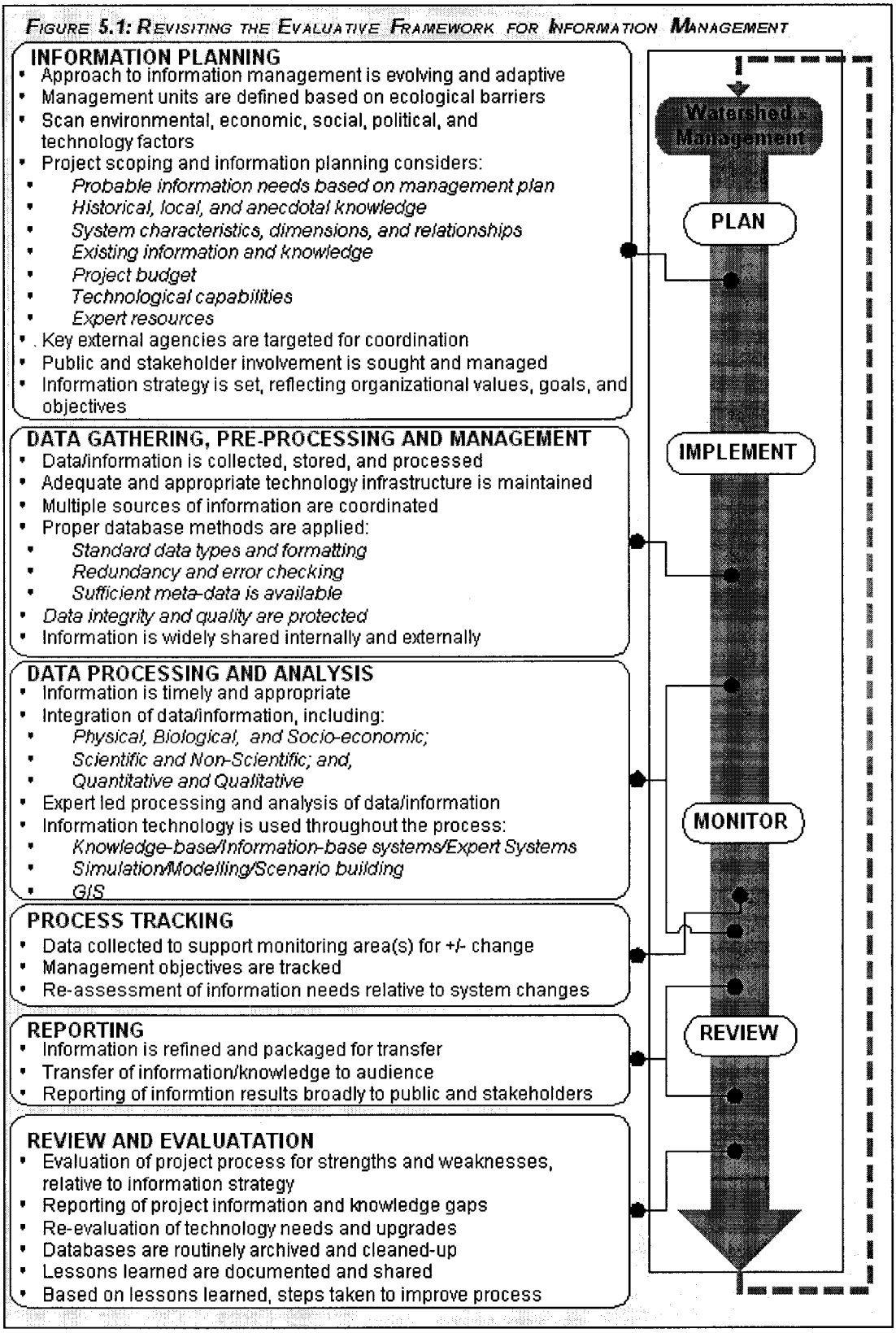
Several staff members from the GRCA and Conservation Ontario felt an element of the framework that needed to be emphasised more was the notion of reporting. Since the purpose of information management is to gain new information, which can be transferred to others, generate new knowledge and understanding, make decisions, and ultimately effect change, reporting has a critical role in transfer and communication. Process tracking as an element will be split to include reporting as a separate element in a revised framework. Reporting will then flow into review and evaluation of information management.

REVIEW AND EVALUATION

Staff interviewed from all organizations supported continually improving approaches to information management based on changing needs and lessons learned. Perhaps the most important element of information management is the development of the process itself. An important tenet of ecosystem-based approaches to watershed management is that management itself is an ongoing process, improving based on iterative learning. Similarly, information management must be ongoing and adaptive, ensuring continued support for the decision-making aspects of watershed management. Adequate monitoring and reporting of changing information needs allows practitioners to improve information management iteratively. Keeping up with technology developments is also important in continuing the process.

Figure 5.1 illustrates a revised framework based on the changes identified through the interview process. This framework is applied to the GRCA in the next section.

FIGURE 5.1: REVISITING THE EVALUATIVE FRAMEWORK FOR INFORMATION MANAGEMENT



5.4 APPLYING THE EVALUATIVE FRAMEWORK

Based on the knowledge and experience gained from this research process, application and deeper consideration of the information framework allows for a number of results. First, the application of the framework to the GRCA demonstrates how it can be used and functions by describing and evaluating the GRCA information management practices. This section applies the five elements of the Evaluative Framework for Information Management to the GRCA, i.e. information planning; data gathering, pre-processing and management; processing and analysis; process tracking; and, review and evaluation. Based on the application of the framework, each section provides evaluates the current practice or condition found at the GRCA.

Information Planning

For the GRCA, information planning is mostly an informal process by comparison with the watershed management process. Both an environmental scan and a strategic planning process support watershed management planning. While information management considerations are tied to this process, it seems to affect high-level directions related to information management, rather than to prescribe a path for how information management will support business services and programs. A senior manager from the GRCA indicated the GRCA management, technical committee, and information services continually review needs and processes for information management. An informal working environment allows for feedback between users and collectors. The Technical Committee should be used on a more regular basis as this presents the best opportunity to open lines of communication across the organization.

Management is done on a watershed, sub-watershed, and site basis. If anything, consistency across the watershed is difficult due to its large size. This causes problems for data collection and monitoring. Data priorities to support watersheds as a management unit are based on a mix of factors including the ecological, financial feasibility, and municipally significant areas. Several staff members from the GRCA identified that to improve the consistency of data and information across the watershed will require more resources, and a more consistent watershed management effort across the watershed at all scales. To achieve this, political and public perception must change to prioritize information management needs

The GRCA conducts PEST and SWOT scans on a yearly basis, as illustrated for the year 2003 in Table 5.1. Such planning activities provide clear and common corporate assessment and direction for information management. A senior information manager felt as a part of the corporate strategy that these scans should be more clearly associated with the actual implementation of information management through linking to information goals and objectives with specific tasks. Additionally, these information management tasks need to be assessed regularly as the organization changes direction with either new legislation or environmental issues, which may have an impact on the information management goals.

Based on a strategic vision (i.e. The Grand Strategy, discussed in Chapter Two) and input from the board of directors and staff, the GRCA has a very well defined strategy that ties in information considerations. As a part of the corporate strategy, an information plan is completed at annual, three and five-year intervals, considering the needs of the organization (See Table 5.2 as an example). In addition, staff members from

the GRCA indicated that Information Services strives to ensure that sections and project teams have someone knowledgeable regarding information management embedded on the team. Finally, project teams looking for support from Information Services must complete a project information form, which assists in planning for information needs. As was identified from the interviews, the Technical Committee should have a larger role in identifying corporate information needs, with the help of a systematic process for setting priorities and determining workload issues related to either acquiring new data or updating existing data. Strategy could be better linked to specific tasks and a more transparent process for setting priorities is needed.

Through partnership projects with municipalities and the province, the GRCA is involved with many external organizations. Participation in projects like WRIP and membership in the OGDE offer the most potential in this area. Past grudges need to be forgotten at all levels of the organization and a more efficient means of sharing agreements and IP rights needs to be found. Through education programs, the GRCA is very good at involving the public. Additionally, planners frequently make field trips to interact directly with stakeholders. However, direct public involvement in information management is low. Information managers from MNR, MOE, and the GRCA recommended where it is feasible (i.e. considering workload and resource issues), more dynamic content, and information should be provided directly to the public. Web applications hold the most potential in this regard.

TABLE 5.1: GRCA ENVIRONMENTAL SCAN SUMMARY	
External Situation Analysis	
Political	Social
• Privatization, alternative service delivery models • Partnership with MNR continues to become less significant • More program delivery for other ministries & fed's • Major legislative changes: Nutrient Management Act, new Municipal Act, Smart Growth • Province directing more delivery service to municipalities • Municipalities want more service from CAs • Walkerton Recommendations call for watershed mgmt	• New focus on water quality, groundwater protection • New recognition of responsibility for drinking water quality in our facilities • Higher community expectations re: water quality, protection of environment, natural/human heritage, service • More public input on GRCA's decisions
Economic	Technological
• Levy has increased, no further increase available short term • Tightened budgets at all levels of government • No cost-sharing arrangement with Province, shut out of provincial funding to municipalities and NGO's	• Market demands faster service • Customers want "electronic" products (GIS, internet reservations, etc.) • Changing nature of work • Technology is rapidly increasing our ability to manage and analyze information, and expectations for this • Growing reliance on the Internet as a communications tool and source of information • Increased reliance on service delivery systems • Security and privacy
Internal Situation Analysis	
Strengths	Opportunities
• World-renowned Governance model • Highly skilled workforce, low turnover • Technical competency, respected expertise in Watershed Management • Extremely valuable infrastructure • GIS data, ortho-imagery, modeling systems, etc.	• In a good position to assume new roles after Walkerton • Consulting • Expanded role • Inter-agency program/service integration
Weaknesses	Threats
• Aging Infrastructure • Internal policies/procedures out of date • Lack of sustainable sources of funding tied to service expectations • Recruitment in a competitive market • Flat organization means poor advancement opportunities	• "Brain drain" resulting from retirements • Budget challenges re: positions, tools, etc • Service expectations exceed resources • Insufficient provincial support for CA model • Walkerton recommendations increase demand for our staff skills
	Source: (Grand River Conservation Authority, 2002b)

TABLE 5.2: GRCA GOALS THAT RELATE TO INFORMATION MANAGEMENT	
Maintain Financial Sustainability	• Update Business Plans for Conservation Areas - re-assess positioning, marketing approaches, expansion/contraction of services, pricing • Evaluate Business Plan for a new Conservation Area (Puslinch) • Assess feasibility of cabins at selected sites • Implement marketing plan to establish new "special events" • Establish new business partnerships with hunting/fishing groups • Review concessions, identify opportunities for improvement
Provide Quality and Value	• Develop visitor services guidelines • Implement "Standards for Clean Facilities" prepared in 2001 • Resolve conflicts between user groups through public process • Implement inspection program for deficiencies & vandalism • Replace workshops, showers etc. • Add interpretive signage to enhance visitor experience
Maintain a Healthy Corporation	
Maintain effective system for Governance	• Ensure effective system to allow appropriate municipal appointments (geographic distribution, fair representation, involved members) • Ensure board has appropriate knowledge/expertise of Conservation Authority's role and watershed issues (orientation & training) • Maintain effective system for board to provide clear direction (Bylaws, Committee Terms of Reference, Meeting Schedules, Record-keeping) • Facilitate effective communication between board and staff • Actively support Conservation Ontario (membership, project cost-sharing) • Influence Province in re-defining relationship with CAs • Provide input to changes in legislation (CA Act, Regulations etc.)
Achieve financial sustainability	• Increase the general levy annually by an amount that offsets budget increases due to inflation • Get Provincial agreement on cost-Sharing for capital (for Water Management Infrastructure) • Operate Conservation Areas in a self-sustaining manner • Implement agreements with School Boards and Foundation re: Outdoor Education Programs • Pursue other sources of funding (Federal, Corporate, Foundation, etc.) • Actively market the Authority and the Foundation as potential recipients of tax-deductible charitable gifts (Cash, Gifts in Kind, Ecologically Sensitive Lands, etc.)
Enhance GRCA's image and profile	• Develop forums to improve relationships with existing partners (municipalities, MNR and other provincial ministries, federal government, Corporations, Community/Volunteer Groups) • Increase profile outside of the watershed by providing service (at cost recovery) to international organizations & developing Countries • Gain ISO 14001 Accreditation • Use web site in a creative, effective manner
Manage GRCA's assets in a responsible manner	• Develop land acquisition policy • Generate revenue from lands if appropriate to GRCA's Vision/Mission • Dispose of surplus lands where appropriate • Establish emergency plans for major dam structures • Maintain a long-term plan and capital forecast for infrastructure maintenance • Decrease infrastructure maintenance deficit over the long term

TABLE 5.2: GRCA GOALS THAT RELATE TO INFORMATION MANAGEMENT	
Maintain leading edge support systems (people, technology)	• Conduct salary/wage survey and adjust grids if necessary • Establish training committee. Integrate training plan into the annual budget. Monitor & ensure training plans are implemented. • Establish Employee Recognition Program for service & performance • Update head office workstations to be more ergonomic and effective • Assign health & safety responsibility to specific position(s) • Establish technical committee to set priorities for systems development and improve inter-departmental communications • Finalize IT staffing plan and continue to hire Qualified technical staff • Continue investing in information technology and systems for Administration, Human Resources and Conservation Areas
Source: (Grand River Conservation Authority, 2002b)	

Data Gathering, Pre-Processing and Management

Scientists working in different business areas conduct data gathering. Information services staff are also responsible for collecting information from other organizations. GRCA uses a central warehouse to house all of its data including sources external to the GRCA. All data is prepared before it is allowed into the warehouse. A range of staff from MNR, MOE, and the GRCA felt that data collection can be increased and improved, including the density of water monitoring network stations, water quality stations, and climate data. In addition, collection of information gathered through resource planning and approvals could be made more efficient. Depending on the use and application of the web, some data could be collected from the public. Sources include municipalities, consultants, and both the provincial and federal government. Staff from MNR and Conservation Ontario agreed efforts need to be aimed at making data sharing more efficient, removing barriers, and reducing workload around data coordination. In-house expertise covering database structure, maintenance, and related issues supports all of the GRCA's information management. While they are fortunate to have such expertise, industry standards are still evolving and efforts need to continue to work to improve data standards, archiving, and use of industry standard meta-data.

External to the GRCA, information is available to those who request it through a data sharing agreement. There are many concerns about the open sharing of data with the province, federal government, or other organizations, including intellectual property rights and cost recovery. With respect to the public, watershed conditions are provided on the web site, but there is very little substantive watershed data shared. Based on the interviews and respones from MNR and Conservation Ontario, there is a need to encourage widespread data sharing and involvement in watershed management that includes the public through web application development.

Data Processing and Analysis

In-house experts provide interpretation and analysis of data and information. Implementation of ArcSDE and strict meta-data standards support dynamic integration of all data stored in the warehouse. Information technology is state of the art at the GRCA especially the desktop GIS and information warehouse. Staff identified further development of technology including query building, modeling, scenario building, and simulation. In addition, web data is largely undeveloped at this point.

Staff would benefit by having a clearer sense of the Information Management picture and direction. According to staff at the GRCA, involvement of the public in information management is non-existent, so strategies for including more local knowledge from the public need to be explored, including the necessary infrastructure, expertise, and possible types of information that could be included. However, workloads facing information experts are already high so public involvement would need to come with more staff resources as required to support GRCA activities and workload.

Process Tracking

Depending on the project or program at the GRCA, there can be either formal or informal activities aimed at determining the impact of management activities and changing conditions. Management objectives are revisited at least on an annual basis as a part of the planning process, but for the most part management objectives are considered a part of a living document that is actively used and updated. Two senior managers at the GRCA agreed objectives need to be revisited more often and changing objectives need to be tracked. Information needs are reassessed primarily based on need, as users tend to discover data needs while working through projects. A regular approach to assessing data needs would be beneficial and could be facilitated by an intranet application.

Reporting

Reporting remains a challenge for the GRCA. A lot of information is not reported on as well as it could be. Improved reporting would help better identify information potential, needs, and gaps. A standard reporting structure could be effective using an online application. While reporting to municipalities is very effective, at this point, reporting of information is not done uniformly across the organization. Monitoring data is collected for water quantity and quality primarily. Many other areas of monitoring need to be explored and the monitoring networks for water quality and quantity need to be improved.

Review and Evaluation

GRCA conducts continuous reviews of its management activity rather than incremental. This approach is still being refined, but ensures that management planning

receives adequate feedback. Informal working relationships, formal strategic processes and technical committees all provide feedback to the information management process. According to several GRCA staff, Information Services meets regularly as a project team to assess progress and determine next steps. Since information management makes up so much of the GRCA's business, there is an opportunity to conduct a more formal review of information management efforts as a part of the larger strategy process. There is no formal direct report process but interaction by embedded staff members and project team members provides a venue for acknowledging information and knowledge gaps. A reporting forum or process should be provided. This also requires a system for determining data priorities. GRCA has proven that it is a learning organization, benefiting from its own successes and failures in terms of lessons learned. One senior manager suggested there are many opportunities for more documentation of lessons and sharing with the wider CA network, which will raise the bar between other CAs. This will benefit the GRCA in the long-term as other CAs become more able to share lessons back, as well as raise public support for Conservation Authorities. Those involved with information management are continually working to improve the process, however, at this time it is not directly linked to formal organizational strategies. By linking information management to the main organizational strategy, information goals and objectives will better support GRCA programs and projects.

With respect to technology, the data warehouse is continually being maintained; however, archiving has not been fully maintained. A new suite of tools included with ArcSDE will enhance these efforts. Several staff working in information management indicated that more attempts to educate the organization and instil an appreciation for

processes such as data maintenance, archiving and cleaning to ensure adequate support and allocation of resources need to be made. Currently Information Services assesses information capabilities and needs and ensures adequate refreshes are made. Technology upgrades need to be modular so replacements can be targeted, customized, and minimised.

5.5 SUMMARY

This Chapter has covered the interview results and lessons learned around information management. The aim has been to share a sense of where information management is at the GRCA and within the province. This has served to help identify key strengths and areas for improvement for the GRCA, the province, and watershed management practitioners in general. The last Chapter will draw some conclusions around Information Management, identify some limitations, and make some suggestions for future research.

CHAPTER SIX – CONCLUSIONS

6.1 REVIEW OF ORIGINAL PROBLEM AND OBJECTIVES

As stated in the introduction, the watershed has emerged as a suitable management unit for co-ordinating environmental and water management efforts across municipal, regional, and provincial boundaries. As an approach, it considers human activity across the watershed rather than parts in isolation. This has proven to be effective, especially as it relates to land-use planning and flood control. Upstream users are required to consider downstream communities and environmental integrity. Problems associated with resource use typically stem from activities that cause unexpected or cumulative impacts downstream. Solving these problems requires sound information about the consequences of actions (Grand River Conservation Authority, 1998ep.1-2). However, watershed management not only requires sound information for decision-making but the scale and complexity of the watershed compound the amount of needed information. A larger region with more communities and human pressures acting on it requires more information, requiring an effective approach to information management.

Management on a watershed basis still presents an enormous challenge to practitioners who have developed either a formal or an informal means of information management designed to support decision-making and planning. As was identified in the first Chapter, these efforts usually include data collection, data processing, data management, analysis, and reporting. This research has considered these major elements of information management and the challenges associated with each within a watershed management agency. Specifically, the research set out to meet the following objectives:

1) To identify the information challenges and opportunities in watershed management organizations in Ontario and elsewhere

2) To develop an evaluative framework for information management useful for watershed management organizations

3) To apply it to the GRCA and identify opportunities for improving information management at the CA and in general in Ontario

With respect to the first objective, the state of information management in Ontario, practices around collecting and managing information are improved. Information technology issues, including both hardware and software are well in hand and technology continues to evolve, providing lower cost solutions that are more scalable. However, information management is not in an optimal state in Ontario as significant challenges include poor information planning, insufficient resources, the scale of watershed problems, conflicting agendas between different levels of government, dysfunctional co-ordination among watershed organizations, lack of an information culture within the watershed agency, virtually no project tracking, poor information reporting, and loss of expertise. Addtionally, some trends within information management such as the rise of data sharing agreements and concerns around intellectual property rights is resulting in agencies restrcing their access to information and limiting data sharing, rather than improving accessibility. As the success of watershed management depends on it, watershed organizations in collaboration with each other need to set a clear vision for information management within the province and embrace these challenges.

For the second objective, the evaluative framework presented in Chapter Three, evolved as a result of the interviews and was then applied to the GRCA in Chapter Five. This provided a means to consider information management challenges facing the GRCA, facilitate a clearer information management strategy, identify ways of reducing inefficiencies and barriers to effective watershed management, and provide a means of evaluating information management practices as they relate to planning, management structures, approaches, policies, and practices. As an example, the framework was applied to the GRCA in Chapter Five, providing a sense of the agency's practices and identifying some areas for improvement with respect to information management. While the framework would likely evolve further with application to additional cases, in its present form, it captures the best management practices and innovative approaches practiced by an organization such as the Grand River Conservation Authority.

The final objective, discussed throughout Chapter Five is clearly summarised in this chapter as specific recommendations are made regarding information management for the GRCA, smaller, rural CAs, and the province of Ontario. In general, information management needs to focus on setting information priorities, establishing meta-data standards, improving access to information, sharing resources, and maintaining core expertise. The next few sections expand on research objectives, make recommendations for information management, assess research limitations, and identify possible future areas for research.

6.2 RESEARCH PROCESS AND OUTCOMES

Information management is still a young tool of watershed management. It is likely evolving at a faster rate than watershed management itself and suffers many similar

organisational challenges. Using a case study approach to explore an evaluative framework has provided an opportunity to document the approaches taken by a watershed agency that has demonstrated innovation in the area of information management. The Grand River Conservation Authority is an example of the state-of-the-art in information management within the province of Ontario. Information management planning is a semi-structured process in most cases, with most formal considerations occurring throughout the strategic planning cycle. Individuals within the organisation who collect information are responsible for maintaining information functionality and accessibility for wider use. Using a centralized database, information is accessible throughout the organisation, as is meta-data. Technology has reduced the time needed for information management and increased the capacity of individuals to work with more information by providing tools such as desktop GIS. Future initiatives will likely include making more information available openly and involving the public in the process. Internal challenges include the analysis process, tracking, evaluation, and reporting. However, the most interesting challenge ahead remains how various organizations within Ontario will work together and possibly combine their information management efforts.

The interview and literature search provided an excellent means to learn about the GRCA as a case, but also other Conservation Authorities, Conservation Ontario, different levels of government including municipal, provincial, and federal. As a result, where the research was originally going to focus on just the GRCA, various iterations of research made it apparent that the role of information management in a watershed management context depends on shared roles and responsibilities. This is reinforced by the Patuxent watershed example described in Chapter Two, where numerous levels of government and

various stakeholders have collaborated together to implement a sophisticated information management system. Similarly, the example of the CVC demonstrates many information management projects integrated across the organization, depending on sources of data and resources both internally and externally.

In addition to the state of information management for watershed management documented in Chapter Two, this thesis has delivered an information management framework (Chapter Three; discussed and revised in Chapter Five), an evaluation of the GRCA case (Chapter Five), and will make recommendations for improving the condition in Ontario based on the discussion (Chapter Six). It is hoped the information management framework presented, in addition to the other objectives will be of use to watershed practitioners who are addressing this various challenges that have been noted.

The next section presents recommendations for watershed organizations. As a product, the evaluative framework offers practitioners an opportunity to consider elements of information management and identify effective areas for information management improvement.

6.3 Recommendations and Lessons Learned for Watershed Management

Concerning information management, it is clear from the interview results that the GRCA is considerably ahead of many other CAs. Unlike other CAs with smaller, diffuse populations, the history of flood damage in the watershed and urban development in the region forced an organized response to flood damage reduction and watershed management. With a number of large cities and towns within the watershed, a large population has provided a strong tax base to sustain the growth of the GRCA. At the

GRCA, many practices around information management represent the current state of the art and/or are considered best management practices amongst watershed practitioners. This section tries to draw the best of the lessons learned from the GRCA, the wider literature review, and some specific recommendations for watershed management practitioners. In some cases, the practices of the GRCA far exceed the capacity of smaller watershed organizations. However, this section attempts to conceptualise points that can be interpreted at different scales. Where it fails at this, some additional points are offered to smaller watershed organizations following the generic recommendations to compensate. The following recommendations are offered to those involved with watershed management organizations looking to ensure their information management is effective:

General recommendations to all watershed organizations:

- Develop an effective, transparent way of priority setting for information management. Scarce resources are evidently a problem for all organizations involved at both provincial and regional levels. Given the cost of information management and shrinking operating budgets, organisations will find it increasingly difficult to maintain information management investment. Organizations need to adopt a systematic approach to priority setting and resource allocation to maintain information management.
- Conduct effective cost/benefit analysis of information management. Getting maximum value out of existing and planned data, time, resources, and capabilities all pose constraints on data management and analysis. Part of the solution here lies in setting priorities. More work on assigning costs per decision based on information

needs to be done so there is an understanding of what gaining more understanding actually costs. Ensure that information management practices and systems are cost effective and account for necessary staff requirements. This is the only way to bridge fluctuating funding cycles.

- Produce useful information. Managing resources can be easier than managing the affected people. Information management needs to consider this and use it to refine information that supports changing behaviour
- Ensure interpretation and use of existing information. More focus on interpretation to further refine the data and ensure benefit for decision-making purposes should happen
- Develop effective monitoring to provide project/program tracking of watershed management efforts. Monitoring provides the means to learn the effectiveness of activities to date and adapt improved management efforts including information management practices.
- Report on all information and information management related projects. Information reporting needs to be a part of every project to ensure the results shared and the rest of the organisation is learning from the experiences. Reporting strengthens the awareness of existing and planning information across an organisation, establishes linkages to projects in other organizations, and helps stretch the information resource.
- Integrate expertise across programs and projects. Wherever possible, embed or consult an information management expert early on a project to ensure information objectives are in line with and co-ordinated with efforts from other parts of the organisation.

- Involve the public for both education purposes and data collection purposes. This is an effective means of influencing public behaviour and awareness of watershed concepts and improves the availability of alternative sources of information.
- Find efficiencies through collaboration and co-ordination with other organizations on data collection, maintenance, processing, and use.
- Invest in information technology that is versatile and scaleable. The ability to build custom applications on top of existing infrastructure allows the organisation to grow and react to the needs of the day.
- Maintain information technology to industry standards or at least to an equivalent level of primary partners' capabilities.
- Define an information management plan and revisit as a part of the corporate strategy planning process.
- Work with partners to define information and meta-data standards to facilitate data sharing and co-ordination.
- Work with partners to define roles and responsibilities for watershed and information management.
- Learn from partners about the state-of-the-are of information management through collective learning opportunities such as symposiums or conferences
- Identify common goals and capabilities in collaboration with other watershed stakeholders through a visioning process. Efforts toward this need to reduce the territorial and even paranoid behaviour government ministries exhibit toward one and another.

RECOMMENDATIONS TO SMALLER OR RURAL WATERSHED ORGANIZATIONS:

- Collaborate and partner with other similar minded groups and organizations. Smaller watershed organizations, such as CAs, need to find information management efficiencies through partnerships with other CAs and provincial ministries. As resources are the biggest challenge, especially for smaller CAs, the best approach is clearly a strategy of partnerships. Larger CAs need to be aware of what products come out of such partnerships. If approaches are scaled down too much, the needs of the lowest common denominator are being served, but potential and innovation are being capped. Ideas of partnership and collaboration should be discussed at a future symposium, such as the Latornell symposium.
- Select information management technology that is modular and flexible so that it can be easily upgraded and adapted.
- Learn from watershed organizations that are further ahead with respect to information management.
- Improve information management practices by working on the information management culture of the organization. Involve staff through information management planning, goal setting, needs assessment, and scenario building.
- Encourage wise information care and maintenance

RECOMMENDATIONS TO IMPROVE INFORMATION MANAGEMENT ACROSS PROVINCE:

- Establish formal provincial and CA interaction to support communication and co-ordination. This seems to be lacking with respect to information management. The nature of watershed management requires communication across government jurisdictions at all levels. Currently, there is a need to increase direct communication

between CAs and the province. The Province needs to demonstrate leadership on watershed management.

- Find new ways to economize across partnerships. Cost of information management is prohibitive for most groups to do seriously, so collaborating with the larger organizations is imperative. The Ontario government could extend access to Conservation Authorities site licenses for some major software applications, which would significantly reduce information management start-up costs for smaller CAs.
- Identify sustainable sources of income. CAs need sustainable sources of income and freedom to develop based on organisational priorities rather than having funds tied to specific projects. Currently, CAs bound by municipal interests do not develop in key areas such as information management unless the municipality has something to gain from the investment.
- Increase investment in staff resources and expertise
- Simplify information sharing policies. Policies around data and information need to open up and recognise that they are already in the public domain. Currently, there is an inappropriate disconnect between data and the public. Municipalities, Conservation Authorities, and the Province continue to do a disservice by cloaking their information management activities. An open policy around information would fuel public participation and support for business services offered by watershed management organisations.
- Define a meta-data standard and communicate project data expectations to all partners.

- Support effective information management. Provincially, there needs to be openness, political buy in, financial support, and technical capacity

6.4 RESEARCH LIMITATIONS AND ASSUMPTIONS

Completion of this research and development of the evaluative framework for information management helped identify some research limitations. There are several areas not addressed by this thesis. Knowledge management was intentionally left out and is currently untouched really in Ontario's environmental management and is large enough to be a thesis on its own. This thesis also does not cover topics of mental material, cognition, memory, or approaches to thinking. These topics are fundamental to any discussion on knowledge as we have seen in the established relationship between knowledge, information, and data. However, this could not be adequately covered in this research. In general, this thesis does address many different areas covered by information management, but it does not address any one in any detail. Rather this research attempts to fit the different pieces together, which results in the reader attaining only a superficial level understanding of any one component. Finally, the evaluative framework is difficult to apply to all scales of watershed organizations. Watershed organizations with a base level of resources, capital, experience, public support, and investment to date will find it easiest to use the framework. Information management and related technologies, by nature are expensive and require long-term investment in resources and expertise. A small rural CA for example with a staff under 10 will likely gain less from the framework than a medium-size conservation authority with a staff over 50. However, the framework does provide insight into conceptual practices behind information management that will lead to more effective watershed management.

Smaller watershed organizations are encouraged to consider the conceptual relationships that exist between different information management pieces and assess the processes from a conceptual perspective. Ideally, the evaluative framework would be applied to multiple case studies, including different levels of government and contrasting examples, including some international examples. Future research, discussed later in this Chapter will present this and provide some additional ideas that were ultimately beyond the scope of this research.

While the information management framework developed for this thesis attempts to provide some strategic ways to evaluate practices, enabling practitioners to improve their information management, there are some major issues that remain to be addressed that are outside of the scope of this framework. One such issue that has plagued watershed management is the challenge of defining roles and responsibilities among organizations in Ontario. This will require an unprecedented level of agreement, coordination, and leadership among organizations. Currently there are too many different agendas overlapping at the same scale of management. The most promising trend for improving clarity around roles and responsibilities is partnerships, which facilitate collaboration, coordination, commitment, and communication among organizations. One of the root causes of this remains that of territoriality. Watershed management organizations with cut budgets feel vulnerable and struggle to maintain their services and jurisdiction. Leadership needs to provide commitment to needed services and sustainable sources of funding to reduce the feeling of vulnerability most organizations experience. Some essential elements not well addressed by this thesis include monitoring, reporting, review and evaluation, and knowledge management. This is partly because the approach

to these things is still evolving and partly because project and program budgets are thin as it is and there is little room to expand tasks. Finally, policies around data sharing in Ontario remain conservative. Reasons for this include the cost associated with information as well as liability issues of putting information in the public realm. Web applications that use coarse data are a positive trend.

6.5 FUTURE RESEARCH

This research has led to the discovery of a number of opportunities that would benefit from further study and examination. Possible areas for future research need to focus on improving the access transfer, and use of information. Using the evaluative framework for information management developed in this research, expand on any individual framework element in detail. The nature of information management is changing quickly enough that each of these elements are evolving continually. This evaluative framework for information management or an adaptation would undoubtedly be improved by applying it to more case studies, including international examples, other provinces, and other conservation authorities.

Similarly, research focusing on an evaluative framework for knowledge management would be useful to watershed organizations in Ontario. Currently there are few examples of best management practices for practitioners to look toward for leadership with respect to knowledge management. Organizational learning, especially learning across section or departmental boundaries needs to be considered. This should include issues of knowledge transfer, shared learning, personnel transition, and knowledge mining, long-term preservation of knowledge, and breaking down organizational barriers to learning, as it relates to watershed management organizations.

In addition, alternate sources of information and knowledge need to be included. For example, farmers are strong land stewards and could be very effective at adding values/attributes to data, as demonstrated in the ground water example by adding well location and farm/field use. Developing effective, efficient ways to include local land stewards as a source of data/information would generate some valuable knowledge for watershed management practitioners.

A major them of information management is the notion of data and information access and ownership. Implications of restricted access, intellectual property rights claims by public organisations and information liability are all important and related areas that need to be addressed from the perspective of the greater good for the public and natural environment. Future research should explore avenues for improving access and sharing information between organizations and with the public. Such areas of research should naturally explore the use of existing and emerging technologies such as the Internet and web-based applications.

At this time, there is no clear way of setting information management priorities. With so many different pressures on practitioner and information needs, allocation of resources is a contentious issue. A systematic approach to priority setting to ensure optimal allocation of resources and to demonstrate transparency in decision-making would improve information management. With so many different watershed organizations and political agendas, research needs to define roles and responsibilities. Complexity of relationships has resulted in watershed management evolving into something that is unclear and inefficient. Roles and responsibilities need to be clearly defined and revisited in an effort to "align the constellations", so to speak. The current

situation introduces too many unnecessary challenges and inefficiencies. Future directions, especially in Ontario may include a combination of provincial, regional, municipal, and private interests, which will all need to be coordinated. In support of this research could facilitate a robust meta-data standard for the province.

6.6 CONCLUSION

Watershed scale, size, and complexity are the technical problems facing practitioners and clearly defined inter and intra-agency roles and responsibilities are the organizational challenges. Resources are evidently a problem for all organizations, budgets are shrinking, and the opportunities to invest in information management are growing. Keeping this in check requires careful collaborating, planning, and decision-making. Information management is in itself both a set of goals for an organization, as well as a means to achieving the strategic objectives of an organization. The effectiveness of information management links with the overall effectiveness of the watershed management agency.

In conclusion, this thesis assessed information challenges and opportunities for information management, developed an evaluative framework for information management; and applied the framework to the Grand River Conservation Authority as a case study. Practitioners can use the framework to investigate the information management of their own organisation and identify areas that are most in need of improvement. Like watershed management, the idea of an evaluative framework for information management is young, and a conceptual tool for improving the tool set for watershed decision-making. This approach is subject to significant theoretical and procedural difficulties. However, despite these problems, this approach is a means of

evaluating approaches to decision-making, watershed management, and information management. Practitioners who are evaluating existing approaches to information management may use the framework to identify the process used, diagnose problems, and implement alternative approaches.

Overall, watershed management will be information challenged for the near future, as resources and commitment will likely remain insufficient. Both the public and politicians do not identify watershed management as a great enough priority to justify larger investment required for compressive information management approaches. Sadly, once there is awareness of watershed issues, likely in response to another crisis such as Walkerton, watershed management organizations will be scrutinized and criticized for their failed management by the public and politicians alike. A more interesting scenario would be to see watershed organizations given the resources and clear mandate to deliver their services and programs, including information management. In either case, the research presented here will give practitioners the opportunity to begin improving their information management now. The challenges facing information management are not new to watershed management; rather they are organisational inefficiencies that have persisted over time. However, the drive for effective information management will encourage organisations to overcome these challenges by adopting new approaches, working together, and reducing institutional barriers to information management.

APPENDIX 1 – INTERVIEW QUESTIONS AND NOTES

A) PERSONAL:

1. What is your role within this organisation?
2. How long with this organisation?
3. What is your disciplinary background?
4. What are the core business activities of your organisation?

B) WATERSHED MANAGEMENT IN ONTARIO AND INFORMATION MANAGEMENT:

1. With respect to watershed management, what are the key challenges facing practitioners?
2. What role does information management have in coping with these challenges?
3. What conditions are prerequisite for effective information and knowledge management within a watershed management organisation?
4. How does the absence or presence of certain conditions affect the information management?
5. How does information management fit into watershed management decision-making for your organisation?
6. Is the existing information adequate for the watershed management decision-making? Explain?
7. What are key challenges and barriers that might impede effective information management? What can be done to overcome these challenges and barriers?

C) INFORMATION PLANNING AND DESIGN:

1. What is the process for setting goals and objectives in your organisation?
2. Are information management planning and the setting of information priorities linked to this process?
3. Is there a specific information management plan? If not, what are the linkage between information management planning and the overall organizations activities and planning?
4. What are the key elements essential for effective information management process? Are there elements that are missing or not as functional as they could be?
5. How are different information needs assessed, planned for, and co-ordinated?
6. Is there a long-term plan for information planning? Who is involved in the information management planning process?
7. Is information management recognised as evolving throughout the process? If so, how does the process evolve?

D) DATA MANAGEMENT, PROCESSING AND ANALYSIS:

1. How does your organisation approach data management, processing and analysis? What are the strengths and weaknesses of this approach?
2. How is long-term access to data and compatibility assured?
3. How is data integration and co-ordination handled?
4. Is there a systematic approach to data storage and archiving? Is there a formal set of adopted data standards?
5. Are there any logistical constraints posed by data management, processing, or analysis that must be considered (i.e. time, resources, capabilities)?

6. How is knowledge management handled?
7. Are linkages made with internal and external sources of information? How?
8. How are gaps in information or knowledge identified?
9. Is meta-data produced to support data and information? Is this sufficient?

E) INFORMATION SHARING & CO-ORDINATION:

1. How does information sharing and co-ordination take place within your organisation?
2. How is knowledge sharing encouraged and facilitated?
3. Is there an atmosphere of openness and trust?
4. How can information efforts be better co-ordinated between and within organizations (*i.e. other CAs?, provincial and federal levels of government, municipalities, stewardship councils*)
5. What conditions are necessary for strong relationships and co-operative information management?
6. How is information shared and collected from the public? What are the costs and benefits of these efforts?

F) INFORMATION MANAGEMENT TECHNOLOGY:

1. What information systems and related information technology are used by your organisation?
2. How does information management technology support decision-making for watershed management? Explain?
3. What benefits does information management technology pose? What problems does information management technology cause? What solutions have been found to these problems?
4. How are matters of technical compatibility addressed?
5. Do existing information management technology capabilities meet the needs of the organisation? How are new technologies assessed for use?
6. Is information management technology used as a means to bring the organisation closer to the public? How?

G) INTERNAL AND EXTERNAL CONSIDERATIONS:

1. Do organisational politics or political issues ever effect information management activities? How so?
2. Who is directly involved in information management? Are there any individuals or groups that you feel are left out?
3. How is job transition and transfer of knowledge handled? How is expertise maintained?
4. Within the organisation, how are boundaries between staff at different levels and departments handled with respect to information management? Is this approach effective? How does the managerial hierarchy/organisational structure affect the flow of information?
5. Do the creators/collectors of information communicate with end-users?
6. To what extent does the organisations existing infrastructure (culture, leadership, modes of communication, other systems and structures) either support or undermine information management?

7. Have either management approaches or institutional arrangements changes had an impact on information management?
8. Are there sufficient resources (technical/computer expertise, expenses, equipment, personnel time, access to particular personnel, etc.) to achieve the information management objectives for the organisation? What expertise is required? Is this available?
9. How has your organization's approach to information management changed or evolved? Is there an effort to foster the implementation of best practices, share lessons learned, or improve on the process of information management?

APPENDIX 2: INTERVIEW LIST

NAME, POSITION, ORGANIZATION, DATE INTERVIEWED, EDUCATION & BACKGROUND DESCRIPTION
Barbara Anderson, Senior policy advisor, Ministry of the Environment, September 12, 2003 • Currently provide support and direction on a range of water management files, with MOE since 1996, 16 years with MNR before that including 10 years in the field. • Undergrad in biology and masters in geography, and partial MBA • Completed an information strategy for the industry/ministry in 1999, policy representative with IMB, mapped capabilities and function of the organization.
Mark Anderson, Water Quality Engineer, Grand River Conservation Authority, August 1, 2003 • Background in chemical engineering; water quality issues, spills, water quality monitoring, beach sampling, discharge waste water treatment, non-point source inputs, and modeling • Undergrad in civil engineering
Scott Christilaw, Business Services Manager, I&IT, Ministry of Natural Resources, July 29, 2003 • Role is to provide coordination of water information and management across cluster • Trying to coordinate across CAs/Government/Municipalities • 21 years experience with MNR, working on lands and waters agenda for the past 5 years. • Graduate forester, undergrad in computer science
Chris Eckstein, Manager Geomatics services, Ministry of Natural Resources, August 11, 2003 • Lead of Geomatics, cartography, remote sensing service centers • Applied Geography Undergraduate degree from Ryerson, Masters of Environmental Studies from Waterloo with a focus on computer science GIS/Remote Sensing; addresses Geographic information core business activity of MNR
Bonnie Fox, Policy and Program Development, Conservation Ontario, September 4, 2003 • Responsible for Provincial Coordination of water issues relating to CAs • 4 years with Conservation Ontario, 8.5 years with MOE, 1.5 years with MNR • Bachelor of Science degree combining major biological sciences and urban environmental studies, Brock University.
Don Greer, Senior Policy Advisor, Ministry of Natural Resources, September 18, 2003 • 30 years experiences with MNR, CVC, GRCA, Queen's Park • Working on watershed management, planning act, living legacy, special issues, with a background in geography and ecosystems.
Frank Kenny, Project Manager WRIP, Ministry of Natural Resources, July 29, 2003 • Started in the remote sensing office/Geomatics group as Project Engineer, 16 years service • Geological Engineering BA, UW; Masters Engineering Geology, University of Dolft, Holland, Started on the LGIS side of things, Undergrad thesis – thermal remote sensing
Phil Lenoir, Database applications specialist, Grand River Conservation Authority, August 1, 2003 • Degree in real time computing/modeling applications developer
Lorrie Minshall, Manager, Water Resources Planning, Grand River Conservation Authority, August 7, 2003 • Water planning, municipal planning, 6 reports back – 3 water, 3 land use planning, watershed planning, source planning, land use planning for 27 years
Chris Powell, Resource Planner, Grand River Conservation Authority, September 2, 2003 • BA Resource Management/MA Resource Management • 2 years experience in planning
Dave Schultz, Public Relations, Grand River Conservation Authority, December 18, 2002 • Responsible for all public relations and communications with the GRCA. • 2 years with the GRCA • Background in Communications

NAME, POSITION, ORGANIZATION, DATE INTERVIEWED, EDUCATION & BACKGROUND DESCRIPTION
Graham Smith, Geomatics coordinator, Grand River Conservation Authority, August 6, 2003 • 'Catch-all' computer support, strategic direction, data maintenance, data modeling, data factors, liaisons with outside organizations, technical aspects, programming, technical support • MES, UW, GIS lab technician program, Fleming, 1 year experience
George Sousa; Manager, IS, Grand River Conservation Authority, August 7, 2003 • 2 roles: 1) functional role, link between business units & info systems. Provide link. Aligning/development IT strategy consistent with corporate goals. Broader IT strategy. Leverage IT for business values. Delivery of capacity/potential to grow business. 2) Leadership Role: Participate in organization: Strategic planning – knowledge Strategic planning • Civil engineer background • IT leadership role with 20 years experience
Aaron Todd, Coordinator, Stream Monitoring Networks, Ministry of the Environment, August 13, 2003 • Responsible for Water Quality 3.5 years experience; • Physical Background in Geography/Masters Trent University
Robin van de Lande, Plan Review Ecologist, Grand River Conservation Authority, August 1, 2003 • 2.5 years experience • Biology/geography BA; Planning/environmental, MSC;
Ian Wilcox, General Manager, Upper Thames River Conservation Authority, August 13, 2003 • CA rep to WRIP. Improve the state of water information to process. • 3 years on WRIP, 14 Years, coordinator UTRCA, Watershed Networks, Planning, • BA, Geog, WLU, Geog Western.
Bruce Wurtele, Information Management Coordinator, Oak Ridges Moraine, Ministry of Natural Resources, July 29, 2003 • *BA in Environmental Studies/Geography at Trent and MES at UW/WLU* • *Coordinator position is intended to work with business leads and information work groups to ensure optimal and efficient use of IT resources; 6 years experience; Broad range in Geography and GIS; Information;*

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