EXPLORING THE APPLICATION OF ADAPTIVE MANAGEMENT AND DECISION ANALYSIS TO INTEGRATED WATERSHED MANAGEMENT

by

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Abstract

Integrated watershed management (IWM) is the process of planning and implementing water and other natural resources management strategies in watersheds with an emphasis on integrating biophysical, socio-economic and institutional considerations. Common difficulties faced by a large majority of IWM processes include reconciling conflicting objectives, managing watersheds as complete ecosystems, coping with uncertainty, and facilitating meaningful stakeholder participation. This thesis explores the application of adaptive management and decision analysis to these challenging aspects of IWM.

Adaptive management (AM) is a systematic approach to improving management and accommodating change by learning from the outcomes of management policies and practices. It involves the design of formal management experiments, the explicit analytical treatment of uncertainty, and the development of ongoing monitoring and adjustment procedures. Decision analysis (DA) is an approach that provides structure for thinking systematically about complex decision situations. Aspects of the approach that are most relevant to IWM include structuring objectives based on stakeholder values, creating and evaluating innovative alternatives, assessing impacts based on subjective technical and value judgments, and dealing with risk and uncertainty.

In the thesis, the literature on AM and DA is first summarized into a subset of principles and tools that appear to have the most potential to address prevalent problems in IWM. These are then integrated into a generic planning framework that can be applied to either guide or evaluate IWM processes. The application of this framework is tested through a case study of the Chapman and Gray Creeks IWM Plan process in coastal British Columbia.

The results of the thesis suggest that AM and DA offer the means to address some, but not all, of the intractable characteristics of IWM. AM provides a formal approach to improving the quality of information over time and hence the understanding of ecosystem function. From a planning perspective, it may also help to break multi-stakeholder gridlock over controversial facts and assumptions by committing to a program of structured learning and continual adjustment. Decision analysis offers a structured way to attack complicated problems. It improves understanding of the relationships between objectives, alternatives and consequences. Again from a planning perspective, it can increase the transparency of decision making by breaking complex problems into manageable sub-components, structuring information and focusing on key trade-offs. Practical resource constraints limit the relevance of some of the more sophisticated tools of AM and DA, but other tools have the potential for more widespread application.

The thesis includes recommendations for improving IWM processes in community watersheds within the provincial planning framework in British Columbia and for areas of further study.

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1 Introduction

1.1 Background

Integrated watershed management (IWM) is the process of planning and implementing water and other natural resources management strategies in watersheds with an emphasis on integrating the biophysical, socio-economic and institutional aspects of natural resources management (Dorcey 1991a; Newsom, 1997).

Practitioners of IWM find that the processes are often long, difficult and controversial. Improvement will require new approaches to planning and management, not just science. Many tools are currently available as aids to environmental planning in general, and to IWM in particular. Many of them have a relatively narrow range of application, but a few are broadly applicable. These broader tools may be better thought of as "tool kits" (Merkhofer, 1999) because they encompass a set of related tools, principles about how to use them, and a step-by-step process to guide implementation. Two approaches that integrate many tools and appear to be broadly applicable to IWM are adaptive management and decision analysis.[1]

Adaptive management (AM) is a systematic approach to improving management and accommodating change by learning from the outcomes of management policies and practices (Holling et al., 1978; Walters, 1986). This involves:

- the design of formal management experiments;
- the explicit analytical treatment of uncertainty; and
- the development of ongoing monitoring and adjustment procedures.

AM was originally intended to improve managers' understanding of the functioning of the ecosystems being managed. However, it may also provide learning about the institutions charged with their management. Across North America many natural resource management agencies are actively adopting and refining principles and practices related to adaptive management (B.C. MOF, 1997; Ontario MNR, 1998; USFS, 1999).

Decision analysis (DA) is an approach that provides structure for thinking systematically about complex decision situations. Aspects of the approach that are particularly effective in dealing with natural resource management issues include:

- structuring objectives based on stakeholder values;
- creating and evaluating innovative alternatives;
- assessing impacts based on subjective technical and value judgments; and
- the explicit treatment of risk and uncertainty.

Structured DA techniques are increasingly being applied by natural resource management agencies as an aid to multi-stakeholder negotiations and public policy analysis (Province of British Columbia, 1998; Maguire, 1995).

[1] Other "tool kits" may include ecological risk assessment and cost benefit analysis.

1.2 Purpose Statement

The purpose of this thesis is to explore the potential contribution of adaptive management and decision analysis to integrated watershed management. Three main research questions are addressed:

- Why is IWM a difficult management problem?

There are a number of common difficulties faced by a large majority of IWM processes. The literature on "soft systems" is used to characterize the intractable nature of IWM problems. Four common and difficult problems faced by many IWM processes are identified and described. This analysis forms the basis for evaluating the relevance of AM and DA concepts for IWM. The ability of AM and/or DA to address (or partially address) these challenges is assessed in the conclusions of the thesis.

- How can DA and AM be applied to IWM?

The literature on AM and DA is comprehensive and diverse, offering a variety of both highly technical tools and broad planning frameworks. The first step is to summarize what is meant by AM and DA. Then it is necessary to identify a subset of principles or tools that appear to have the most potential to address prevalent problems in IWM and show how they could be incorporated into planning. The goal is to present AM and DA in a way that helps planners put them into practice in IWM processes.

- What are the major opportunities and challenges with respect to implementation?

The practical potential of AM and DA tools and approaches may be limited or amplified by the technical or institutional nature of IWM problems. This is examined through a case study of a community watershed IWM process in coastal British Columbia. Conclusions are drawn on the use of AM and DA in IWM generally. Recommendations are targeted specifically to planning and policy considerations for IWM in community watersheds in BC.

The thesis will be of interest to:

- planners who wish to incorporate elements of AM and/or DA into IWM processes;
- provincial government agencies and those responsible for policy related to IWM in BC;
- researchers and academics in the field of integrated watershed management; and
- participants in collaborative decision making processes.

1.3 Structure of the Thesis

Chapter 2 introduces the systems approach and recent developments in soft systems theory. It then introduces the IWM process and characterizes it as a systems problem generally, and a soft systems problem in particular. This analysis forms the basis for evaluating the relevance of AM and DA concepts for IWM.

Chapter 3 provides a primer on AM and DA, focusing on a summary of the process, principles and tools suggested by each, as derived from a cross-section of literature. The primer also includes a selective summary of experience in implementation. Chapter 3 then develops an analytical framework for integrating AM and DA tools and approaches into a generic IWM planning framework. The framework includes investigative questions designed to serve as a checklist either for planning or evaluating IWM processes. It also summarizes key triggers for the use of each tool/approach. This chapter will be of particular relevance to those directly responsible for the planning and management of watersheds.

Chapter 4 presents a case study of the Chapman and Gray (C/G) Creeks IWM Plan development and implementation process. The case study uses the analytical framework to guide an assessment of opportunities and challenges for AM and DA in the C/G watershed. In order to understand the planning and policy framework of the C/G case, a summary of the broader provincial context for community watershed planning is presented first. The case study is a retrospective look at the planning process, with the purpose of examining how elements of AM or DA were or could have been used to improve the process, and what opportunities or barriers existed to incorporate them. The purpose is not to find weaknesses with the C/G process specifically, but to gain insight about the broader relevance of AM and DA to IWM generally.

Conclusions and recommendations are summarized in Chapter 5. Recommendations are directed toward improving IWM processes in community watersheds within the provincial planning framework in BC and toward identifying areas for further study.

2 Integrated Watershed Management: A Soft Systems Perspective

2.1 Soft Systems Defined

The Systems Approach

The roots of the soft systems approach can be traced to the rise of general systems theory in the 1940s (Bertalanffy 1968). The central tenet of this meta-discipline is that systems — or organized complex entities — display three primary characteristics (Checkland, 1981):

- *emergent properties*: properties which are meaningful only when attributed to the whole, not its parts;
- *hierarchical organization*: internal and external hierarchical arrangements of systems and subsystems; and
- *adaptive capability*: functional interactions between systems, subsystems and their environment.

The systems approach recognizes these characteristics and applies specific methodologies designed to cope with the complexity of real world problems. In the water resources sector, early efforts at applying the systems approach aimed at "providing a better understanding of the system and interlinkages of the various subsystems, by predicting the consequences of several alternative courses of action, or by selecting a suitable course of action that will accomplish a prescribed result" (Biswas, 1976). The early emphasis was on the development and application of computer simulation models, and this 'hard science' approach to systems analysis has continued to the present. However, it is now complimented with a more broadly-based view of the potential for applying a systems approach to real-world management problems.

Hard Systems and Soft Systems

Since the 1970s, the systems concept has been further refined into two distinct and complementary approaches, namely the *hard systems* and *soft systems* approach (Checkland and Scholes, 1990). Walker (1996) presents a detailed account of the contrasting philosophical concepts, problem conceptualizations and general methodologies of the two approaches.[2]

The hard systems approach conceptualizes problems with well-defined boundaries and simple linkages with other problems. Goals, alternatives and consequences are well-defined. The standard management technique is to collect and analyse data, unilaterally decide on a best course of action, and implement accordingly. An example of a hard systems approach to a management problem is the use of optimization models to determine reservoir levels for maximum hydro-power production efficiency.

[2] The hard and soft systems approaches each provide a basic guide for conceptualizing and structuring management problems. Distinguishing between them is not necessarily meant to imply that either is right or wrong. Indeed, it many cases it is advantageous to adopt an approach that exploits the notion of *soft/hard complementarity*, with the soft systems approach providing an overall problem management framework, and the hard systems approach focused on appropriate sub-problems (Walker, 1996).

In contrast, soft systems problems are viewed as having the following characteristics:

- *ambiguous boundaries* and *complex linkages* with other problems;
- *goals, alternatives*, and *consequences* which are not well-defined or well-understood;
- *pervasive uncertainty* which may not be quantifiable; and
- iterative management which involves *conflict and negotiation among multiple stakeholders* with divergent interests and values.

An example of a soft systems approach to a management problem is the use of a multi-stakeholder planning and decision making process to determine reservoir levels for hydro-power production while meeting instream flow requirements for fisheries and recreation.

This taxonomy for soft systems problems will be used below to describe the generic problem of integrated watershed management.

2.2 Integrated Watershed Management Defined

Integrated watershed management (IWM) is not an exact science. It is an approach to environmental management that uses the topographically delineated area drained by a stream system as both the physical and analytical boundary of analysis. IWM encourages examination of all biophysical and socio-economic linkages such as those that exist among natural resource sectors (e.g. forestry, fisheries, agriculture and water supply), or those that exist between upstream activities and downstream impacts. Consistent with the evolution from the hard to soft systems approach over the decades, IWM has evolved from more technocratic approach (see e.g., Dixon and Easter 1986; Saha and Barrow, 1981) to a more holistic approach (see e.g., Heathcote, 1998; Dorcey, 1991b)

IWM has been widely adopted in virtually all regions of the world (see e.g., Newsom, 1997; USEPA, 1996; Hufschmidt and Tejwani, 1993; Naiman, 1992; Koodstaal et al., 1992). In Canada alone, a broad body of literature has developed on integrated watershed management strategies (see e.g., Heathcote, 1998; Child and Armour, 1995; Mitchell and Shrubsole, 1994; Ontario MEE/ MNR, 1993; Dorcey, 1991b; Shrubsole, 1990). Many labels have been attached to the basic concept, including "integrated water resources management", "river basin management", "land and water management", and of course "integrated watershed management". From the literature, the defining elements of integrated watershed management can be synthesized to include:

- *A transdisciplinary focus*: meeting the challenge of IWM requires collaboration among specialists in widely varying disciplines including biological sciences, engineering, geoscience, economics, sociology, law and ethics.
- *The balancing of social, economic and environmental values*: as IWM processes strive to balance the full spectrum of social, economic and environmental considerations, the necessity to make trade-offs becomes inevitable and new approaches are required.

- *An emphasis on strategic action*: as government and non-government agencies are forced to manage with ever decreasing financial and human resources, IWM processes must find ways to target key issues and tasks that are essential to success.
- *The need to cope with uncertainty and complexity*: water resource managers are increasingly acknowledging that understanding of complex ecosystem and socio-economic systems is riddled with uncertainty, and that new analytical tools and approaches are required.
- *An ecosystem management approach*: IWM stresses the need to consider *all* natural resources within the watershed, and necessitates that environmental considerations (e.g., the maintenance of biodiversity and ecological function) be treated equally and simultaneously with human considerations (e.g., economic and social development).
- *A need for more devolved decision making and consensual processes*: the use of consensual approaches to planning and decision making is clearly set as IWM processes are increasingly challenged to address natural resource development and community development issues simultaneously.
- *Innovative institutional structures and processes that are more resilient*: for any of the above to be achieved there is prerequisite for new institutional structures and processes to emerge that are responsive to localized requirements, yet consistent across broader jurisdictional reaches, dynamic and flexible, yet focused and effective.

2.3 Integrated Watershed Management as a Soft Systems Problem

Application of the general systems concept to water resources and watershed management problems has a long history that can be used as a starting point for developing a soft systems perspective of integrated watershed management (see e.g., Biswas, 1976; Easter, Dixon and Hufschmidt, 1986; Saha and Barrow, 1981; and Dorcey 1991a). There is general consensus within the literature that a useful approach involves the integrated analysis of both "natural" and "human" systems. Consistent with this literature, integrated watershed management can be conceptualized in terms of three interrelated systems: the biophysical, the socio-economic and the institutional.

The Biophysical System

From a systems perspective, addressing the land-water interface is key to the watershed approach (Brooks, et al., 1991). The hydrologic cycle often serves as the starting point for the study of the interrelationships between forest, range, agricultural and urban land management practices and the resultant hydrological and water quality impacts. These efforts are leading to the development of an improved array of structural and non-structural approaches to riparian zone management, floodplain management, irrigation system design and urban stormwater runoff programs, to name just a few.

Hamilton and Pearce (1986) classify the biophysical effects of land-use practices within a watershed into six categories: i) soil erosion at the land-use site, ii) sediment delivery off-site, iii) pollution of water by chemicals, iv) changes in total water yield in streams, v) changes in the timing of water delivery in streams, and vi) changes in groundwater behaviour. While categorizing effects is useful, it is even more important from a systems perspective to penetrate the interrelationships between different effects, and the possibility for cumulative effects.

More recently, the application of ecosystem approaches has both increased the understanding of biophysical processes and, more importantly, highlighted the uncertainties in them. The watershed approach thus focuses the attention of both management and research activities to the overall structure, function and dynamics of watersheds as complete ecosystems (USEPA, 1996).

The Socio-economic System

Within most watersheds, both land and water resources are largely managed for the production of goods and services for human populations. Thus, the human element, or socio-economic system, is essential to the development and understanding of the watershed approach.

Water can be used as an example to illustrate the need for a socio-economic systems perspective for watershed management. "Consumptive" uses of water include domestic, irrigation and industrial uses, while "non-consumptive" uses include hydro-electricity generation, flood control, navigation and recreation. Allocating water usage across the range of possible consumptive and non-consumptive uses requires a comprehensive understanding of: i) who are the various stakeholders?, and ii) what are their needs? Based on the recognition that simple benefit-cost analyses are incapable of dealing with complex value tradeoffs about whose needs should take priority, tools (e.g., multiple account evaluations for improved decision making) and strategies (e.g., the integration of regulatory and economic mechanisms) are needed to provide both control and flexibility with respect to overall socio-economic objectives.

In addition, evolving value systems based on sustainability principles require a commitment to ethics and equity considerations that go far beyond utilitarian considerations alone (Dorcey, 1991b). Making the conceptual links from present to future generations' needs, and from local to regional and global scales are fundamental challenges to be addressed within the socio-economic system.

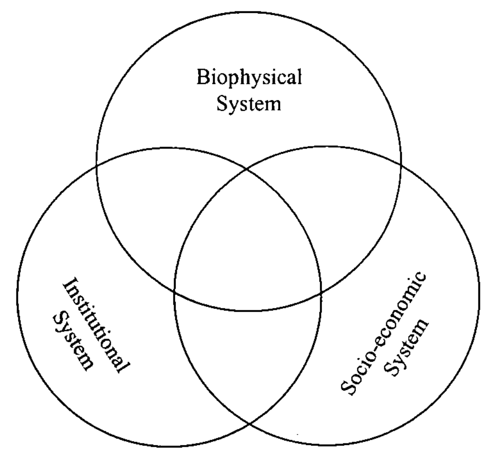
The Institutional System

The institutional system for watershed management refers to the administrative framework that facilitates the implementation of policies and programs, delineates the rights and responsibilities of agencies and resource users, and mediates the conflicting interests of stakeholders. It comprises the government agencies with planning and regulatory functions, and their rules for resource allocation and management. It further comprises the full range of interest groups that have a stake in the use of natural resources from private sector industries to environmental and community groups. And finally, it comprises the full range of channels for communication and interaction. While many of these "components" of the institutional system function above and beyond the context of any given watershed, it is their inclusion *within* the context of a given watershed that is necessary for a complete systems perspective to be adopted.

Integrated watershed management recognizes and encourages the evolution of institutional systems toward more devolved decision making and consensual processes. Further, it emphasizes the need to i) identify the wide range of institutions involved in each context, ii) support innovative structures and processes that are more resilient, and iii) demand greater accountability from elected officials (Dorcey, 1991b).

There is, of course, a tremendous degree of overlap and interaction among these three systems (Figure 2-1).[3] And it is precisely this overlap and interaction that makes integrated watershed management such a challenging undertaking.

Figure 2-1: The Systems of IWM



Soft Systems Characteristics of IWM

As a first step toward gaining a better understanding of the challenges, the four basic characteristics of soft systems problems can be used to organize and penetrate the general integrated watershed management problem. Note that many of these are consistent with the defining elements of IWM as described in Section 2.2.

Ambiguous Boundaries and Complex Linkages

"Watersheds are logical divisions or regions of the natural landscape, and for some purposes they are ultimately the best framework to use for management. Yet it is also true that for every natural watershed there is a 'shadow watershed' defined by human and natural components that extend the decisionmaker's interest beyond the boundaries of the physical watershed" (NRC, 1998).

- Cross-boundary impacts: Policies developed for one watershed may have a wide impact on other watersheds or resource sectors within the same institutional jurisdiction.
- Cross-boundary influences: Economic and social priorities and trends that transcend the physical watershed boundaries influence activities within the watershed and may limit local control.
- Cross-disciplinary scope: While watershed activities are most often managed by foresters and geoscientists, many downstream implications (e.g., water supply, fisheries) are managed by engineers, biologists, economists and other professionals. Collaborative planning is often weak or non-existent.

[3] This is only one of many possible ways to conceptualize the relationship between the various systems components of integrated watershed management. For further reference see Dorcey 1991a.

Difficulty with Objectives, Alternatives and Consequences

> *"Watershed management sounds like a world of few tradeoffs and no value conflicts. As a result there may be little interest in scientific analysis or in the systematic and critical assessment of tradeoffs and cost effectiveness in the utilization of limited resources."* (NRC, 1998).

- Unclear objectives: Water quality, resource extraction, and environmental stewardship objectives are often difficult to define and harder to measure.
- Complicated alternatives: There are dozens of possible alternatives and ways of combining alternatives, so that organizing and evaluating them becomes complex and time-consuming.
- Inherent conflict: Many management alternatives will have a positive impact on one objective and a negative impact on another, necessitating complex and controversial trade-offs.
- Data overload: At times, there is an over-abundance of detailed technical data, making it difficult to discern the key issues, relationships and trade-offs.

Pervasive Uncertainty

> *"Risk and uncertainty are parts of the natural as well as institutional settings for watershed management, and they can limit the effectiveness of applying the watershed approach."* (NRC, 1998).

- Uncertain ecosystem relationships: the science underlying predictions of the effects of management activities and the ability of ecosystems to respond and adapt to perturbation is uncertain and controversial. Even when individual effects can be estimated with confidence, the cumulative effects of multiple management actions are largely unknown.
- Uncertain socio-economic relationships: predicting the socio-economic effects of management activity is often undertaken using linear relationships between resource development (e.g., timber harvest) and socio-economic effect (e.g., employment). While suitable data may exist to support these relationships over short time periods, longer term projections are vulnerable to numerous uncertainties including technological change, fluctuating world commodity prices, and changing social preferences.
- Evolving institutional and legislative bounds: As a process, IWM faces further uncertainty when bureaucracies, which are often fragmented along sectoral lines, are experimenting with or implementing a range of regulatory approaches (i.e., standards-based, economic mechanisms, planning-based) in tandem.

Multiple Stakeholder Conflict

> *"Agencies should give more attention to the identification of different values held by watershed stakeholders that can lead to conflicts over possible solutions. Failure to acknowledge fundamental differences in values can undermine the search for an acceptable means to address these differences."* (NRC, 1998).

- Gridlock over facts and values: stakeholders differ not only in their beliefs about how management activities impact ecosystems (the facts) but also in their beliefs about the relative importance of multiple objectives (underlying values). This significantly complicates decision making.
- Potential for escalation of conflict: because livelihoods and lifestyles depend on the outcome of integrated watershed management processes, there is tremendous potential for escalation of conflict.
- Lack of transparency in decision making: because of the complexities of multiple objectives, alternatives, uncertainties and values, the rationale for decisions made is often unclear, resulting in further stakeholder dissatisfaction.

2.4 Summary

In sum, IWM is a systems problem generally, and a soft systems problem in particular. The soft systems nature of IWM creates significant challenges:

Ambiguous Boundaries and Complex Linkages
- Cross-boundary impacts
- Cross-boundary influences
- Cross-disciplinary scope

Difficulty with Objectives, Alternatives and Consequences
- Unclear objectives
- Complicated alternatives
- Inherent conflict
- Data overload

Pervasive Uncertainty
- Uncertain ecosystem relationships
- Uncertain socio-economic relationships
- Evolving institutional and legislative bounds

Multiple Stakeholder Conflict
- Gridlock over facts and values
- Potential for escalation of conflict
- Lack of transparency in decision making

To evaluate whether adaptive management or decision analysis can contribute to IWM, this thesis assesses the ability of these approaches to address these soft-systems problems.

3 Integrating Adaptive Management and Decision Analysis into Integrated Watershed Management

As outlined in the introduction, the purpose of this thesis is to explore the potential contribution of adaptive management and decision analysis to integrated watershed management. In this chapter, the principles, tools and process from each field are distilled into a set of actions that are most relevant to the soft systems nature of IWM (Figure 3-1). A selective review of experience in implementation outlines some successes and limitations in practice.

Figure 3-1: Integrating Adaptive Management and Decision Analysis into IWM

3.1 A Primer on Adaptive Management

3.1.1 Overview

Adaptive management is designed primarily to help managers deal with uncertainty. It is a systematic approach to improving management and accommodating change by learning from the outcomes of management policies and practices (Holling et al., 1978; Walters, 1986). It improves managers' understanding of ecosystem functioning through the implementation of carefully designed management interventions and monitoring programs. Further, it permits management to proceed in the absence of a complete scientific foundation for action (McAllister and Peterman, 1992).

Both the theory and the practice of adaptive management have expanded greatly over the past two decades since the concept was first proposed. Adaptive management first emerged from a desire to address practical problems of environmental and natural resources management (Holling et al., 1978). One of the challenges posed by adaptive management is that it requires learning to occur at spatial and temporal scales relevant to the defined management task (Lee, 1993; Gunderson et al., 1995). In the case of integrated watershed management, this may require learning about ecosystem functioning over hundreds of square kilometers, and learning about the cumulative effects of interventions over a time scale of decades.

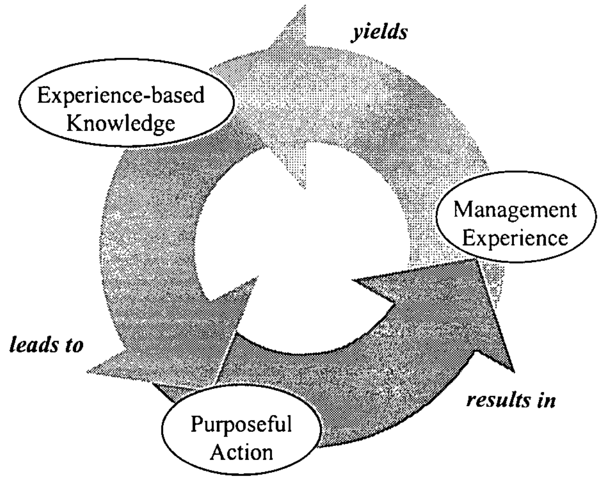
The earlier efforts of Holling et al. (1978) and Walters (1986) made progress toward the goal of improved ecosystem understanding through development of theory and quantitative techniques supporting adaptive management. More recently, the efforts of Lee (1993) and Gunderson et al. (1995) have made similar strides toward the goal of developing improved institutional support for adaptive management.

From Lee's (1993) analysis of institutional learning we can conclude the following lessons:

- Learning occurs first at the individual level, then at the institutional level;
- Institutions require incentive structures that encourage learning;
- Institutions should strive toward rational decision making, recognizing that true rationality may never be achieved;
- Double-loop learning[4] should be encouraged; institutions should regularly revisit their goals and objectives.

From both an institutional and ecosystem management perspective, continuous and deliberate learning emerges as a result of an experience-knowledge-action cycle (Figure 3-2). The cycle suggests that purposeful action derived from experience-based knowledge will itself result in new knowledge (Checkland and Scholes, 1990).

Figure 3-2: The Experience-Knowledge-Action Cycle
(Checkland and Scholes, 1990)



There are two kinds of adaptive management, "passive" and "active", which vary in degree of scientific rigour and experimental design (Walters and Holling, 1990; Halbert, 1993).[5]

In passive adaptive management, managers typically:

- use historical data to develop a single "best guess" hypothesis;
- implement a single course of action perceived to be the "best";
- monitor outcomes; and
- use new information to update hypotheses and adjust actions.

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[4]Double-loop learning occurs when new information challenges existing decision making processes, creating the need not just to modify action, but to examine and refine underlying premises and goals.
[5] Note that McConnaha and Paquet (1996) identify a third kind, which is "opportunistic learning". This approach relies on the natural variability in systems to create opportunities for structured learning without deliberate intervention or manipulation of the system.

In practice, passive adaptive management often turns into basic trial and error learning.[6] Learning does occur, but at a relatively slow pace, with greater potential for error as complex interactions and cumulative effects may confound post-implementation analysis.

In active adaptive management, managers typically:

- define competing hypotheses about the impact of management activities on ecosystem functions;
- design experiments to prove or disprove the hypotheses; and
- deliberately perturb systems, often with several alternative types of management activities, in order to observe and compare results.

An active approach will deliver more information – and especially more statistically valid information – in a shorter period of time. However, it requires more resources to plan and implement, may involve risks to sensitive species or other values, and requires willingness and capacity to act on new information. Both approaches are valuable and either may be considered more appropriate depending on the circumstances of a given management problem.

3.1.2 The Process, Principles and Tools

The original proponents of adaptive management specifically avoided outlining a step-by-step "cookbook" procedure for it, feeling that such a prescription would stifle the intended flexibility of the approach (Holling, 1978). Nonetheless, over the years a generic process has emerged. The overview of this process below offers a good introduction to the adaptive management approach.

The Generic Adaptive Management Process

Step	Description
1. *Define Problem Boundaries*	Most environmental management problems are fraught with uncertainty and complexity. To make them tractable, boundaries of the management problem are clearly defined. Walters (1986) suggests bounding the problem in four dimensions: 1) the breadth of factors considered, 2) the depth of detail, 3) the spatial scale, and 4) the time scale and resolution.
2. *Identify Key Uncertainties*	Explicitly identify what is unknown about the ecosystem being managed. More specifically, identify which of these unknowns are most important to resolve in order to increase confidence in management interventions and policy directions (Walters, 1986).

[6] In trial and error learning, the use of historical data is haphazard, explicit hypotheses are absent and therefore do not influence management planning, monitoring is incomplete, new information is used to make relatively small incremental changes in management plans.

3. *Choose Ecosystem Indicators*	Appropriate ecosystem indicators are established based directly on the key uncertainties that need to be resolved. A commitment to thorough monitoring is made up front, and sufficient resources are allocated. Marcot (1998) identifies that for AM studies, an indicator should: 1) respond rapidly to changes, 2) signal changes in other variables of interest, 3) be monitored efficiently, and 4) be causally linked to changes of interest.
4. *Generate Alternate Hypotheses*	Alternate hypotheses are generated that centre on the key uncertainties. These hypotheses guide the design of management experiments.
5. *Design Management Experiments*	Experiments are designed in conjunction with ongoing management activities. Both qualitative and quantitative aspects of good experiment design are addressed to test alternative hypotheses (Lee, 1993).
6. *Implement and Monitor*	Managers, researchers and technicians collaborate to meet both management and research goals. Data collection activities focus on previously chosen ecosystem indicators – in most cases these will be consistent with ongoing management data requirements (e.g., water quality measures) (Taylor et al., 1997).
7. *Feedback Results*	Experimental results are applied toward the ongoing improvement of management activities. Results are used to improve understanding of ecosystem functioning and to update original hypotheses.

Adaptive management can be further described in terms of six major principles. Some of the principles are more important to the ecosystem aspects of management, while others are more important to the institutional aspects.

Adaptive Management Principles

Principle	**Description**
1. *Continuous and Deliberate Learning*	Ecosystems are inherently complex and continually evolving as a result of natural and anthropogenic processes. Uncertainty is the key issue that underlies all major resource and environmental management problems. A formal and structured approach to learning about the functional relationships that drive these evolutionary processes is central to the adaptive management approach (Holling et al., 1978)

2. *Field Science and Formal Experimentation*	Adaptive management is field science. Functional knowledge of ecosystem behaviour can only be developed by carrying out formal experiments that test hypotheses (Dorcey, 1986). Adaptive management advocates the use of *experimental management* techniques for developing and testing hypotheses (Walters and Holling, 1990). These hypotheses usually take the form of predictions about how one or more important ecosystem indicators will respond to management interventions.
3. *Systems Approach*	Adaptive management is based on a formal application of systems theory, which focuses on i) wholes and their emergent properties, ii) internal and external hierarchical arrangements of wholes, and iii) functional interactions between component parts of wholes (Checkland, 1981).
4. *Integration of Management and Research*	Adaptive management calls for the integration of management and research into a single activity, with resource managers actively involved in the process of defining problems, generating and testing hypotheses, and evaluating outcomes (Holling, 1978; ESSA, 1982). An implicit assumption is that information gained in the process of implementation will be used to meet management objectives.

Finally, adaptive management can be described in terms of its primary tools. While the principles discussed above serve as a conceptual guide to adaptive management, the tools relate more specifically to the actual implementation of an adaptive management program.

Adaptive Management Tools

Tool	Description
1. *Modelling*	Adaptive management makes use of all forms of modelling, including:
a) Conceptual Modeling	Conceptual models synthesize current understanding of ecosystem functioning or describe hypotheses of ecosystem response to management intervention. They can be presented with a combination of words, symbols or mathematical expressions (Walker, 1996).
b) Simulation Modeling	Simulation models use one or more algorithms to transform a set of input data into output data. Their use is primarily predictive, helping to test a particular theory or propose a particular management action. Models serve four important functions: i) as a means of organising thought, ii) as a means of structuring large amounts of data, iii) as a tool for comparisons and simulations, and iv) as a means of facilitating collaborative problem solving.

Adaptive management proponents stress that it is the process of model building rather than the results of model simulation that are most important in terms of gaining improved overall understanding of resource management situations (Walters, 1986).[7]

2. *Interdisciplinary Workshops*

In an effective adaptive management process, government resource management professionals, scientists and other stakeholders enter into a partnership to regularly redefine objectives and redirect management actions. A unique interdisciplinary approach to this is found in the *Adaptive Environmental Assessment and Management (AEAM) Workshop* process developed by the early practitioners of adaptive management (Holling et al., 1978). These workshops have three general goals: i) to include all stakeholder interests, ii) to work across jurisdictional boundaries, and iii) to bound conflict.

3. *Experimental Design*

Adaptive management requires large-scale experimentation at the scale of ecosystems. Effective experimental management requires rigorous attention to the details of experimental design (McAllister and Peterman, 1992). Specific considerations include:

a) *The Fundamentals*

Well designed experiments are often structured around the use of *controls* (against which to compare one or more experimental treatments) and *replicates* (of both controls and treatments, ideally in both space and time) (Taylor et al., 1997). *Randomization* and *blocking* of experimental treatments are important techniques to minimize the risk of bias entering into the results (Nemec, 1998).

b) *Statistical Power Analysis*

Classical approaches to experimental design focus on the avoidance of Type I and Type II errors.[8] Statistical power analysis is a well established body of classical statistics theory that is used to design experimental and monitoring programs or evaluate their results (Peterman and M'Gonigle, 1992). The "statistical power" of an experiment is simply a measure of the probability of correctly accepting as true an hypothesis that is true; that is, it is an inverse measure of the chance of making a Type II error. Calculating the statistical power as part of a formal adaptive management program enables researchers and managers to judge how much confidence to place in their monitoring results. Further, statistical power analysis can be used to design new experiments, monitoring systems and data analysis programs that have a higher chance of delivering valid results, and even to rank alternative designs.

[7] Unfortunately, experience has shown that all too often participants in a model-building exercise have overly high expectations regarding the actual model results (ESSA, 1982).

[8] Type I errors are those that result in accepting as true an hypothesis that is false. Type II errors are those that result in accepting as false an hypothesis that is true. Scientists have typically been more concerned with the avoidance of Type I errors. Yet from an adaptive management perspective, the avoidance of Type II errors may in fact be more important: "There is more concern that a useful hypothesis might be rejected [due to type II errors] than a false one might be accepted [due to type I errors]" (Holling, 1995).

c) Bayesian Statistics

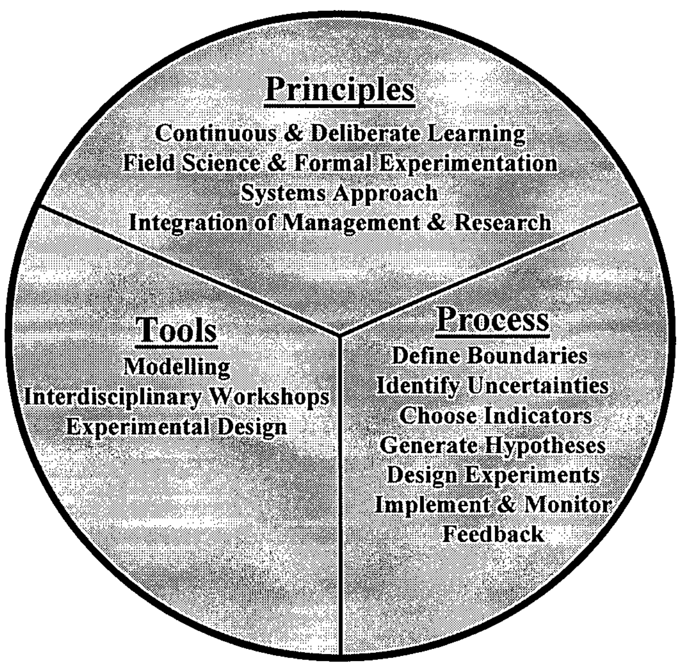
Bayesian statistical analysis is an approach that has been developed for cases where a lack of existing data sets or a lack of controls and replicates occurs. The approach allows experimenters to assess impacts by assigning a *prior probability* that a hypothesis is correct (based on expert opinion), and then uses data collected during experimentation to update the assigned probability (Berger and Berry, 1988). Although the task is computationally intensive, it allows experimental management to proceed in a structured manner.

d) Qualitative Tests of Validity

The validity of experimental results can also be tested for validity by qualitative means. Internal threats to validity are those that lead to questions of whether something else really caused the observed effect in an experiment. Examples include *Hawthorne effects* where the act of experimentation itself actually causes the effect, and *maturation effects* where the effect would have occurred anyway as a result of forces already in effect. External threats to validity are those that question whether the experimental result can be applied to other circumstances. Examples here include *cumulative effects* where it is difficult to determine which of several simultaneous interventions actually caused the effect, and *complexity effects* where it is difficult to even identify the relationships between cause and effect. Understanding these possible qualitative threats is vital to the experimental management design process (Lee, 1993).

Figure 3-3 summarizes the generic process, major principles and primary tools of adaptive management. In summary, adaptive management is an approach that integrates management action with research enquiry in a structured and explicit learning process. It highlights that both policy directions and management actions are, in fact, experiments, and suggests that they be structured to investigate critical uncertainties regarding natural resource management problems. Adaptive management therefore allows resource managers to proceed responsibly in an atmosphere of scientific uncertainty.

Figure 3-3: Adaptive Management in Summary



3.1.3 Experience in Implementation

The literature demonstrates that adaptive management has been applied to ecosystem management problems with varying spatial scales, ecosystem complexity and risk, socio-economic implications, and political, regulatory and jurisdictional complexity.

Some applications are relatively simple and small-scale. The BC Forest Service for example has conducted experiments to evaluate alternative forest harvesting techniques, such as the Sicamous Creek Silvicultural Systems Project and the Date Creek Silvicultural Systems Project (see Taylor et al., 1997 for a summary of these projects). These applications of AM occur on sample plots on Forest Service land, are subject only to the regulatory oversight of the Forest Service, address a single management question (for example, Sicamous Creek is designed to answer "what is the effect of cutblock size on forest structure and function?"), and have limited impacts beyond the treatment site, posing no threat to the viability of the overall ecosystem or any individual species.

In contrast, the application of AM to the Columbia River Basin is far more complex. There, experiments affect multiple interests (farmers, industry, fishers, First Nations), may seriously interfere with local economic activity, require cooperation from multiple regulatory agencies and have the potential to gravely threaten endangered salmon stocks[9]. In this difficult environment, AM is credited with facilitating the formation of a regional systems-based vision of the Columbia River, increasing the understanding by multiple stakeholders and agencies of the complexities and interdependencies of the system, and creating an acceptance, at least in principle, of an experimental approach to management (McConnaha and Paquet, 1996). However, due to social, political and ecological difficulties in implementing statistically valid experiments, virtually all of the critical questions that faced the Northwest Power Planning Council in 1984 when it adopted the AM concept are still unresolved (NMFS, 1995).

Not surprisingly, some sources suggest that AM is most feasible and most likely to be successful when the number of regulatory bodies is relatively small, the number of interest groups is small and the impacts on them are not severe, and the risk of driving any species to extinction is low (McConnaha and Paquet, 1996). Most IWM processes will be smaller in geographic scale than the Columbia River System and may not be complicated by risks to endangered species, but they will likely involve similar regulatory and jurisdictional complexity and a high potential for significant multi-stakeholder impacts.

Some authors have noted the need for integrating formal decision analysis techniques into adaptive management.[10] For example, Peterman and Peters (1998) describe how decision analysis is particularly effective during the planning stage of an active adaptive management because it can compare the expected performance of alternative experimental designs. Rogers (1998) uses the term "strategic adaptive management" for an adaptive management process that begins by building an "objectives hierarchy" (see Section 3.2.2). And finally, Sainsbury (1987) shows how decision analysis was used to compare the potential economic performance of experimental and non-experimental strategies and to refine experimental design for management of a large-scale multi-species fishery.

[9] See also Walters et al. (1992) for an example of water management in the Florida everglades, which shares similar economic and social impacts, ecological risks, and difficulty with controls and replicates.
[10] In fact, some authors trace the roots of adaptive management to the decision analysis field (Walters, 1986).

Much of the more recent literature probes the question of why adaptive management has not been more widely adopted than it has. Carl Walters, one of the fathers of AM, notes that out of the 25 major planning exercises for adaptive management that he has participated in, only seven resulted in relatively large-scale management experiments, and only two could be considered well-planned in terms of statistical design (Walters, 1997). Other initiatives have either "vanished with no visible product" or become "trapped in an apparently endless process of model development and refinement".

As noted above, some of the reasons for difficulty in implementing AM stem from issues related to regulatory and jurisdictional complexity, stakeholder impacts, and ecosystem considerations. However, there are a number of other difficulties related to *how* AM is implemented that have contributed to its failure to achieve widespread adoption and its rather modest success when adopted. These include:

- failure to define what is meant by adaptive management and how it will be implemented;
- an absence of strategic thinking about the end-points of scientific inquiry;
- tendency for AM processes to evolve into continuous and costly modeling exercises;
- over-reliance on a passive adaptive approach - i.e., better use of monitoring information – accompanied by a failure to ensure that monitoring delivers statistically useful information;
- belief that effective experiments are excessively expensive and/or ecologically risky (even when baseline options cannot be said to be low-cost or low-risk);
- fear on the part of individuals in management agencies that acknowledging uncertainty will compromise public confidence in the agency;
- failure of scientists to understand management priorities and to recognize the need to provide information that can be directly used by managers in decision making;
- tendency of scientists with self interests to overstate their capability to measure complex functional relationship through experimentation;
- lack of emphasis or attention to the processes required for shared understanding or shared decision making among diverse stakeholders (Walters, 1997; McLean and Lee, 1996; Rogers, 1998; Halbert, 1993).

Despite these challenges, modest successes are being reported in practice, and numerous government agencies are initiating adaptive management programs as a key part of their overall management strategy. A few examples include:

B.C. Forest Service (B.C. MOF, 1997)	In 1995, the BCFS initiated a program to review the principles and potential of adaptive management. Through a combination of pilot study projects and background investigation the program aims to continuously improve forestry practices throughout the province, and to refine and test aspects of the Forest Practices Code.
U.S. Forest Service (USFS, 1999)	Ten "Adaptive Management Areas" (AMAs) have been established in the U.S. Pacific Northwest ranging in size from 92,000 to 500,000 acres. In each AMA, management agencies are developing and testing a variety of technical and social approaches to achieving desired ecological, economic, and other social objectives.

Ontario Ministry of Natural Resources (Ontario MNR, 1998)	The Ministry has launched several programs that incorporate the adaptive management approach. For example, management experiments have been implemented to test various hypotheses regarding the effects of habitat change and harvest levels (both controlled and uncontrolled) on lake fisheries. Recently, an adaptive environmental management framework for stream and valley corridor management has been launched.

Despite the wide ranging interpretations of adaptive management (e.g., see Halbert, 1993), and despite the limited success in implementing a comprehensive active adaptive management approach at the scale of large ecosystems, these initiatives confirm that, in principle at least, adaptive management is widely regarded as a useful tool for resource managers.

3.2 A Primer on Decision Analysis

Today's decision makers[11] and resource managers are faced with problems characterized by increasing demands upon a limited resource base, increasing complexity resulting from the interaction of biophysical, socio-economic and institutional systems, and increasing awareness of the uncertainty that pervades the understanding of these systems. The decision context is further complicated by the now commonplace necessity to involve multiple stakeholders and their multiple objectives in the decision-making process. Under these complex and dynamic circumstances, a structured approach to decision making supported by appropriate analytical tools is imperative if good decisions are to be made.

3.2.1 Overview

Decision analysis is founded on a set of axioms that philosophically imply that the attractiveness of alternatives should be based on i) the likelihoods of the possible consequences of the alternatives; and ii) the preferences of decision makers for those consequences (Keeney, 1982).

In practice, decision analysis is often boiled down to a set of quantitative techniques for analysing alternatives associated with complex decision problems. One of the original driving forces for developing decision analysis was to formally introduce and process subjective judgments in the evaluation of alternatives – both subjective technical judgments and subjective value judgments (Keeney, 1982). Techniques for this are well developed and described in the literature.[12]

However, the more *qualitative* aspects of the decision analysis approach may also have significant relevance to IWM.[13] Two key features capture the essence of this qualitative approach.

[11] The term decision maker is used here generally to refer to the individual, group or agency responsible for making decisions regarding the management of natural resources.
[12] See *Making Hard Decisions: An Introduction to Decision Analysis* by Robert T. Clemen (1991) for a review of many standard techniques.
[13] See *Value-Focused Thinking: A Path to Creative Decisionmaking* by Ralph L. Keeney (1992) for a more detailed review of these concepts.

First, the approach emphasizes the importance of concentrating on decision makers' values. Values are the basic principles that guide actions and preferences. Developing a clear understanding of values is essential for properly defining decision situations, articulating objectives and creating and evaluating alternatives (Keeney, 1992). Only after this front-end analysis is complete will the quantitative tools and techniques of more traditional decision analysis be useful in supporting the analysis and selection of appropriate alternatives.

The second key feature is the concept of structuring and modeling the decision situation. Recognizing the complexity of most environmental decisions, the basic approach is to decompose complex decisions into manageable units that are more suitable to analysis (Clemen, 1991). Fact and value information are then incorporated into the component parts of the decision situation, and the parts are restructured again for analysis of the whole.

The literature on decision analysis consistently emphasizes the importance of a clear separation between facts and values. Facts are the estimated consequences (or outcomes) of an alternative. Facts may often be disputed and/or may be qualified with discussion of the uncertainty surrounding the facts. Nonetheless, facts are arrived at primarily through technical or functional knowledge and analysis.[14] Values, on the other hand, are what drive decision makers' preferences for different outcomes. They do not depend on technical or functional knowledge, and there is no "right" set of values. Clarifying the distinction between facts and values can help to improve decision quality, to understand the source of conflicts among multiple decision makers, and to improve the transparency of a decision to other stakeholders.

The intent of this structuring and modeling process is more to provide insight and understanding to decision-makers than it is to produce the "right" decision. The *process* of modeling therefore provides both a structured way to think about the decision situation, and a structured way to incorporate new insights and understanding of both facts and values as they emerge (Clemen, 1991).

For the purposes of this thesis then, decision analysis is defined as *an approach that provides guidance and structure for thinking systematically about decisions that involve situational complexity, inherent uncertainty, and multiple objectives among multiple stakeholders*. The focus of the approach is on structuring a problem situation, taking into account the decision makers' preferences and their beliefs regarding uncertainty, in order to gain insight and understanding.

3.2.2 The Process, Principles and Tools

Over the past several decades, many approaches to decision analysis have emerged. Keeney (1982) suggests a four-stage process that is adapted here (Figure 3-4) to provide a generic overview. Each step is described below.

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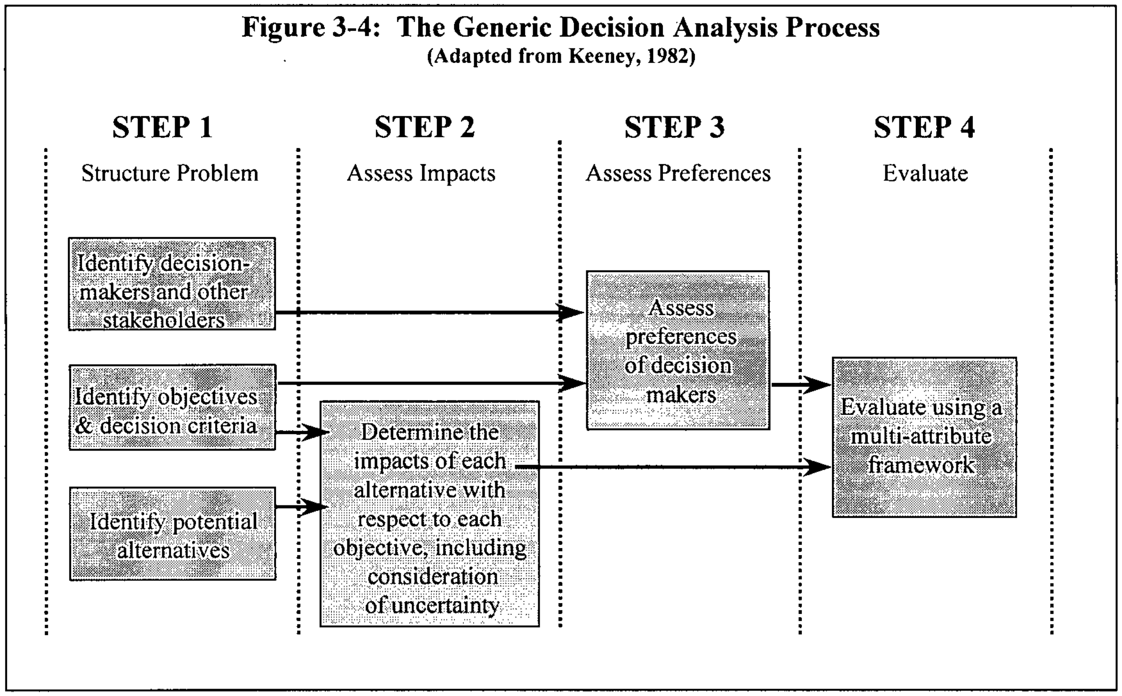
[14] This separation of facts and values is, admittedly, an oversimplification. Especially in the presence of uncertainty, the interpretation of scientific information is dependent on values and preferences. Thus, there is no absolute distinction between facts and values. Nonetheless, this simplification is useful in that there is a role for scientific experts in informing decision making processes that is qualitatively different from the role of affected stakeholders in assigning preferences to alternative outcomes or objectives. It is in this general sense that the distinction is made here. For more detailed discussion, see Dorcey (1991b).



The Generic Decision Analysis Process

Step	Description
1. Define and Structure the Decision Problem	Define the specific decisions to be made, and identify the decision makers and the affected stakeholders. Define and structure the available alternatives, as well as the objectives and decision criteria that are needed to select among the alternatives.
2. Assess the Impacts	Specify the impact of each alternative on each objective of importance. In the case of IWM, these impacts will be developed using natural resource models, environmental studies, and financial and engineering analyses among other sources. Special emphasis is placed on modelling uncertainty as a means of both recognizing and coping with the inherent uncertainties that pervade most environmental decision analyses.
3. Assess the Preferences	Decision analysis recognizes that within the range of objectives emerging from step one, some objectives will be conflicting. Decision makers therefore must analyse their preferences, and make value tradeoffs. Here, special emphasis is placed on modelling the preferences and value tradeoffs as a means of providing improved insight and understanding of the complex decision situation.

4. Evaluate and Compare Alternatives	Once the decision problem is structured, and the impacts and preferences are assessed, the information must be synthesized for the purpose of evaluating the alternatives. Key within this synthesis is i) the use of a multi-attribute framework to make explicit tradeoffs among objectives, ii) the use of sensitivity analyses targeting the results of both steps two and three, and iii) the use of iteration to incorporate improvements in understanding.

Four major principles capture the importance of the decision analysis approach to the management of natural resources.

Decision Analysis Principles

Principle	Description
1. Value-Focused Thinking	Traditional decision making processes start by recognizing a problem, then identifying alternatives, and then looking for criteria to help evaluate the alternatives. Value-focused thinking reverses the process – it starts by identifying objectives, and only then investigates alternatives (Keeney, 1992). Value-focused thinking is intentionally both broad and proactive. The premise is that focusing early and consistently on values when faced with difficult problems will lead to more creative alternatives and more desirable outcomes.
2. Problem Structuring	Both objectives and alternatives can be structured to break a complex decision situation into manageable sub-problems, to provide clarity, and to clearly differentiate between facts and values.
i) Objectives	i) Objectives articulate values, qualitatively stating all that is important in a decision situation and providing the foundation for quantitative analysis. Objectives must focus on fundamental "ends" rather than "means".[15]
ii) Alternatives	ii) Properly identifying and screening alternatives is also crucial to sound problem structuring. A good decision analysis approach is one in which the development of alternatives is made into a creative, open-ended and broadening process.

[15] Fundamental or "end" objectives are the things that are important in and of themselves. Means are the methods used to achieve fundamental objectives. In many decision processes, decision makers focus on means, and may state means-oriented objectives. An example of a means-oriented objective is "to implement streambank rehabilitation projects". In reality, this is an alternative. The fundamental objective is more likely "to improve water quality". Streambank rehabilitation projects are one (of perhaps many) means of achieving it. Too much emphasis on means can result in sub-optimal decisions. Structuring objectives and clarifying differences between fundamental objectives and means of achieving them is a key aspect of problem structuring.

3. *Improved Multiple Stakeholder Involvement*	Experience has shown that proper attention to stakeholder selection and early involvement will provide important benefits in terms of overall public support and the associated ability to implement resultant decisions and plans (Keeney, 1992). Further, techniques for addressing the implementation challenges posed by multiple stakeholder involvement in public decision-making processes have improved greatly in the last two decades (Keeney, 1988). These include processes from soliciting and weighing multiple objectives through to principled negotiation.
4. *Transparency*	By providing structure to the evaluation process, clarifying objectives and clearly reporting impacts, decision analysis makes decisions less arbitrary.

Finally, decision analysis can be described in terms its primary tools. While the principles discussed above serve as a conceptual guide to decision analysis, the tools relate more specifically to its application. Below, some of the most common and widely applicable tools are summarized. For more detailed understanding of how the tools work, see the references noted.

Decision Analysis Tools

Tool	**Description**
1. *Objectives Hierarchies*	The most important aspect of the objective structuring process is the identification and structuring of an appropriate *fundamental objectives hierarchy* (Keeney, 1992). Hierarchies specify all reasons for interest in the given decision situation. Within the hierarchy, any higher level objective is defined by a set of lower-level objectives that can be quantified by measurable attributes, herein termed decision criteria. Once complete, the fundamental objectives hierarchy serves as a useful tool for either quantitative or qualitative evaluation of alternatives. Objectives hierarchies can also be complemented with means-ends diagrams (Keeney, 1992). Means-ends diagrams map alternatives (or means) back to the fundamental objectives that they support. Such diagrams can be useful for keeping planning efforts focused on fundamental objectives.
2. *Strategy Table*	Many decisions require that a series of smaller decisions be made in specific areas – that is, a "strategy" must be developed that links compatible or synergistic choices. Often there are many possible alternatives within each sub-area, resulting in a prohibitively long list of possibilities, when all combinations are considered. A strategy table uses a "strategy theme" to identify choices that make sense together. It enables people to discuss a few significantly different strategies rather than an exhaustive list. It is a useful tool for helping people think their way through problems where there are literally hundreds of possible combinations (Howard, 1988).

3. *Decision Modelling*

Decision modelling involves the decomposition of a decision situation into smaller, more manageable component parts. Two commonly used tools are influence diagrams and decision trees.

a) *Influence Diagrams*

An influence diagram is a simple, graphical representation of a complex decision situation (Clemen, 1991). It can provide a useful starting point for analysis because it allows many aspects of a decision situation to be developed and modelled in a compact and intuitive form. Elements of a decision situation included in an influence diagram include: i) the decisions to be made, ii) the uncertain events, and iii) the resultant outcomes. Moreover, the influence diagram displays the specific relationships between these three elements.

b) *Decision Trees*

Decision trees offer an alternative and complementary representation of a decision situation (Clemen, 1991). They provide the format for more detailed analysis of a decision situation in either qualitative or quantitative terms. Within the structure of a decision tree, the decisions to be made, uncertain events and resultant outcomes are all displayed together in a branched tree format. Decision trees allow decision makers to clearly see the possible future outcomes given their decisions when combined with important uncertain events, and can also be developed to include the analysis of imperfect information, multiple objectives, and sequential decisions (Clemen, 1991).

Decision trees may be combined with probabilistic analysis to provide quantitative estimates of the "expected value" of various alternatives (see below), or they can be used qualitatively to simply show the range of possible outcomes given a range of uncertain events or conditions that may affect outcomes.

4. *Treatment of Uncertainty*

The uncertainty associated with estimates of the outcomes of a management alternative should be described as clearly as possible. This can be performed with greater or lesser degrees of analytical rigour depending on both the nature and the magnitude of the uncertainty itself, the potential consequences of being wrong, and the resources available (Morgan and Henrion, 1989; Morgan et al., 1984). Broad approaches include: i) setting value ranges for individual variables, ii) conducting sensitivity analysis; iii) constructing scenarios for sets of variables, iv) calculating "expected values" with point probabilities assigned to possible outcomes v) building continuous probability distributions for outcomes, vi) conducting combined probability modelling, and vii) conducting bounding analysis. Two of these techniques – calculating expected values and conducting sensitivity analysis – are particularly useful and are described below. The remaining techniques are described briefly in Appendix A.

a) *Expected Value Calculations*

Decision analysis advocates making decisions on an "expected value" basis. The expected value of any decision is the probability-weighted average of all possible outcomes. It can be thought of as the "best guess" for the value of an uncertain quantity or random variable (Clemen, 1991). The expected value as calculated is unlikely to be the value that actually occurs. However, when comparing two alternatives, the one with the higher calculated expected value is, on a probabilistic basis, more likely to yield a higher value in reality.

From a practical perspective, using expected value techniques requires that decision makers identify all possible uncertain events, assign a probability to each, estimate the outcome of interest, and calculate the probability-weighted average.

b) *Sensitivity Analysis*

Sensitivity analysis is a fairly simple tool used to determine which variables most affect outcomes (Clemen, 1991). By testing whether a decision would change as a result of switching the value of an uncertain parameter within a plausible range of values, this may either show that the uncertainty does not affect the decision, or indicate where information gathering efforts should be directed. Sensitivity analysis can (but does not necessarily have to) be used in conjunction with expected value calculations.

c) *Probability Elicitation (Encoding)*

Where data are not readily available, the probability of an uncertain event or condition cannot be known. Instead, decision analysis relies upon the judgment of professionals in providing probability estimates. A decision analyst may elicit probabilities from technical experts and use these to characterize the uncertainties associated with the outcome of an alternative. Probability elicitation techniques and the potential pitfalls are well described in the literature (von Winterfeldt and Edwards, 1986; Clemen, 1991; Kirkwood, 1997).

d) *Expected Value of Information Analysis*

Expected value of information (EVI) methods provide estimates of the value (typically in monetary terms, but can be non-monetary) that the decision-maker would gain from having improved information. Consequently, these methods provide a sense of the amount of resources that should reasonably be spent to obtain better information. The calculations are done on an "expected value" basis.[16]

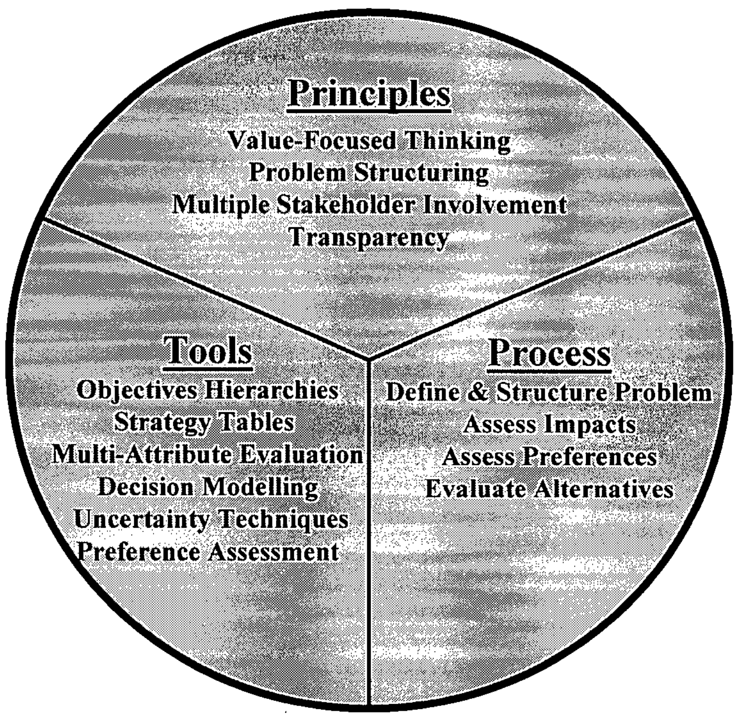
[16] EVI can be used in combination with decision trees that incorporate sequential decisions to quantify the benefits of delaying a decision until more information is available. The converse is also true; EVI analysis may also show that waiting for more information will not help to resolve a certain decision. Certain risk-based engineering design efforts also use an EVI approach (or "data worth" approach) to assess the worth of a program of data collection prior to undertaking it (Freeze et al., 1990). The data collection program is only carried out if the calculations show that reduction in risk achieved (as a result of better information) is greater than the cost of carrying it out.

5. *Multi-Attribute Evaluation Frameworks* — A multi-attribute evaluation framework structures the decision situation in a fashion that clearly and concisely summarizes the effect of each alternative on each stated objective. It is a simple matrix that lists the objectives along one axis and the alternatives along the other.[17] The framework is a useful tool for clarifying trade-offs required either within a single alternative or among several alternatives. It should be a clear presentation of the "facts" about the consequences of each alternative under consideration.

6. *Preference Assessment Techniques* — There are a number of qualitative and quantitative approaches to identifying decision makers' preferences to support making decision trade-offs. Some of the more common techniques include: i) overview assessment, ii) goal setting, iii) weighted averaging, iv) swing weighting, and v) multi-attribute utility techniques (see Appendix B). All seek to find a preferred alternative based on a set of stated objectives and decision makers' stated preferences for outcomes.

Figure 3-5 summarizes the generic process, major principles, and primary tools of decision analysis. In summary, decision analysis offers a structured framework for analysing complex natural resource management situations. It highlights the need to i) explicitly state management objectives (that will inevitably be in conflict), ii) design and evaluate creative alternatives, iii) explicitly address uncertainty, and iv) incorporate stakeholder values. Decision analysis allows resource managers to proceed responsibly in an atmosphere of both scientific uncertainty and public scrutiny.

Figure 3-5: Decision Analysis in Summary



[17] A commonly used framework used in the Province of B.C. is the "Multiple Account Evaluation" framework (see e.g., B.C. Crown Corporations Secretariat, 1993).

3.2.3 Experience in Implementation

Decision analysis has been extensively applied for decades. Much of this has been conducted in a corporate environment or for government / regulatory agencies. In these conditions, the decision making context is not complicated by multi-stakeholder considerations. Examples of applications of decision analysis include private sector capital investment decisions, public and private sector resource allocation, and the evaluation and selection of regulatory standards (see e.g., Howard, 1988; Edwards and von Winterfeldt, 1987). In the natural resources management field, while not as widespread, there is a growing list of successful applications of decision analysis (see e.g., McDaniels, 1992a and 1992b; Gregory and Keeney, 1994; Maguire et al., 1995).

Decision analysis is particularly well suited to situations where there is a single decision maker, or a group of decision makers with very similar values. In these situations, a good decision analysis can lead to an unambiguous recommendation on an optimal decision. Where there are multiple stakeholders, and where value differences are profound, decision analysis cannot determine the optimal solution unless it is clear whose values are to be given priority. As a result, its use in a multi-stakeholder context is substantially different. In such cases, it offers a means of better understanding value differences among decision makers, informing decision makers about stakeholder values, and ensuring that decision makers are rational and consistent in applying their values.

Methods for assessing preferences are perhaps the most controversial aspect of decision analysis, particularly in a multi-stakeholder context. None of the approaches outlined here is universally better than the others. Indeed, at least two recent experiences suggest that applying a combination of approaches can often lead to more reliable results, better stakeholder satisfaction with the process, and improved insight (Hobbs and Meier, 1994; Hobbs and Horn, 1995).[18]

Recent practical experience in multi-stakeholder public planning processes for resource management has raised questions about the optimal use of technical analyses in public participation processes. Some practitioners suggest that technical analysis may be useful only "behind the scenes" and that it has no place in face to face discussion in multi-stakeholder negotiation processes (Maguire et al., 1995; Young, 1991). Maguire et al. found qualitative tools such as means/ends diagrams and objectives hierarchies very useful. However, sophisticated decision analysis and mathematical modeling tools had limited application. In particular, recent experience suggests that where trust among the parties is low and the level of technical knowledge is highly imbalanced among parties, (both of which can be characteristic of resource planning processes) technical analysis can appear to some parties to be deliberately used to put others at a disadvantage. Maguire et al. concluded that more sophisticated quantitative analysis was not appropriate in their application. Although this may have meant reaching a solution that was sub-optimal (in the sense that further joint gains might have been possible), that was preferable to losing the cooperation of some parties.

[18] Hobbs and Horn (1995) offered stakeholders the chance to see how their preferences translated into ranking of alternatives under three different methods of preference assessment (ratio assessment, trade-off weighting, and holistic assessment). Based on stakeholder feedback, they conclude that no one method was clearly preferred. Interestingly, holistic assessment was most highly recommended by stakeholders for use in resource planning. (Problem structuring and clarification of trade-offs likely facilitated holistic assessments.) They also found that the use of three methods helped ensure that stakeholders didn't see the analysis as a black box that delivered a single solution.

In sum, recent literature on the use of decision analysis in complex natural resource planning processes (Hobbs and Horn, 1995; Maguire et al., 1995; Freeze et. al., 1990; Peterman and Peters, 1998), suggest that its adoption rate may be hindered by:

- resistance to transparency by the responsible agencies;
- resistance to the use of subjective judgment by scientists or professionals;
- lack of political and/or public acceptance of decisions based on subjective technical or scientific assumptions;
- lack of trust by non-technical stakeholders in the technical analyses put forward by project/plan proponents;
- lack of resources for the necessary cost and time requirements;

Issues related to how decision analysis is implemented include:

- an overemphasis on quantitative analysis that is not intuitive for non-technical stakeholders;
- black-box approach to modeling and claims that analysis provides the answer;
- poor technical / analytical skills;
- weak personal interaction skills of the analyst;
- lack of emphasis or attention to the processes required for shared understanding or shared decision making among diverse stakeholders.[19]

Despite these challenges, numerous successes are being reported both in practice and in the literature. For example, McDaniels (1992a) applied decision analysis techniques to facilitate resolution of a controversial land use planning decision in northwestern B.C. that had wilderness preservation and the potential economic benefits associated with a major mining development as fundamentally conflicting objectives. In a similar situation involving the implications of a major mineral development project in Malaysia, Gregory and Keeney (1994) used decision analysis to facilitate the development and analysis of policy alternatives and to structure a controversial economic and environmental tradeoff process. And finally, Maguire et al. (1995) facilitated the development of a scientifically based forest management plan, in an atmosphere of chronic multi-stakeholder dispute and distrust, by applying various decision analysis tools.

[19] See in particular Maguire et al. (1995) for the discussion of the integration of decision analysis with interest-based negotiation techniques to improve science-intensive public planning.

3.3 The Analytical Framework

In this section, an analytical framework is developed that builds on the process, principles and tools of AM and DA as described in the previous sections. It is a normative framework that illustrates how adaptive management and decision analysis can be applied to the general problem of integrated watershed management. The framework could be applied either as a *prescriptive* tool (i.e., to guide the development of an integrated watershed management program), or as an *evaluative* tool (i.e., to evaluate the effectiveness of existing programs and management activities). In either case, the elements of the framework are not necessarily universally and equally applicable to all management situations. Instead, the framework offers a suite of actions that can be applied as needed to improve the effectiveness of integrated watershed management.

The framework builds on a generic six-step process common to many government planning and management processes (Figure 3-6). Although the process is shown in linear fashion, management processes rarely proceed in such discrete steps. Instead, steps often overlap, repeat, and managers may move both forward and backward through the overall process, or find themselves implementing several steps at once. At each step of the planning process, Figure 3-6 shows the integration of actions related to adaptive management and decision analysis.

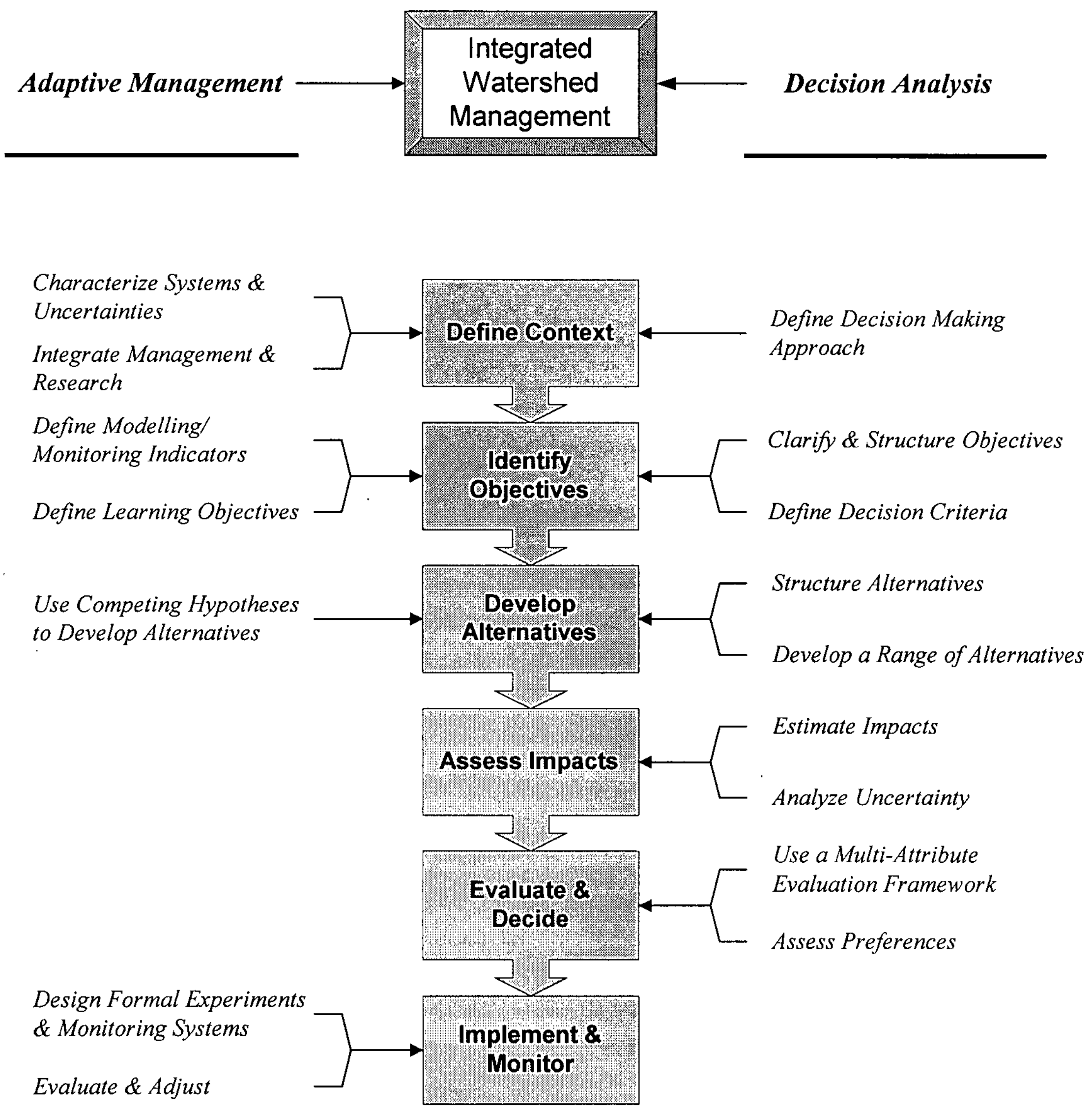
While some of the actions suggested are not necessarily germane to either adaptive management or decision analysis, nonetheless they are recommended by these fields.

Each of the following sub-sections includes, for each step of the planning process:

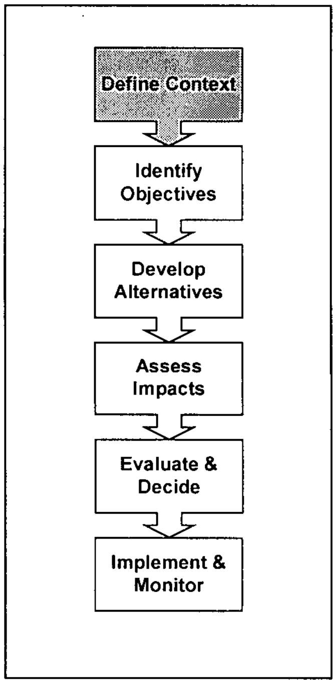
1. a short generic description of the step;
2. a set of investigative questions that focus on the incremental actions or emphasis suggested by AM and DA; and
3. a summary table of the circumstances most likely to trigger the use of the proposed actions.

The "triggers" represent conditions that may flag a particular benefit that could be gained from adoption of the action in question. However, many of the actions may have benefits in a wide range of situations, not just those identified in the table.

Figure 3-6: The Contribution of Adaptive Management and Decision Analysis to Integrated Watershed Management



3.3.1 Define Management Context



In practice, defining the management context is a step that is often omitted or conducted implicitly. It should include identifying key issues, defining problem boundaries, and identifying administrative, legal or jurisdictional constraints and opportunities. The following highlight the actions suggested by AM and DA. Table 3-1 summarizes the considerations that might trigger the use of these actions.

Define Decision Making Approach

Decision analysis suggests a logical, structured and explicit approach to decision making. It is important to define the decision making approach early so that all participants in the planning process have clear expectations. Defining the decision making approach involves answering the following questions:

- *Who has ultimate authority for decision making?*
- *What is the role of stakeholders in decision making? For example are they serving in an advisory capacity or is there some level of shared authority?*
- *What is the decision making process?*

Characterize Systems and Uncertainties

Adaptive management suggests starting any management problem by defining the problem boundaries and characterizing the systems being managed. Further, both decision analysis and adaptive management suggest a need to be clear about uncertainties. Specific tools and approaches are offered at the early stages of the planning process. Consider:

- *Are the relevant issues clearly identified (e.g., water quality, timber production, fisheries, local economic development, etc.)?*
- *Are the physical boundaries and planning timeframe clear?*
- *Is there a common understanding of how systems work? For example, can conceptual models be constructed to illustrate common understanding and highlight points of difference?*
- *Are key uncertainties defined up-front?*
- *Are there clear agreements on the assumptions to be used or hypotheses to be tested?*

Integrate Management and Research

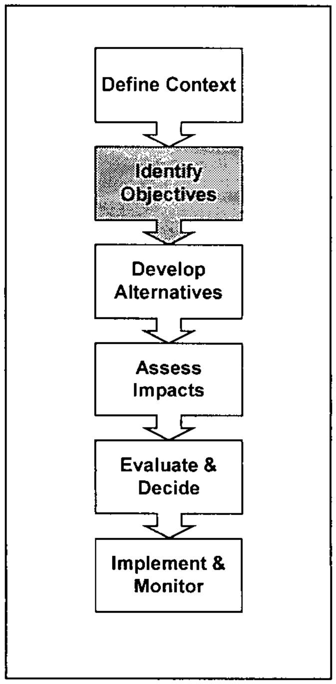
Adaptive management suggests that research objectives and functions should be integrated with management. Considerations include:

- *Are research interests represented at the stakeholder table?*
- *Are there both scientists and managers involved in the process?*

Table 3-1: Summary of Triggers for AM and DA actions at Step 1

Action	Triggers
Define Decision Making Approach	▪ The process has a fixed timeline or budget constraint. ▪ There is controversy or uncertainty about whether stakeholders will provide input or share decision making authority.
Characterize Systems and Uncertainties	▪ There is a mix of both technical and non-technical stakeholders at the table. In this case, a clear characterization helps provide a common level of understanding. ▪ There are diverse opinions about how systems work and how options affect watershed outcomes. In this case, explicit characterization helps identify uncertainties.
Integrate Management and Research	▪ There is uncertainty or debate about the relationship between management options and watershed outcomes. ▪ There are opportunities for partnerships with academic institutions or other research agencies.

3.3.2 Define Objectives



This step defines the resources within the watershed that stakeholders want to protect or enhance, and/or the outcomes they want to achieve. The following highlight the actions suggested by AM and DA. Table 3-2 summarizes the considerations that might trigger the use of these actions.

Clarify and Structure Objectives

Most planning processes set objectives of some sort. However, they are often a confusing mix of objectives, policies, commitments or constraints that play little role in actual decision making. Decision analysis suggests that fundamental objectives should serve as the evaluation criteria that are used to compare options. This suggests the following considerations when setting objectives:

- *Are the objectives comprehensive (i.e., addressing environmental, social and economic aspects) yet concise enough to use as evaluation criteria?*
- *Are they ends-oriented – that is, related to the fundamental "ends" of the planning process rather than to specific means?*

Define Decision Criteria

Decision criteria are used to bring broadly stated objectives down to a more operational level by attaching real-world measures of performance to them. They define precisely the meaning of each objective and allow measurement of the degree to which the objectives are achieved.

- *Are measurable criteria defined and used to report impacts on each objective?*
- *Does each criteria fulfill the following requirements:*
  - *Accurate: Adequately describing the degree to which options meet the associated objectives;*
  - *Practical: Meaning the future impact of each management option with respect to the measure can be estimated with a reasonable level of effort;*
  - *Understandable: To stakeholders and decision makers.*

Define Modelling/Monitoring Indicators

Building directly on the "characterize systems and uncertainties" action in the previous step, key indicators of system functioning must be defined for both modelling (if applicable) and monitoring purposes. Detailed considerations include:

- *For modelling purposes, are a small number of indicators identified that capture the most important aspects of the system characterizations, and in particular the uncertainties of interest?*

- *For monitoring purposes, do the chosen indicators respond rapidly to changes while signaling changes in other variables of interest? Can they be monitored efficiently?*

Define Learning Objectives

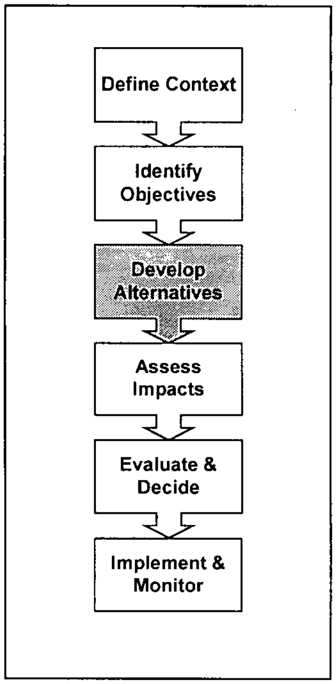
If Step 1 reveals that there are key uncertainties affecting the planning process (almost inevitable in an integrated watershed management context), both decision analysis and adaptive management suggest articulating an explicit learning objective. This both formalizes learning as a valid justification for expending time and money in research, and helps stakeholders/decision makers see that there may be trade-offs between learning and other objectives. For example, learning may involve stressing ecosystems, thus putting some species or system functions at risk, at least temporarily. To formally incorporate learning into the plan, consider:

- *Are learning objectives defined?*
- *Is it clear what uncertain variable or relationship will be resolved?*
- *Is it clear which decisions, management plans or activities could change as a result?*

Table 3-2: Summary of Triggers for AM and DA actions at Step 2

Action	Triggers
Clarify and Structure Objectives	▪ The planning process has multiple objectives. In practice, this means all IWMs, and most if not all problems in natural resource management. ▪ There are multiple stakeholders. The need to clarify and structure is amplified when the objectives stem from multiple parties.
Define Decision Criteria	▪ There is a desire or need to report the expected impact of alternatives on multiple objectives explicitly and concisely. ▪ Decision criteria are particularly relevant if the process has access to tools to quantitatively model the decision.
Define Modeling/Monitoring Indicators	▪ There is access to tools for quantitative modeling. ▪ Planners intend to scientifically test competing hypotheses. ▪ There is a desire to track the outcomes of the plan and use that information in subsequent planning processes.
Define Learning Objectives	▪ The resolution of uncertainties could change future decisions (as opposed to simply improving scientific understanding of system functioning). ▪ The key uncertainties cannot be resolved quickly (within the scope and timeline of the planning process). ▪ There is a desire to improve the practical relevance of data generated through scientific investigations (i.e., relevance to on-going management).

3.3.3 Develop Alternatives



In this step, alternative projects, programs or operational guidelines are developed. The watershed may be subdivided into sub-drainages or zones to allow for different management emphases based on localized conditions. The following highlight the actions suggested by AM and DA. Table 3-3 summarizes the considerations that might trigger the use of these actions.

Structure Alternatives

In most integrated watershed management processes, there are many possible options (i.e., projects, programs or operational guidelines) under consideration. It is therefore beneficial to structure these options into broad, logical alternatives in order to avoid the prohibitively cumbersome analysis of each individually. Some tools and considerations for structuring alternatives include:

- *Are individual options grouped together by type for structuring purposes?*
- *Can logical strategies be developed that link options that are mutually supportive?*

Develop a Range of Alternatives

Beyond structuring options into alternatives, decision analysis suggests that it is useful to develop a wide range of alternatives for analysis and stakeholder review. In order to build creative and diverse alternatives, consider:

- *Are alternatives that are substantially different in scope or approach developed?*
    - *Does it make sense to brainstorm alternatives by objective? For example, if one objective is to enhance fisheries and another is to increase timber harvest, consider generating one alternative that strongly (but not exclusively) supports fish and another that tends to support timber.*
    - *Does it make sense to develop alternatives by theme? For example, one alternative might be a more-or-less "hands-off" approach, another more interventionist; or one might be more mitigative, another more restorative, etc.*
    - *Does it make sense to allow different stakeholder groups to develop their own alternatives independently?*

The process of developing and evaluating alternatives is iterative, and none of the first alternatives put forward is likely to be accepted without refinements.

Use Competing Hypotheses to Develop Alternatives

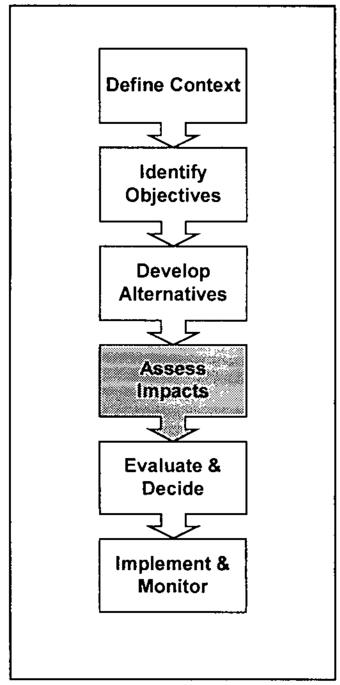
Building on earlier steps, adaptive management suggests that there is value in developing alternatives that incorporate management experiments to test competing hypotheses about key uncertainties. In this way, uncertainties can be reduced over time, and future decisions may be based on a more accurate system characterization. Consider:

- *Are management experiments identified that are capable of testing alternative hypotheses?*
- *Are models used to pre-test hypotheses?*

Table 3-3: Summary of Triggers for AM and DA actions at Step 3

Action	Trigger
Structure Alternatives	▪ There are many possible projects, types of projects, and combinations of projects. ▪ Projects interact with each other (i.e., some make sense together, some don't; impacts or costs are synergistic).
Develop a Range of Alternatives	▪ The Plan is expected to undergo public review, and facilitating input on alternatives that reflect a range of values is desired. ▪ The process is not overly constrained in scope, and has the flexibility to consider creative solutions that focus on fundamental "ends".
Use Hypotheses to Develop Alternatives	▪ There are polarized views among experts about functional relationships. ▪ The opportunity exists to test competing hypotheses, either in different locations or through tine sequenced trials. ▪ There is a clear link between alternative hypotheses and choice of management action.

3.3.4 Assess Impacts



The purpose of the impact assessment step is to generate and list the consequences for each of the biophysical and socio-economic outcomes of interest resulting from each of the proposed alternatives. The following highlight the actions suggested by DA. Table 3-4 summarizes the considerations that might trigger the use of these actions.

Estimate Impacts

Impacts may be assessed qualitatively or quantitatively, with the assistance of computer or mathematical models, or through expert or lay judgment. Decision analysis suggests that it is critical that some attempt is made to estimate how the alternatives affect the fundamental objectives, therefore:

- *Is the impact of each alternative on each fundamental objective estimated?*

Analyze Uncertainty

Both decision analysis and adaptive management suggest that how uncertainties are handled during the impact assessment step is crucial. Depending on the complexity of the situation (and assuming that uncertainties and base assumptions have already been clearly identified and documented in Step 1), some considerations for uncertainty analysis may include:

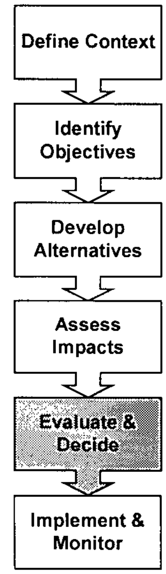
- *Has the uncertainty associated with each alternative been described for each outcome of interest? That is, can decision makers see the minimum, most-likely, and maximum expected value of the outcome, given plausible*[20] *ranges of values for uncertain parameters? Are decisions made on an "expected value" basis?*
- *Has sensitivity and/or scenario analysis been conducted to see if outcomes are sensitive to plausible changes in uncertain values? Is the ranking of alternatives*[21] *sensitive to these changes?*
- *Are there sub-problems for which a decision tree could help decision makers understand how uncertain factors or events affect the desirability of options?*
- *Can the potential costs and benefits of management experiments or further data collection or monitoring be estimated using "expected value of information" calculations?*

[20] "Plausible" means that all (or at least a large majority) of stakeholders and/or experts agree that the real value of an uncertain parameter will not lie outside this range under any realistic (as opposed to any conceivable) scenario.
[21] This can only be determined after alternatives are ranked in the next step "Evaluate and Decide". Even if an outcome is sensitive to an uncertain parameter, that uncertainty may affect all alternatives equally. As a result it may not be significant in terms of decision making.

Table 3-4: Summary of Triggers for AM and DA actions at Step 4

Action	Trigger
Estimate Impacts	▪ Impact assessment is always applicable.
Analyze Uncertainty	▪ More complex analyses may be triggered by: ▪ Decision making is hindered by debate over uncertain values, relationships or modeling techniques. ▪ The cost of, or time required to resolve uncertainty is high. ▪ The cost of being wrong is high and/or outcomes are irreversible.

3.3.5 Evaluate and Decide



In this step, the information from the Impact Assessment step is organized to support formal evaluation and decision making. Whether implicit or explicit, the evaluation and decision process always centres on the trade-offs among multiple objectives. The decision may be based on a holistic assessment, a mathematical calculation (e.g., weighting and rating, multi-attribute utility technique, etc.) or bargaining and negotiation.

The following highlight the actions suggested by DA. Table 3-5 summarizes the considerations that might trigger the use of these actions.

Use a Multi-Attribute Evaluation Framework

Decision analysis suggests that there is always value in reporting the performance of alternatives against the objectives set for the process. Therefore:

- *Is a structured evaluation framework used to summarize the consequences of each alternative with respect to each objective?*
- *Does the framework help to clarify the differences between "facts" (i.e., the estimated consequences, qualified by discussion of uncertainty) and "values" (i.e., the importance stakeholders/decision makers attach to different consequences)?*

Assess Preferences

Some form of preference assessment is required for ranking alternatives. However it may also create opportunities for learning among stakeholders, so that subsequent negotiations are based on a clear understanding of each stakeholders interests and preferences. Some considerations when assessing preferences include:

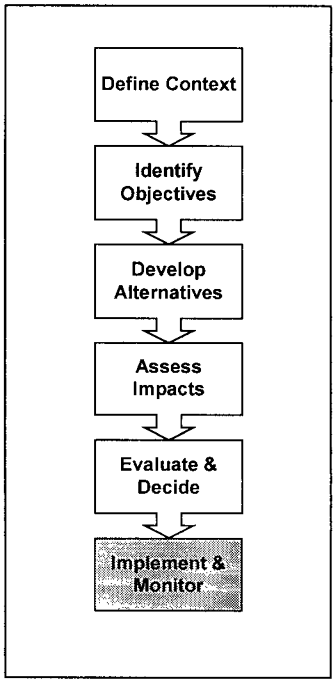
- *Are formal preference assessment techniques used to provide stakeholders with an opportunity to demonstrate explicitly how they value different outcomes?*
- *Are stakeholders' stated preferences based on a clear understanding of the actual trade-offs implied by the alternatives under consideration?*
- *Are multiple methods of assessing preferences and ranking alternatives used and the relative rankings of alternatives that result from each presented? Options may include:*
  - *a holistic assessment of preferences*
  - *rating and weighting*
  - *multi-attribute trade-off analysis technique (MATA).*
- *Are stakeholders/decision makers given opportunities to revisit their stated preferences in order to incorporate learnings and resolve inconsistencies?*

Table 3-5: Summary of Triggers for AM and DA actions at Step 5

Action	Trigger
Use a Multi-Attribute Evaluation Framework	▪ The process involves multiple objectives ▪ There is a desire for transparency in decision making.
Assess Preferences	▪ The process involves multiple objectives. ▪ Stakeholders value objectives and outcomes differently. ▪ No alternative dominates on all objectives – trade-offs are required. ▪ The decision maker is willing to consider diverse stakeholder values.
Conduct MATA[22]	▪ Consensus is not easily achieved. ▪ Trade-offs are complicated and value differences profound. ▪ Decision criteria are quantifiable. ▪ Quantitative models are available. ▪ Technical decision analysis expertise is available. ▪ Stakeholders are amenable to quantitative decision modeling

[22] MATA is one method of assessing preferences. Because of its technical nature, its use may be more limited than other methods. As a result, separate triggers are noted here.

3.3.6 Implement & Monitor



Effective plan implementation requires a clear understanding of roles and responsibilities of the various stakeholders involved. It includes the more detailed level planning, permitting and licensing for specific activities (such as resource development), complete with budgets, timelines, responsibilities and deliverables

A well designed monitoring program gauges both the effectiveness and efficiency of implementation activities. Adjustments are made in response to monitoring results both in the short term (e.g., through yearly operational plans) and in the long term (e.g., program reviews).

The following highlight the actions suggested by AM. Table 3-6 summarizes the considerations that might trigger the use of these actions.

Design Formal Management Experiments and Monitoring Systems

Adaptive management suggests that management activities be designed as formal experiments to address key outstanding uncertainties. Assuming that management experiments capable of testing competing hypotheses have been identified in earlier steps and incorporated into the chosen alternative, then the following questions become relevant:

- *Do the management experiments adhere to the principles of experimental design: randomization, replication, blocking and representation?*
- *Are monitoring systems developed up-front? Are suitable statistical tests and methods used to validate the confidence, power and relevance of monitoring results? That is, can causation be determined?*

Evaluate and Adjust

Responding to information gained through improved monitoring is fundamental to the adaptive management approach. Information distilled from monitoring is used both to determine the effectiveness of implementation activities, and to test the hypotheses that originally formed the basis of the management action. Corresponding adjustments are made to implementation activities, management objectives, and any models used to make original forecasts.

- *In the short term, are monitoring results used to adjust ongoing implementation activities?*
- *Are results used to fundamentally change management decisions made with previous information?*
- *In the longer term, are monitoring results used to update system characterizations, research hypotheses and experimental designs? Are they used to re-examine objectives?*

Table 3-6: Summary of Triggers for AM and DA actions at Step 6

Action	Trigger
Design Formal Management Experiments and Monitoring Systems	▪ There are paired watersheds or paired sites that could be used for experimentation, or there are opportunities for time-sequenced trials. ▪ Commitment and resources for long-term planning are available. ▪ Partnerships exist between scientists and managers. ▪ There is a clear link between uncertainty and the choice of management action. ▪ Results from experiments are expected to be widely applicable (other watersheds, other parts of same watershed, etc.).
Evaluate and Adjust	▪ Evaluation and adjustment are always applicable.

3.3.7 Summary of the Framework

From the diversity of literature on AM and DA, this thesis proposes the above analytical framework to guide watershed managers in integrating elements of each approach into the IWM process. The framework includes a set of investigative questions that guide implementation, and a set of triggers that help managers assess whether it is likely that AM or DA tools will be applicable.

In order to test whether the AM and DA actions as identified are useful and practical in IWM, the framework is applied to a case study in the next section.

4 Case Study: The Chapman/Gray IWMP

In this section, the Chapman and Gray Creeks Integrated Watershed Management Plan (C/G IWMP) development and implementation process is reviewed. The review begins by placing the C/G IWMP, as a *community* watershed planning process, within the broader provincial land use planning context. This is followed by a situation analysis specific to the Chapman and Gray Creek watersheds. Finally, a review of the C/G IWMP is undertaken using the analytical framework developed in the previous chapter.

4.1 The Provincial Context for IWM in Community Watersheds

4.1.1 Community Watersheds in British Columbia

The term *community watershed* is an official designation used by the British Columbia government for Crown watershed lands identified for use as community water supply sources. The *Guidelines for Watershed Management of Crown Lands used as Community Water Supplies* (Guidelines Task Force, 1980) contained the original criteria for designating community watersheds, which included:

- a drainage area of no greater than 500 km^2;
- a land base that is at least 50% Crown owned;
- a community water users' group holds a valid water license issued under the Water Act.[23]

There are currently over 450 community watersheds designated in British Columbia covering 1.5 per cent of the total land base and providing water to 75 per cent of the population (B.C. MOF, 1996b)

Community watershed plans are typically developed at the "local" planning level within the provincial land use planning framework (Table 4-1). From the time community watersheds were first designated in the early 1980s the principle means of planning for community watersheds has been the IWMP process (see 4.1.2 below). However, by 1992 growing demands on water supplies and increasing resource use conflicts in community watersheds sparked a review of how these watersheds were designated, planned and managed (Rueggeberg, 1993). A multi-agency technical advisory committee set out to develop a new set of guidelines for protecting drinking water in community watersheds from the impacts of multiple resource use – logging, road building, recreation, agriculture, etc. – and to update the list of designated community watersheds (B.C. MELP, 1998). Prior to completing this task however, the Provincial Government brought in the Forest Practices Code (FPC), which includes specific provisions for planning and forestry and range management within community watersheds (see 4.1.3 below). Many of the guidelines being developed for forestry activities by the multi-agency technical advisory committee were incorporated into the FPC, and their efforts were halted.

[23] The Forest Practices Code of British Columbia contains additional criteria for designating community watersheds (see B.C. MOF, 1996b).

Table 4-1: Summary of the Provincial Land Use Planning Framework
(adapted from LUCO (1997) and CORE (1994))

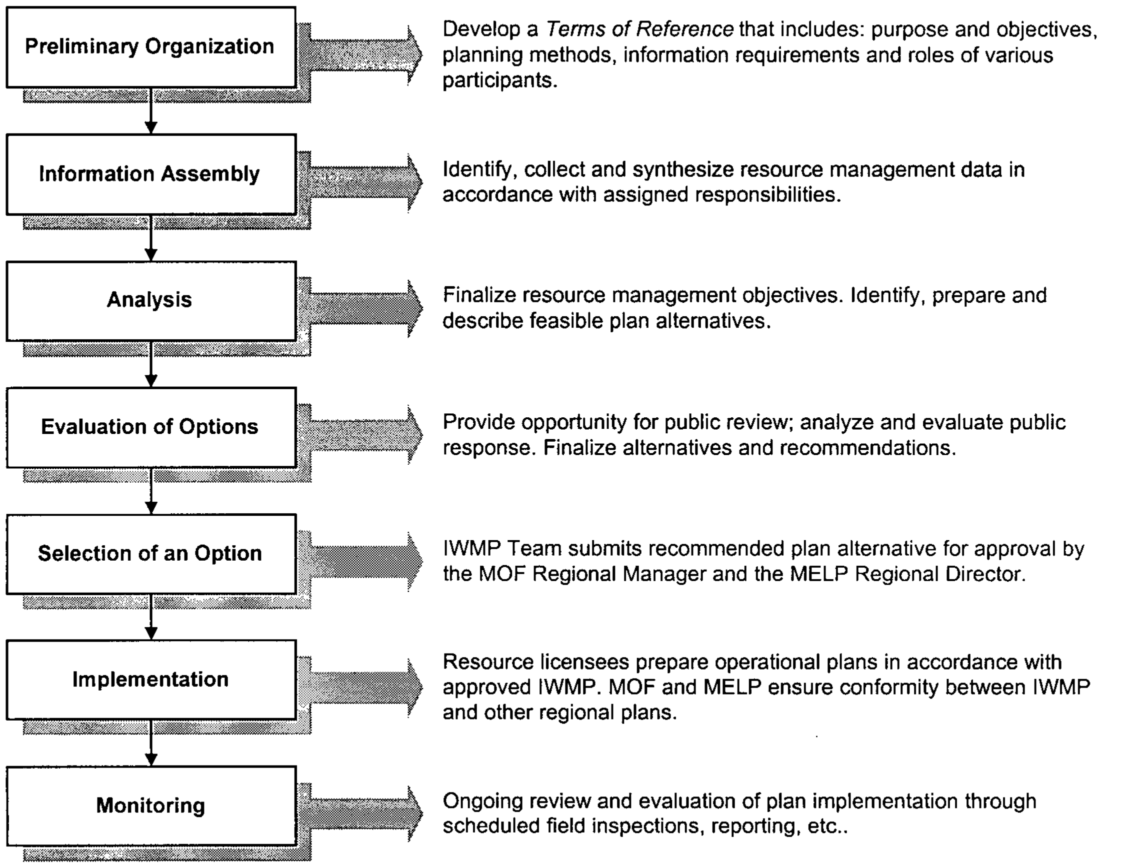
Level	Typical Scale	Features	Examples
Provincial	1:2,000,000 (province-wide)	▪ direction-setting goals and policies ▪ broad resource sector strategies	▪ Provincial Land Use Charter ▪ Protected Areas Strategy
Strategic	1:250,000 (1 – 8 million hectares)	▪ broad land use zonation ▪ resource management objectives ▪ economic development strategies	▪ Vancouver Island Regional Plan ▪ Fraser Basin Initiative ▪ Land and Resource Management Plans (LRMPs)
Local	1:50,000 (up to 100,000 hectares)	▪ refined land use zonation ▪ specific resource management objectives	▪ Local Resource Use Plans ▪ Integrated Watershed Management Plans ▪ Landscape Unit Plans
Operational	1:5,000 (up to 5,000 hectares)	▪ implementation plans ▪ resource development details	▪ Timber Operating Management Plans ▪ Recreation Site Plans

4.1.2 The Integrated Watershed Management Plan Process

The Integrated Watershed Management Plan (IWMP) process was developed in the early 1980s to serve as an approach to addressing multiple resource use planning issues in community watersheds (Guidelines Task Force, 1980; Guidelines Task Force, 1984). The B. C. Ministry of Environment, Lands and Parks (MELP) and the B.C. Ministry of Forests (MOF) are jointly responsible for the development of IWMPs. These Ministries convene a multi-disciplinary team consisting of other affected Provincial, Federal and Local Government agencies, First Nations, and licensed resource users to directly participate in the preparation of the plan. Interested public individuals and groups are given the opportunity to provide information for use in developing the IWMP, and to review draft outcomes of the IWMP process, but do not participate as active IWMP team members.

IWMPs are intended to direct the planning and management of Crown land "on an integrated resource management basis with priority given to the protection of water supplies" (Guidelines Task Force, 1984). They are intended to address the full spectrum of land and water management issues including water supply, low flow management, mineral activity, recreation, and forestry. Approved IWMPs contain detailed guidelines to which all future resource development activities within the community watershed must adhere. The general procedure to be followed in producing an IWMP is shown in Figure 4-1.

Figure 4-1: The IWMP Process



The unique characteristics of the IWMP process, compared to other Crown land use planning processes, are:

- the primary focus on water;
- the provision of guidelines for *all* forms of resource development activity (not just forestry);
- the joint management structure between MELP and MOF.[24]

Despite its primary focus on community water supplies, a limitation of the IWMP process results from the fact that it is fundamentally directed toward land use management issues and options, and does not normally address water supply and water treatment issues and options.[25] While resource development activities like forestry clearly affect community water supplies by influencing the quality and timing of water flows on a watershed scale, so too can water supply

[24] The vast majority of other Crown land use planning processes in British Columbia are administered solely by MOF, a consequence of its jurisdiction over the forest land base.
[25] However, there are a couple of examples of IWMP processes that did formally address water supply issues despite the lack of mandate to do so (V. Cameron MELP, personal communication).

and water treatment affect the ultimate goal of achieving a quality community potable water supply. Hence, true 'integrated' planning for community water supplies from source to tap is not undertaken within the IWMP process, or any other provincial planning process in British Columbia.

As a mechanism for community watershed planning in B.C., the IWMP process does not appear to have a future. Of the 494 community watersheds currently designated in British Columbia, 60 were originally identified as having a priority need for IWMP processes (Rueggeberg, 1993), and only 22 had been completed or initiated by 1995 (B.C. MOF, 1996b). This seeming lack of progress is the result of two primary factors. First, IWMPs have been chronically under-resourced with existing provincial ministry staff expected to facilitate the processes on top of their current duties (Jamieson, 1996; Rueggeberg, 1993). Second, the broader land use planning and water resource management framework in British Columbia has been in a state of major transition in recent years. Major reviews of the overall provincial land use planning system (CORE, 1995) and water resource management system (B.C. MELP, 1993) have been undertaken, and changes are in various stages of reform and implementation. In contrast to these broad provincial initiatives that have been slow to evolve and take effect, the Forest Practices Code has emerged with immediate and significant implications for community watersheds.

4.1.3 Forest Practices Code

The 1995 Forest Practices Code of British Columbia (the Code) provides the first legislated framework for forest management activities in community watersheds. The Code consists of three parts (B.C. MOF, 1998a):

i. the *Forest Practices Code of British Columbia Act* that serves as the legislative umbrella,

ii. the province-wide forest practices *regulations*,

iii. the *guidebooks* that describe recommended procedures and practices in greater detail, and

The Code places heavy emphasis on planning at both the strategic and operational levels, within which community watersheds are subject to much stricter requirements than non-community watersheds (Baisley and Cameron, 1996). At the strategic level, a "higher level plan" designation system is used to empower a variety of existing and new land use planning mechanisms with the full legislative authority of the Code.[26] Higher level plans establish the broader, strategic context for operational plans by providing objectives that determine the mix of forest resources to be managed in a given area (B.C. MOF, 1996a).

[26] Important changes to the Higher Level Plan designation system affecting community watersheds were introduced in the 1997 *Forest Statutes Amendment Act* (B.C. MOF, 1998c). Both legislation and policy for the various planning mechanisms within the FPC are likely to continue to evolve as experience is gained during implementation.

B.C. MOF (1998b) recently described that for community watersheds there are now two primary mechanisms available for achieving higher level plan designation under the Code[27]:

1) **Resource Management Zones**: Resource management zones (RMZs) are divisions of Crown land distinguished by biophysical characteristics or resource management issues. RMZs are mainly associated with strategic level planning in the province (Table 4-1). At this level, a community watershed can be zoned as a RMZ and specific objectives can be developed to guide resource management activities. Authority to establish RMZs resides at the ministerial level.

2) **Landscape Units**: Landscape units are areas designated for long-term planning of resource management activities at the local level within the provincial framework (Table 4-1). While the initial emphasis for landscape unit planning in the province is directed toward integrating resource management activities with biodiversity conservation measures, a landscape unit could be designated directly for a community watershed boundary allowing for water resource management objectives to be formally established.

To date however, neither of these mechanisms has been used to manage or direct a *new* community watershed planning process. For *existing* community watershed plans, which were initiated as IWMPs, higher level plan designation can be achieved by rewording resource management strategies and guidelines as objectives, and either pursuing resource management zone designation, or integrating them into landscape unit plans as they are developed. It is important to understand that the Code does not address all of the resource management activities that may have been developed as part of an IWMP process such as those for mineral development and recreation.

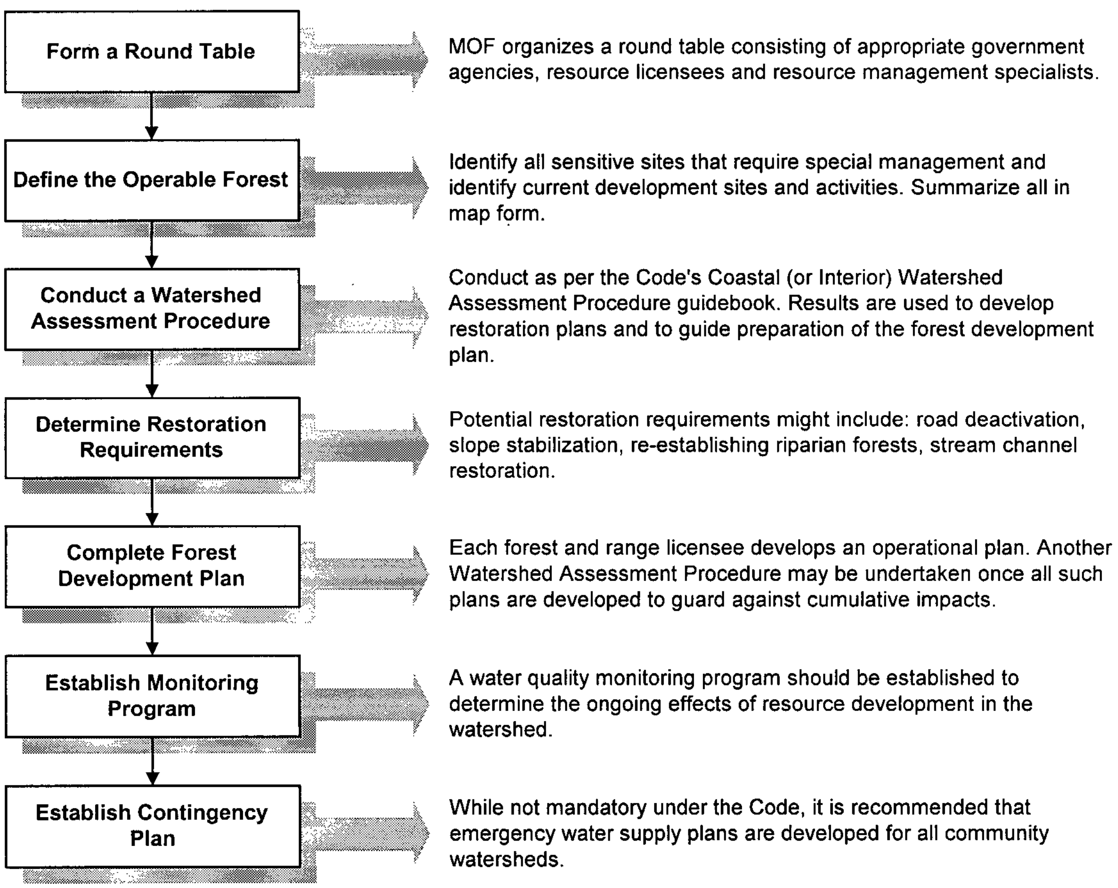
At the operational level, the Code's *Community Watershed Guidebook* (BC MOF, 1996b) describes the process to be followed in completing the mandatory watershed assessments and forest development plans in community watersheds (Figure 4-2).[28] The Code gives community watersheds special status that requires joint approval of completed forest development plans by both MOF and MELP (replacing a former system of referrals). These operational plans must also adhere to the specific Code regulations set forth for community watersheds with respect to:

- riparian zone management,
- terrain hazard mapping,
- harvest scheduling and cutblock size,
- forest road engineering,
- range management,
- fertilizer and pesticide management.

[27] A third mechanism, gaining sensitive area designation, is possible yet most likely only to be used for spring source areas.
[28] The *Community Watershed Guidebook* (B.C. MOF, 1996b), as with the entire Forest Practices Code, pertains only to Crown provincial forest land. However, in British Columbia some community watersheds contain private land. A companion document to guidebook, the *Community Watershed Manual*, which was intended to contain recommendations for activities on private lands, has not yet been produced.

While similar in a few respects, there are important differences between this operational planning for community watersheds under the Code and the IWMP process. The most significant of these revolves around the fact that this new process for developing operational plans is designed primarily as a technical exercise undertaken by government agency staff and resource licensees. The opportunity for broader consideration of other resource values (e.g., recreation, mining, etc.) and stakeholder participation in the community watershed management process would presumably happen at the higher level plan stage. However, as mentioned above this remains untested as there has yet to be a new community watershed planning process initiated under the Code planning framework.

Figure 4-2: Operational Planning in Community Watersheds



4.1.4 Forest Renewal British Columbia

Forest Renewal British Columbia (FRBC) is a Crown corporation created in 1994 to plan and implement a program of investments to renew the forest economy of British Columbia (FRBC, 1998). Its current mandate is to:

- enhance the productive capacity and environmental values of forest lands;
- create jobs;

- provide training for forest workers; and
- strengthen local communities that depend on the forest industry.

Through revenue generated by increased stumpage rates charged to the forest industry, FRBC has launched a land and resources program area[29] that supports activity in programs such as enhanced forestry, operational resources inventory, and watershed restoration. Many resource management professionals in B.C. view FRBC as an important complement to the Forest Practices Code (Baisley and Cameron, 1996).

FRBC funding is being used to fund projects directly relating to watershed management and community watersheds. For example, in watershed restoration programs across the province, projects have been underway to address poor past logging practices by replanting steep slopes, restoring displaced river channels and removing roads from steep-sloped terrain. In another important program, MELP is greatly expanding its baseline water quality monitoring efforts in community watersheds across the province (K. Rothe, MELP, personal communication). Although still in its infancy and susceptible to politically-driven changes in mandate, FRBC has the potential of becoming an important resource for the long term management of community watersheds in B.C..

4.1.5 Summary of the Provincial Context for Community Watersheds

The framework for community watershed planning and management in B.C. is evolving. The IWMP process, originally designed as a means of incorporating the full range of resource management issues, has been under-resourced and it is unlikely that any new IWMP processes will be initiated. The Forest Practices Code, along with its own planning framework and resource management regulations, is taking over as the dominant vehicle for community watershed management in B.C..

From the perspective of community watershed management there are two primary issues of concern with respect to the Code planning framework:

- The Code deals primarily with forestry related issues of community watershed management. Other issues including water management, recreation, range management, mining and exploration, etc. are given only cursory treatment.

- Referring back to the overall provincial land use planning framework in Table 4-1, the Code does not currently offer an appropriate local level planning mechanism suitable to stakeholder involvement. The strategic level mechanism of developing higher level plans is at too large a scale, and the technically-based operational level plans are too narrowly focused to address stakeholder concerns.

Although the Code planning framework is largely untested to date, further evolution of legislation and policy will likely be required to provide a sound basis for community watershed planning in B.C..

[29] Other FRBC program areas include i) value-added and ii) communities and workforce.

4.2 Situation Analysis

4.2.1 The Chapman and Gray Creek Watersheds

Physical Characteristics

The Chapman and Gray Creek community watersheds cover approximately 10,500 ha of Sechelt Provincial Forest land along the Sunshine Coast of south-western British Columbia (Figure 4-3). The watersheds lie in the Sechelt and Howe Sound tracts of the southern coastal mountains with elevations ranging from 1737 metres at Tetrahedron Peak down to 175 metres at the Chapman Creek water supply intake. From an ecosystem perspective, the watersheds contain primarily Coastal Western Hemlock and Mountain Hemlock biogeoclimatic zones[30], and there are a number of unique alpine lakes located in the Tetrahedron headwater plateau (B.C. MELP/MOF, 1996).

Elevation is the major factor affecting precipitation and runoff in the watersheds (Chapman and Reksten, 1991). Average annual precipitation ranges from 1350 mm at lower elevations to over 3500 mm at higher elevations. The winter months of November and December receive the highest precipitation while the summer months of July and August receive the lowest. Greater than 95% of the precipitation occurs as rain in the lower elevations, while at higher elevations a much greater proportion falls as snow helping to redistribute a large portion of the annual precipitation from the winter into the spring snowmelt period. May and June are the months of highest monthly flow. However, during the winter period from October to February, the largest instantaneous peak flows occur as a result of heavy rainfall and occasional rain on snow events (Summit, 1997).

Like much of southwestern coastal B.C., the Chapman Creek and Gray Creek watersheds are dominated by steep forested mountains and an abundant sediment supply as a result of past glaciation. The combination of this physiography and the hydrological characteristics results in very large amounts of runoff per unit area of land, and, consequently, the erosion and transport of large volumes of sediment. Not surprisingly, land use practices such as forestry can greatly amplify this effect.

Natural Resources

As a result of their strategic location within the larger settlement areas of the Sunshine Coast, the Chapman and Gray Creek watersheds serve as the only viable source of water for the regional domestic supply system (Dayton and Knight, 1968). At present, the regional water supply system services over 21,000 people in widely dispersed communities along the Sunshine Coast. With added storage capacity, the Chapman and Gray creeks would be capable of servicing the water supply needs of a population of up to 200,000 in the long term.

In addition to providing a community water supply, the Chapman and Gray watersheds support a full range of other resource values and resource uses including:

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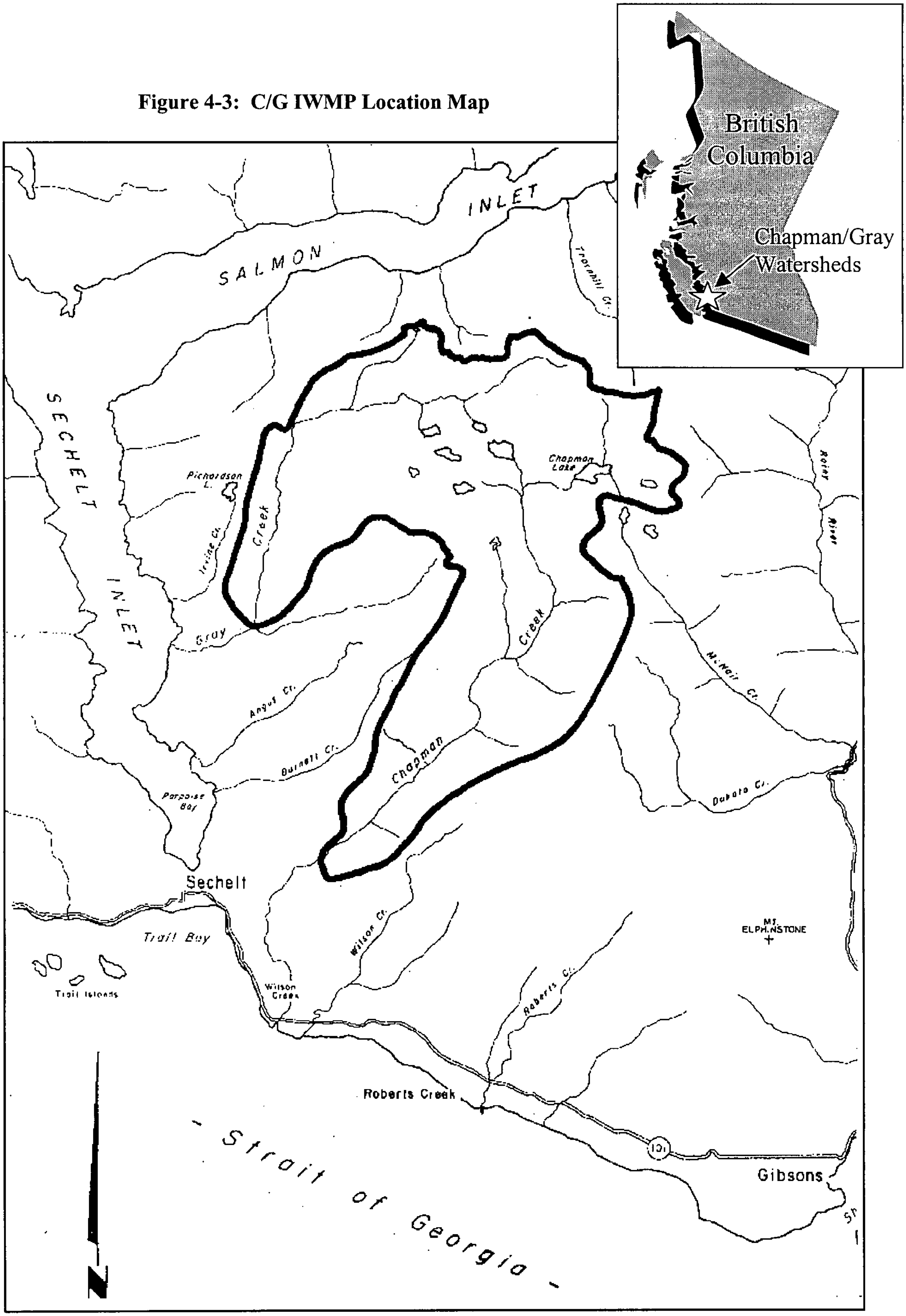
[30] The primary tree species in these biogeoclimatic zones are amabalis and Douglas fir, western and mountain hemlock, and yellow and western red cedar.

Forestry	The total accessible timber volume in the watersheds is 1.51 million m^3, and an average of 50,000 m^3 has been harvested annually as part of the Annual Allowable Cut of the Sunshine Coast Timber Supply Area.
Wildlife	A wide variety of birds, furbearing animals, amphibians and reptiles exist. In terms of sensitive species, marbled murrelets have been confirmed and the watersheds are considered as the last possible area on the Sunshine Coast where northern spotted owls could be supported.
Fisheries	Coho, pink and chum salmon species and wild steelhead are all supported in small numbers in the lower creek reaches. The headwater sections also support resident populations of Dolly Varden char and rainbow trout. Both private and non-profit fish hatcheries are in operation.
Recreation	The alpine area within the Tetrahedron plateau supports year-round opportunities for hiking, ski touring, snow shoeing, orienteering and climbing. Lower elevation areas are used for camping, hunting, angling, swimming, wildlife viewing and mountain biking. A cabin system is in place to support recreationists.
Minerals	Based on current geological knowledge and prevailing economic conditions, the watersheds are stated as having a moderate potential for metallic mineral development (i.e., copper, zinc, lead, silver and gold), a low potential for industrial mineral development (i.e., limestone, wollastone, dimension stone and clay), and a moderate to high potential for aggregate mineral development (i.e., sand and gravel).
Utility Corridors	Both a hydro electric power transmission and a natural gas pipeline right-of-way exist in the watersheds.
Cultural/spiritual	Most local residents attach a strong cultural significance to the watersheds lands, although their reasons differ widely. Recreationists and environmentalists value the watersheds for containing some of the last old-growth forests on the Sunshine Coast. Forestry workers value the economic stability that the forest resource has offered local communities. And First Nations value past traditions and future opportunities for social, economic and cultural ties to watershed resources.

Figure 4-3: C/G IWMP Location Map



By 1990, a broad spectrum of stakeholders that included local government, community-based groups and B.C. Ministry of Health staff were expressing increased concerns over forestry-related impacts on other watershed resource values (Jamieson, 1996). In response, the B.C. Ministry of Environment, Lands and Parks and the B.C. Ministry of Forests launched the Chapman and Gray Creeks Integrated Watershed Management Plan (C/G IWMP) process. Box 4-1 at the end of this section provides an overview summary situation analysis for the C/G IWMP process,[31] helping to place it within the larger historical, political, administrative and regulatory context. Consistent with the overall intent of the IWMP process, the *Terms of Reference* developed for the C/G IWMP contained the following stated goals (B.C. MELP/MOF, 1990):

1. To ensure that integrated resource management is practiced in the Chapman Creek and Gray Creek Watersheds as per Appendix H of the *Guidelines for Watershed Management of Crown Lands as Community Water Supplies* (Guidelines Task Force, 1980; Guidelines Task Force, 1984);
2. To ensure that water quality, quantity and timing of flows are of the highest priority; and
3. To consider all those resource activities which do not pose an unacceptable risk to the Chapman/Gary Creek Watersheds' water resources within the short term or long term and to minimize the impact of resource development (historic and planned) on the water quality, quantity and timing of flows.

To date, the C/G IWMP planning team has proceeded through the first five steps of the process as indicated in Figure 4-1. The final plan document – *Chapman and Gray Creeks Integrated Watershed Management Plan* (B.C. MELP/MOF, 1998) – is the result of a long and often arduous process of negotiation among the participants. Key components of the Plan include:

- zoning and resource management unit designations;
- detailed resource management guidelines for forestry, recreation, mineral exploration and development, and utility corridors; and
- work plans to direct future efforts of the planning team.

In 1994, funding was obtained from the FRBC Watershed Restoration Program (WRP) for a project that has made significant contributions to the overall C/G IWMP. The main components of the ongoing project include:

i. a comprehensive water quality and discharge monitoring program;

ii. watershed restoration activities such as road deactivation, gully/landslide rehabilitation, and riparian zone/fisheries enhancement; and

iii. community awareness and participation.

This WRP project provided much needed information in support of IWMP negotiations, while providing a mechanism for improved cooperation both internally among IWMP team members, and externally with the public (Jamieson, 1996).

[31] The format of the overview is based on a practice setting template developed by Christensen, 1993.

The B.C. Forest Practices Code also emerged during the life of the C/G IWMP (see section 4.1.3). The Code guided, but in some respects complicated, the ongoing negotiations regarding forestry issues. Many of the guidelines developed for the C/G IWMP — such as those for cutblock sizes, harvesting techniques, riparian zone management and biodiversity corridors — go well beyond Code requirements.

As of January 1999, the status of the C/G IWMP is:

- The Plan document has been completed.
- Many IWMP planning team participants (and the agencies they represent) have chosen not to sign off on the final plan and thus commit to either its content or implementation. Some of the reasons put forth include:
  - The Sechelt Indian band are uncertain about potential impact that signing might have on long term land claim negotiations for the area.
  - Forest licensees feel that restricting forest development activities more stringently than required within the FPC is inappropriate given the current economic outlook in B.C.
  - SCRD, in support of citizen input, have questioned the overall land tenure for the watersheds.
- Given that IWMP planning team consensus was not reached, the Plan has been elevated to the provincial ministerial level for final review. It is unclear what actions may emerge from this review, or when such action is likely to occur.

Box 4-1: Summary Situation Analysis of The Chapman/Gray IWMP

History:

The Sechelt First Nations people have inhabited the region for nearly 10,000 years.
1930 - 1990: timber resource extraction has been the dominant land use.
1967 - today: the Sunshine Coast Regional District involved in the development of a regional waterworks system.
1990: launch of the Chapman/Gray Integrated Watershed Management Plan process.

Authority/Mandate:

The original goal of the IWMP was to develop guidelines for *all* resource development activities.
The FPC emerged part way into the process with detailed regulations for forestry and range management.

Ideal Process:

Consensus-based decision making process.
Integrated resource management approach.

Key Issues:

Long term protection of water quality, quantity and timing of flows.
Long term environmental integrity of watersheds.
Long term economic and social stability in local communities and local industry.

Organization of Work:

IWMP team members undertake work under their jurisdiction.
C/G Watershed Restoration Program used to generate technical data.

Stakeholders:

BC Environment: Water Management (Co-chair) and Fish and Fish & Wildlife Branches
BC Ministry of Forests: Sunshine Coast Forest District (Co-chair)
BC Ministry of Employment and Investment: Energy and Mines Division
BC Ministry of Health: Coast Garibaldi Health Unit
Sunshine Coast Regional District
Federal Department of Fisheries and Oceans
Sechelt Indian Band
Canadian Forest Products Ltd.
International Forests Products Ltd.

Patterns of Interaction:

Roundtable meetings with active team members, consultative team members and observers.
Public involvement included i) written submissions, ii) observation of IWMP meetings and iii) open house review of the draft plans.

Regulatory Framework:

1) Provincial Forest Practices Code
2) Provincial Forest Act
3) Provincial Water Act
4) Provincial Land Act
5) Provincial Wildlife Act
6) Federal Fisheries Act
7) Canadian Drinking Water Standards (1993)
8) B.C. Drinking Water Regulations (1992)
9) MELP Guidelines for Management of Crown Lands as Community Water Supplies (1984)
10) Guidelines for Mineral Exploration (1992)

4.2.3 Chapman/Gray IWMP as a Soft Systems Problem

The Chapman/Gray IWMP displays most of the characteristics of soft systems problems as outlined in Chapter 2. The following selective examples provide a basic understanding of the range of uncertainties and the complexity of issues that have challenged the planning team over many years.

Ambiguous Boundaries and Complex Linkages

> *"There is some uncertainty about the lower boundary of the IWMP, and it has been suggested that the study area boundary be extended to the mouth of Chapman Creek"* (C/G IWMP, p.114; B.C. MELP/MOF, 1998).

- Cross-boundary impacts: The Chapman/Gray watersheds historically contributed an average of 50,000 m^3 to the designated annual allowable cut of the Sunshine Coast Timber Supply Area (4.5 percent of the total). No reduction in the volume of timber available from the watersheds as a result of the C/G IWMP was factored into the 1995 Timber Supply Analysis (Crane, 1995). Both MOF and forest company licensees were therefore left with uncertainty – and the potential for increased planning and negotiation efforts – regarding the provision of additional timber resources from elsewhere in the Sunshine Coast Timber Supply Area to replace those eliminated in the C/G watersheds.
- Cross-boundary influences: In 1992 the B.C. Provincial Government announced its Protected Areas Strategy, an initiative to protect 12 percent of the provincial land base by the year 2000. Through this process, the Tetrahedron Plateau area that includes most of the upper elevation areas of the Chapman and Gray watersheds was declared a Provincial Park in July of 1995. This provincial-level decision precluded any form of development within a 3,020 hectare area, and was superimposed on to the C/G IWMP process, which had already been wrestling with this part of the watersheds for a number of years.
- Cross-disciplinary scope: Long-range water supply and treatment plans for the Sunshine Coast region extending from Langdale to Secret Cove are integrally dependent on the quality and quantity of the source water available in the Chapman and Gray watersheds. Despite this dependence, planning for water supply and treatment is done separately from that of the watersheds.

Difficulties with Objectives, Alternatives and Consequences

> *"Formation of this strategy was not an easy task as the complex systems involved do not lend themselves to the creation of objective criteria for decision making"* (C/G IWMP, executive summary; B.C. MELP/MOF, 1998).

- Unclear objectives: The plan contains 24 pages of discussion around issues and objectives, with no clear synthesis or structure to guide planning efforts.
- Complicated alternatives: The SCRD is licensed to withdraw 238 litres per second (l/s) from Chapman Creek while DFO has stated that for fisheries purposes instream flows should never

drop below 300 l/s. Recent studies indicate that for one year in ten, Chapman Creek discharge will likely drop below 190 (l/s) meeting neither water supply nor fisheries needs (Chapman and Reksten, 1991). Long term management alternatives for Chapman and Edwards Lakes for storage purposes, and instream mitigation alternatives for fisheries purposes are therefore integrally linked. However the IWMP process was not set up to formally reconcile this wide range of alternatives. (Development of a low-flow agreement between SCRD and DFO was not achieved as part of the plan.)

- Inherent conflict: Improvements in long term water quality of the Chapman/Gray watersheds could be achieved through significant changes in forest development activities over historical rates. Such reductions however would have direct negative consequences with respect to local employment and other socio-economic considerations. It is difficult, if not impossible, to avoid this fundamental conflict.
- Data overload: This was not an obvious problem faced by the C/G IWMP.

Pervasive Uncertainty

> *"No one was certain what was the dominant source of sediments, under what conditions sediments were released, or indeed, if they could be controlled at all. To further complicate matters, it was not possible to say with any certainty what portion of the turbidity measured on the lower reaches of the Chapman or Gray Creek could be ascribed to inorganic sediments"* (Carson, 1996).

- Uncertain ecosystem relationships: Developing a complete understanding of the origin and transport of organic and inorganic sediments in the watersheds and the correlation between sedimentation and resultant water quality parameters (e.g., turbidity, true colour) has been the subject of investigation by the C/G WRP. Three years of intensive monitoring has provided improved baseline understanding of watershed processes. However, several additional studies have been identified within the C/G IWMP, most of which aim to better understand the potential effects of management activity. This indicates that fundamental uncertainties remain.
- Uncertain socio-economic relationships: Numerous socio-economic uncertainties were present during the course of plan development. There were multiple uncertainties related to the local forest resource-based economy ranging from the costs and possible benefits of increased government regulation (i.e., the Code), to the prospects for a transition to a more value-added and multiple resource use strategy. As another example, the Sechelt Indian Band, while participating actively in the development of the C/G IWMP, was simultaneously negotiating a land claim with the provincial and federal governments over lands that include both watersheds. The final plan document recognizes the uncertainty introduced by this situation by stating that all guidelines recommended by the plan are without prejudice to the negotiating and legal positions of all parties involved in the treaty process.
- Evolving institutional and legislative bounds: The C/G IWMP was undertaken during a time of significant institutional and legislative reform in British Columbia. For example, during the course of plan development the planning team was forced to understand and attempt to integrate changes including: i) the regulation-based focus of the Forest Practices Code, ii) the funding opportunities presented by FRBC, iii) the province wide protected area strategy (which eventually designated a park within the planning area), and iv) recommended changes to the overall land use planning framework by the Commission on Resources and

Environment. These and other changes introduced significant uncertainty, as it was not always clear how and when they would be implemented or what the overall implications were.

Multiple Stakeholder Conflict

> *" The planning team often entrenched itself in unproductive positional bargaining based on perspectives and information from each area of expertise"* (Jamieson, 1996).

- Gridlock over facts and values: Despite the stated primary focus on water protection, the C/G IWMP process revolved around striking a balance between water protection and other objectives for timber, mineral development, fish and wildlife protection and recreation. Yet different stakeholders had fundamentally different values about the relative importance of these different resources (i.e., values), and fundamentally different views about the effect of management actions on resources (i.e., facts). The lengthy timeline associated with the planning process was due, in part at least, to the tension and controversy created by these differences.
- Potential for escalation of conflict: Given a long history of vocal opposition to resource development activities within the watersheds, the C/G IWMP was poised for escalation of conflict. Indeed, escalation occurred at various instances during the process (for example, when local government threatened a court injunction against ongoing logging activities, or when public review of a draft plan was met with intense opposition). At the planning table itself, stakeholders became entrenched in an unproductive positional bargaining exercise that extended over a period of many years. A lack of skills and experience in negotiation and consensus-building has been blamed (Jamieson, 1996).
- Lack of transparency in decision making: Each time the planning team went to the public with a draft plan (1994, 1996 and 1998), the plan was met with discontent about both the content and the overall planning and decision making process (Jamieson, 1996).[32] The lack of transparency in the process, real or perceived, was undoubtedly exacerbated by the lack of funding needed to facilitate meaningful public consultation, especially in the early years.

4.2.4 Summary of the Situation Analysis

The C/G IWMP process has been long and difficult. Acceptance of the Plan has yet to be achieved. Throughout the process, many of the soft systems problems identified in Section 2.3 have been evident. The remainder of this section examines how a planning framework incorporating elements of AM and DA could have been applied. Section 4.3.7 (Potential Impact of AM and DA on the Current Status of the Plan) and Chapter 5 (Conclusions and Recommendations) discuss the extent to which AM and DA could have addressed these problems.

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[32] Jamieson comments on the 1994 and 1996 drafts only. However, the experience was common to all draft plan roll-outs.

4.3 Chapman/Gray IWMP Review

In this Chapter, the Chapman and Gray Creeks Integrated Watershed Management Plan development process is reviewed using the analytical framework developed in section 3.3. This review is not intended to be a critique of the C/G IWMP process. Rather, it is a selective analysis that uses the C/G IWMP experience to build insight into which components of adaptive management and decision analysis offer a significant contribution to integrated watershed management, and what practical limitations may exist.

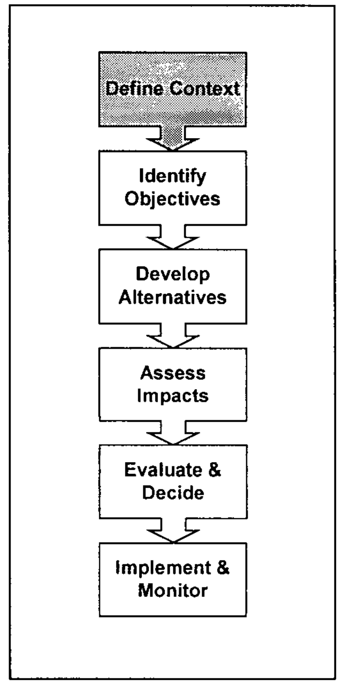
The case study was prepared primarily on the basis of a review of relevant documentation of the planning process and the Plan itself, augmented by discussions with some of the planning team members. The final plan document is entitled the *Chapman and Gray Creeks Integrated Watershed Management Plan* (B.C. MELP/MOF, 1998), and is hereafter referred to as the Plan. In parallel with the planning team's effort over the last four years, an FRBC-funded Watershed Restoration Program (WRP) for the Chapman and Gray Creek Watersheds has initiated activities related to both implementation and monitoring. For the purposes of this review, these WRP activities have also been taken into consideration.

For each step of the planning process, this review provides:

1. a summary response to the investigative questions posed in the analytical framework;[33] and
2. an illustrative example to demonstrate in more detail the potential application of some of the adaptive management and decision analysis tools.

[33] Although the C/G IWMP planning team was not specifically following the process steps outlined in Figure 3-6, it has undertaken activities related to the first five steps.

4.3.1 Define Management Context



Define Decision Making Approach

Who has ultimate authority for decision making? What is the role of stakeholders in decision making?

The 1990 Terms of Reference describe the process to be followed in developing the Plan. It was clearly intended to be a consensus-based approach, with all planning team representatives expected to become signatories on behalf of their organizations. Final approval of the Plan was recognized as the joint responsibility of MOF and MELP.

What is the decision making process?

Other than a reliance on consensus-based negotiations, there was no explicit or formal framework or decision making process. From a decision analysis perspective, there was no means for presenting information to inform negotiations (e.g., a multiple account evaluation framework) or for exploring different stakeholder values (e.g., a structured trade-off analysis).

Characterize Systems and Uncertainties

Are the relevant issues clearly identified?

The C/G IWMP Terms of Reference clearly identified the process as an integrated resource management exercise with a priority placed on the water resource and full consideration given to forestry, mining, recreation and other potential resource uses.

Are the physical boundaries and planning timeframe clear?

The physical area under consideration was recognized to be the two watersheds (although the actual boundaries were debated and evolved during the process). There was recognition that downstream needs should also be taken into consideration (e.g., water treatment considerations), and that planning for the forest resource had regional socio-economic implications. However, it was not clear how these needs and implications were to be addressed during plan development as it was generally outside of the planning team's mandate.

Is there a common understanding of how systems work? Are conceptual models used?

The discussion of resources, objectives and issues (chapters 2 and 3 of the Plan), provides some insight into each planning team member's understanding of the watershed systems, both biophysical and socio-economic. There are detailed descriptions of many 'system elements' such as raw water quality, treated water quality, forest resource development, the socio-economics of forest resource development. These descriptions are an important first step toward developing a basic understanding of the watershed systems being managed. However, since they were developed and reported 'by sector' and 'from each team member's perspective' they provide little insight into i) how these elements are integrated and how changes in one area might affect another, or ii) the degree to which stakeholders either understand or agree upon the stated relationships.

From an adaptive management perspective then, it can be said that little effort went into jointly characterizing the watershed systems. This is not to say that such understanding and perspectives did not exist. Clearly team members understood that the management of all resources was inter-related. What is missing however is the formal shared articulation and documentation of the interrelationships using tools such as conceptual models or explicitly stated hypotheses.

Are key uncertainties defined up front?

Not explicitly. Several technical studies were used and commissioned by the IWMP team (e.g., detailed hydrological studies) suggesting a general acknowledgment of uncertainties and a desire to address them. However, from an adaptive management perspective, there was no formal attempt in the formative stages of the process to link key uncertainties to fundamental management problems, data requirements and potential solutions. The process was driven by the desire to reach a consensus outcome rather than a desire to increase knowledge over time by formally addressing key uncertainties.

Are there clear agreements on the assumptions to be used or hypotheses to be tested?

Since key uncertainties were not directly defined and agreed upon by all stakeholders, no agreements were made about what assumptions or hypotheses would be adopted for the development of the Plan. Examples of the type of assumptions or hypotheses that could have been stated include:

- a reduction of timber harvest by x% coupled with extensive watershed restoration activities will lead to a y% improvement in overall water quality; or
- a reduction of timber harvest by x% coupled with an increased emphasis on recreation (tourism) will have a negligible effect on the local economy.

Integrate Management and Research

Are research interests represented at the stakeholder table?

Although none of the stakeholders had formal research agendas, several planning team members did state important and relevant research interests. For example, the SCRD state a research goal of determining how various biophysical units of the watershed contribute to the hydrological regime. As a further example, the B.C. MELP Wildlife Program expressed a research goal of testing stand manipulation techniques to accelerate the development of old seral stage attributes within the forest ecosystem network. Although these and other examples of research interests can be found within the Plan, few if any can be traced to actual work plan commitments or funding sources (with the exception of ongoing commitments of the WRP water monitoring program). Each of them represents an uncertainty that could have affected decision making.

Are there both scientists and managers involved in the process?

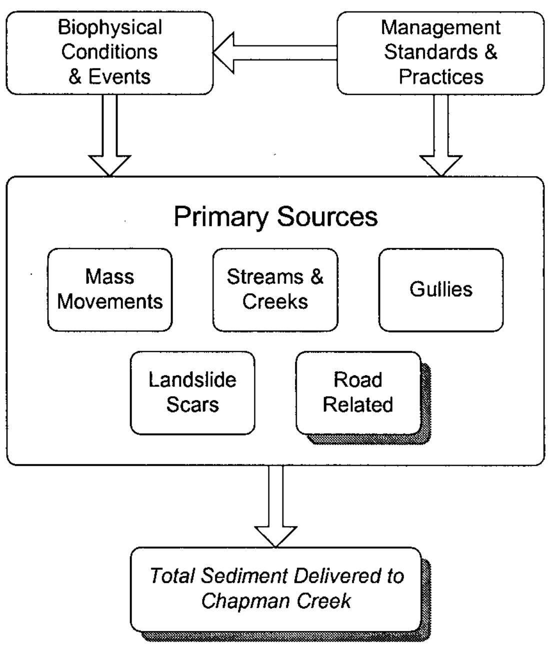
The C/G IWMP team was composed of members with a primary focus on management rather than research. However, most agency representatives did have research and other technical resources at their disposal to either undertake or help interpret some of the technical data or studies commissioned by the team. With the start of the WRP in 1994, monitoring and research efforts were formally initiated in support of the planning process. While this was widely recognized as being beneficial to the overall plan development process, the WRP operated, for the most part, at arms length from the C/G IWMP team.

Example 1: Conceptual Models to Clarify Systems Understanding

This example will show how simple conceptual models can be used to facilitate a common understanding of biophysical systems and to help set initial priorities on management issues early in a planning process.

In the Chapman and Gray watersheds, water quality is affected by sediment delivered to streams from a variety of primary sources (Figure 4-4). Each sediment source is affected by a set of underlying biophysical conditions (e.g., surficial geology) and events (e.g., storms), as well as management standards and practice. This overview conceptual model could be used as a starting point for discussions regarding the most significant primary sources of sediment delivery.

Figure 4-4: Primary Sediment Sources

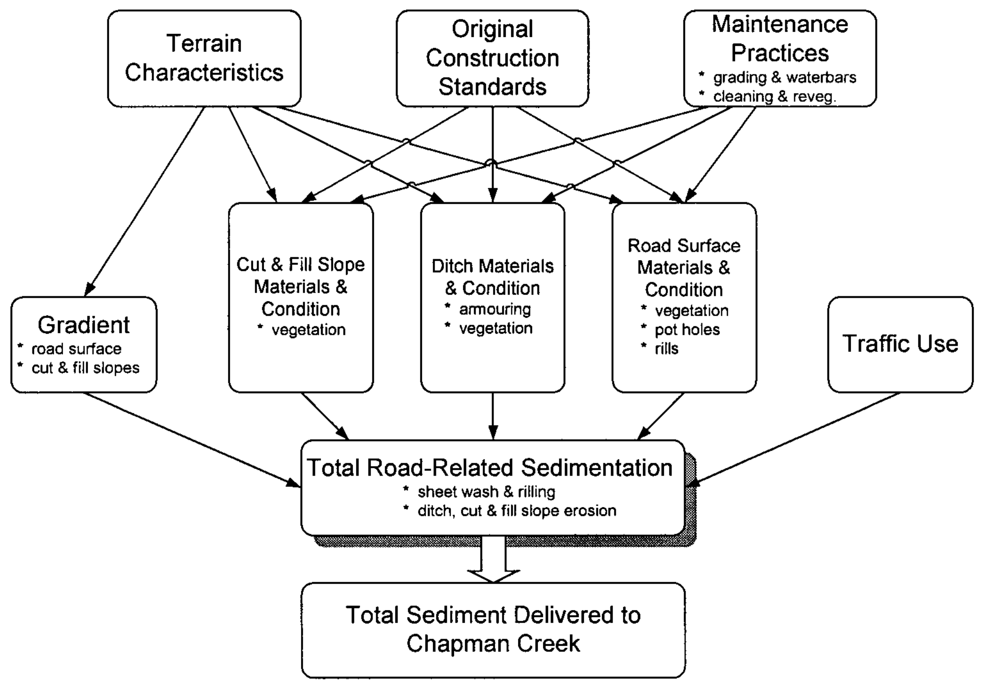


In the case of the Chapman and Gray watersheds, road-related sedimentation is suspected as being a major contributor and has been the focus of past and current watershed restoration program efforts. A more detailed conceptual model of road-related sedimentation is shown in Figure 4-5, showing the major factors influencing the total amount sediment delivery.

These diagrams can be used early in the planning process as a focus of discussions about:

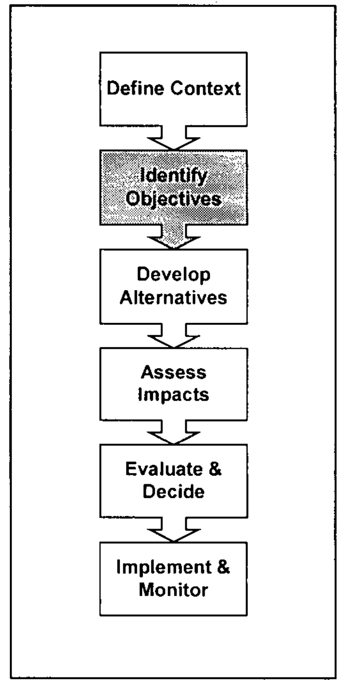
- Which factors are the most important? Is there agreement on these factors?
- Are there additional factors that should be shown?
- What data are available to quantify the relationships shown? Is there a need for further data gathering?
- Which factors are controllable and can be affected by management interventions?
- Are there alternative hypotheses about how sediment is generated?
- What is the base set of assumptions that will be used in any modeling or other analysis undertaken for this planning process?

Figure 4-5: Road-Related Sedimentation



In summary, simple conceptual models such as those shown above can serve as a valuable communication tool among both technical and non-technical planning team members. A common understanding of watershed issues may be developed, but if not, differences in opinion will at least be better understood. Key uncertainties may be highlighted and agreement reached on the priority that should be placed on next steps such as data gathering. This approach can help to simplify and clarify complex sub-problems within the broader planning context.

4.3.2 Define Objectives



Clarify and Structure Objectives

Are the objectives comprehensive and concise? Are they "ends-oriented"?

Objective setting was included as a part of the first "preliminary organization" step of the IWMP process. The Plan includes twenty-four pages of discussion on objectives and issues. Objectives were set "for each perspective" (i.e., by each stakeholder) to reflect both their values (environmental, social and economic) and their constraints (e.g., legislative mandates) (B.C. MELP/MOF, 1998: p. 41). The objectives are comprehensive, but not concise.

From a decision analysis perspective, the objectives of the Plan are "unstructured". They are a mixture of fundamental and means objectives, management constraints and operational procedures. As a result, the objectives offer little help in focusing the planning process and guiding decision making.

Further, as a result of a lack of focus on the fundamental ends of the planning process, a majority of the plan development effort was spent negotiating detailed guidelines for operational issues such as riparian management area widths, handling of slash during new road construction, and road drainage control structures (many of which were subsequently mandated through the Forest Practices Code). These guidelines were driven primarily by means objectives such as MOF's objective to support programs and projects that reduce erosion and sedimentation attributable to forestry activities (roads and harvesting). There was little effort spent addressing broader ends-oriented decisions, such as the overall level of forest activity to be undertaken in consideration of potential water quality impacts, environmental impacts and regional economic impacts.

For the C/G IWMP, setting clear and concise objectives may represent the single most important thing that could have been done to streamline the seven-year planning process. It would have helped focus the planning process on ends rather than means, and provided a framework for reporting on the likely performance of management options. Even though only one option was generated, it would have been useful to report expected progress toward fundamental objectives that would result from Plan implementation, from a baseline to some future point in time.

The release of the Draft Plan was ultimately met by considerable controversy. Although there may be many reasons for this, certainly one reason is that some stakeholders could not see what the impact of the Plan would be on both water and non-water related objectives. Had clear objectives been articulated and used as evaluation criteria or even as a simple reporting framework, even qualitatively, some accountability for the Plan objectives would have been introduced.

From a DA perspective, setting clear and concise objectives will facilitate quantitative system modelling and decision analysis later on. However, it is clear from reviewing the C/G experience that good objective-setting has the potential to improve the planning process by providing focus and clarity *even if no quantitative modeling of systems or decisions is conducted.*

Define Decision Criteria

Are measurable criteria defined and used to report impacts on each objective?

No specific decision criteria were established to indicate the merits of proposed management guidelines. As a result, the resulting impacts of the Plan on objectives of importance to all stakeholders remain unreported. For example, protecting water quality, quantity and timing of flows are clearly stated as primary, "end" objectives of the Plan. However, the primary 'results' of the planning process are stated as guidelines for the activities or "means" (e.g., forestry) that drive water quality effects. The linkage between the proposed guidelines and projected water quality, quantity and timing of flows is never made explicit. Similarly, it is not clear from reading the Plan what the financial or employment impacts of the Plan are, even though the Plan articulates objectives related to these.

DA suggests the use of *measurable* decision criteria. These are particularly useful when they can be quantitatively modeled or when systems are simple enough to establish meaningful qualitative scales for comparing options. In the area of water quality, however, quantitative modeling is exceedingly complex. In the absence of a sophisticated quantitative model for water quality, the effect of management options on the decision criteria would need to be estimated by expert opinion. There are DA tools and approaches for eliciting expert opinion (see section 3.2.2) and for resolving differences among experts (e.g., Delphi technique, Richey et al., 1985). These techniques are also technically challenging and time consuming. Most IWM planning processes will have limited access to sophisticated quantitative models and limited resources for DA specialists to elicit probability judgments. This difficulty suggests an important limitation in the application of DA to IWM.

Define Modelling/Monitoring Indicators

For modelling purposes, are a small number of indicators identified that capture the most important aspects of the system characterizations, in particular the uncertainties of interest?

No models were developed or applied during the development of the Plan. However the use of a GIS-based model of the watersheds has been identified for use during the implementation phase to enable the SCRD to "provide recommendations to the IWMP planning team on the hydrological implications of proposed cutblocks" (B.C. MELP/MOF, 1998: 104). To date there has been little progress made toward the development of such a model, therefore details are unavailable.

For monitoring purposes, do the chosen indicators respond rapidly to changes while signaling changes in other variables of interest? Can they be monitored efficiently?

In terms of water monitoring, the WRP monitoring program used a comprehensive list of indicators to capture important aspects of both water quantity (e.g., both peak and low flow) and water quality (e.g., turbidity, suspended sediments, and natural organic matter). Experience obtained during the program can now be drawn upon to design an efficient and effective longer term monitoring strategy (Carson, 1998).[34] Long term monitoring indicators for other resources (i.e., forest cover, wildlife, fisheries, recreation, etc.) have yet to be developed.

[34] For more detail regarding the successes of the WRP water monitoring program see section 4.3.6.

Define Learning Objectives

Are learning objectives defined? Is it clear what uncertain variable or relationship will be resolved and which decisions, management plans or activities could change as a result?

The Plan identifies several uncertainties such as understanding the functional relationships between harvesting and turbidity, and understanding the effect of changing riparian vegetation on nutrient generation and water quality. The WRP water monitoring program was initiated to address these and other uncertainties with the expectation that improved data obtained through study and monitoring would reduce or eliminate uncertainties over time. The WRP also identified numerous studies that could be related to an overall learning objective (see section 4.3.6). However, the WRP was initiated several years following the start of the C/G IWMP, and operated at arm's length from the planning process. This limited the extent to which these details could have been rolled up into well-articulated learning objectives for the Plan.

In general, there are three implications of defining learning objectives and specifying uncertainties to be addressed early in the process:

i. it implies that the extent to which different alternatives might yield new information about key uncertainties should be a consideration in evaluating alternatives;

ii. it strengthens the need to be clear about how new information would affect management, and if it would not affect management, may call into question the value of the information; and

iii. it implies the need for formalizing learning, either through management experiments or simply a more structured approach to monitoring and analysis.

Example 2: Objectives Hierarchy

From a decision analysis perspective, the objectives as currently written in the Plan are an "unstructured" mixture of fundamental objectives, means objectives, management constraints and operational procedures (Table 4-2). This example will address concerns regarding the usefulness of objectives that are set out in this way.

A fundamental objectives hierarchy has been developed to demonstrate the value of formally structuring objectives for the C/G IWMP (Table 4-3). The potential benefits of structuring the objectives as shown are:

1. The hierarchy contains only fundamental objectives, directing early planning efforts toward the strategic decision making requirements rather than detailed operational issues.
2. A concise and structured set of objectives establishes the basis for a transparent approach to evaluating alternatives.
3. Decision criteria are defined that will serve as the basis for evaluating proposed alternatives and stating predicted Plan outcomes, even if they are defined qualitatively.
4. A learning objective is included to ensure that later evaluation and decision making steps address key uncertainties.

Table 4-2: Selected Examples of C/G IWMP Plan Objectives[35]

Stakeholder	Stated Objectives
First Nations (Sechelt Indian Band, Squamish Nation)	▪ To support continued evolution of land use planning processes within Sechelt traditional territory. ▪ To protect biodiversity, botanical products and other values through strong conservation measures and limited access.
Water Resources (MELP Water Management Program, SCRD, CGHU)	▪ To maintain and/or enhance water quality, quantity and timing of flows. ▪ To minimize risk to life and property from floods, erosion and debris torrents. ▪ To pursue sustainable management of consumptive and instream uses. ▪ To identify, locate and, where possible, mitigate those watershed activities and sources that are significantly contributing to suspended solids and organic material entering streams. ▪ To establish appropriate raw water quality objectives.
Forestry (MOF & the forest industry)	▪ To optimize the development of the forest resource in an environmentally sound, yet cost effective manner, to ensure that timber supplies and employment stability are sustainable. ▪ To conduct basic and intensive silviculture activities to maintain, and if possible, enhance the Allowable Annual Cut contribution to the Sunshine Coast Timber Supply Area while protecting water characteristics. ▪ To sustain forest recreational opportunities. ▪ To assist in programs and projects to maintain and improve water characteristics, such as reducing erosion and siltation attributable to forestry activities (roads and harvesting). ▪ To concentrate silvicultural spending on stable areas of the land base to reduce potential future negative economic impacts of land withdrawals.
Wildlife (MELP)	▪ To protect wildlife habitat and maintain species diversity and viability of populations. ▪ To promote non-consumptive wildlife viewing activities. ▪ To further establish and maintain corridors of mature timber within the watersheds between upper and lower elevation sites as a strategy that would benefit both game and non-game wildlife populations.

[35] Table 4-2 presents merely a subset of the many objectives stated in Chapter 3 of the Plan.

Table 4-2: Selected Examples of C/G IWMP Plan Objectives (con't)

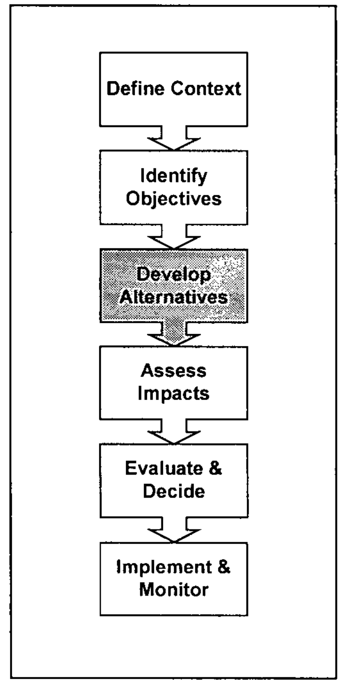
Stakeholder	Stated Objectives
Fisheries (DFO, MELP)	▪ To maintain wild steelhead populations by protecting spawning and rearing habitat and ensuring an adequate water supply. ▪ To increase salmon production through a program of conservation, protection and enhancement. ▪ To ensure adequate minimum fisheries flows are maintained through critical low flow periods. ▪ To provide an uncrowded angling opportunity for catch and release wild steelhead along with a limited harvest of hatchery steelhead. ▪ To maintain existing recreational lake fisheries through natural recruitment.
Recreation (MOF)	▪ To determine the recreation carrying capacity and then reduce unsustainable use of the entire watershed. ▪ To shift concentrated recreation use to more durable sites in order to minimize water resource conflicts. ▪ To shift recreation use to times of the year when it is least likely to impact the environment and water quality.
Mineral Resources (MEI, Energy & Mines Division)	▪ To administer responsible exploration, development and reclamation to ensure protection of water quality and quantity. ▪ To control the scheduling of mineral exploration activities to avoid times critical to slope instability and water quality deterioration. ▪ To apply the established provincial Mine Development Review Process or Environmental Assessment Process to mine development proposals.

Table 4-3: A Structured Fundamental Objectives Hierarchy for C/G IWMP

Objectives	Possible Decision Criteria
Overall Goal *To conduct effective, long term integrated resource management within the Chapman and Gray Creek community watersheds.*	
1. Provide a Quality Community Water Supply	
1.1 Protect or Enhance Water Quality	
1.1.1 Physical	▪ suspended sediment concentration
1.1.2 Micro-biological	▪ coliform concentration
1.1.3 Chemical	▪ nutrient concentration, pH, etc.
1.2 Protect or Enhance Water Quantity	
1.2.1 Improve Timing of Flows	▪ peak winter flows and low summer flows (litres/second)
2. Support Economic Resource Development	
2.1 Forestry: Maximize Timber Supply	▪ change in AAC (m3)
2.2 Minerals: Retain Development Potential	▪ hectares of class 1 exploration land
2.3 Overall Employment	▪ number of direct/indirect jobs
3. Maintain a Quality Natural Environment	
3.1 Maximize Biodiversity	▪ hectares in forest ecosystem network
3.2 Maximize Mature Forest Cover	▪ hectares of mature seral stage cover
3.3 Maximize Fish Populations	▪ expected escapement (annual number)
3.4 Maximize Wildlife Habitat	▪ hectares of suitable habitat for identified game and non-game species
4. Minimize Flood Risks	▪ reduction in flood frequency
5. Maximize Recreation Opportunities	▪ user days/hectare/year
6. Preserve First Nations Future Options	▪ constructed scale[36]
7. Improve System Knowledge (Through Adaptive Learning)	▪ number of key uncertainties addressed
7.1 Confirm Relationship Between Harvesting and Water Quality	
7.2 Confirm Efficiency of Alternative WRP Techniques	
7.3 Other	

[36] For some objectives, there are no readily available attributes that stand out as good decision criteria. In such cases, it is necessary to create one that measures the degree to which the objective is achieved in qualitative terms. These "constructed scales" must have at least two distinct levels of achievement (see Keeney (1992) for good examples).

4.3.3 Develop Alternatives



Structure Alternatives

Are individual options grouped together by type for structuring purposes? Can logical strategies be developed?

The C/G IWMP planning team developed forty pages (i.e., the largest component of the Plan document) of detailed management guidelines for forestry, mineral exploration, utility corridors and recreation. Statements were also included to provide direction for further watershed restoration program and access management planning, and to provide protection of aboriginal rights. This task began with each stakeholder unilaterally defining specific guidelines to address their own objectives and issues. Using this information, the co-chairs then drafted a complete set of guidelines (i.e., the 1994 Draft Plan). Collectively, these guidelines represent the single watershed management alternative that was refined and debated amongst planning team members for the next four years.

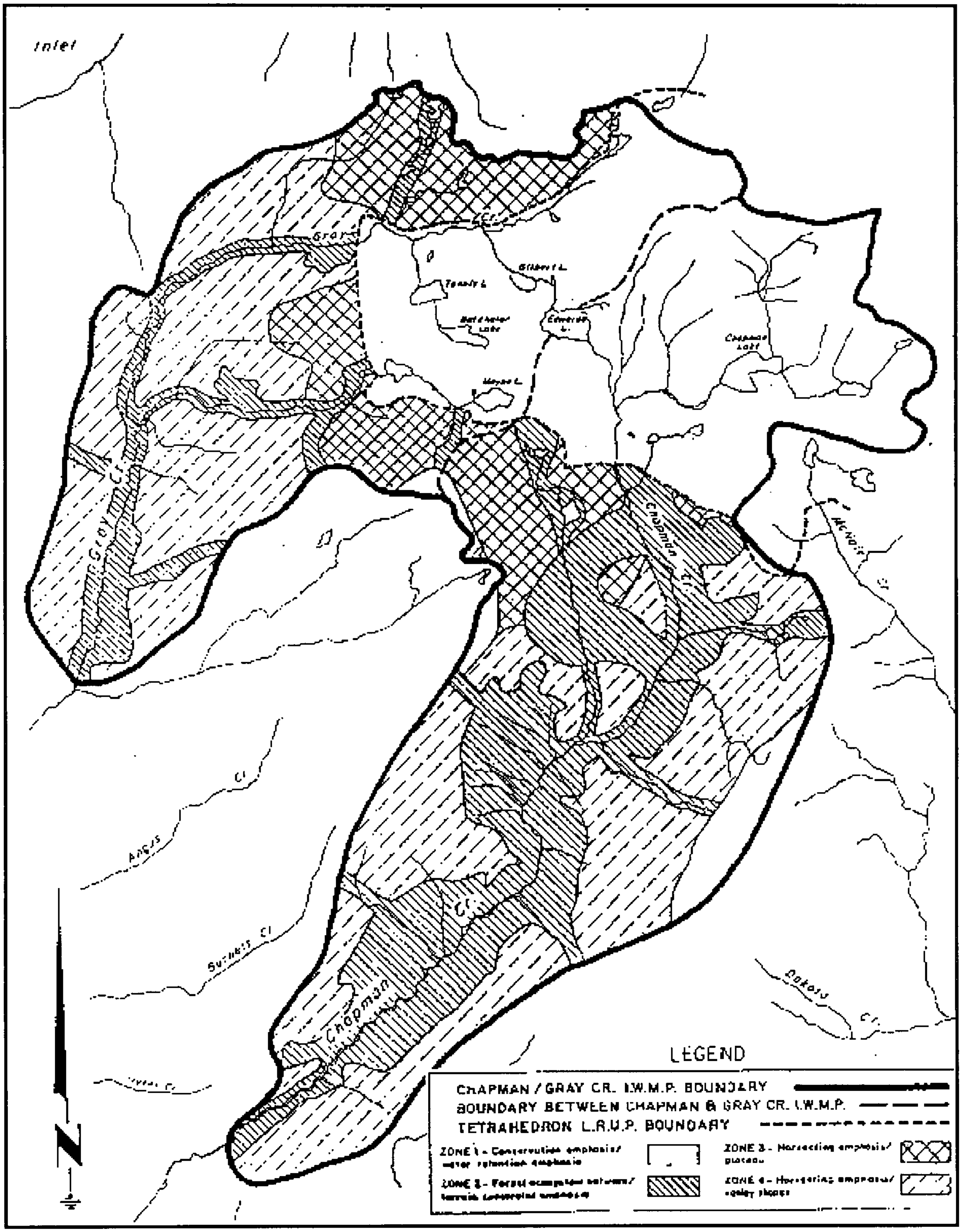
The natural grouping of options by major resource area provided a logical structure for presentation and review purposes. Another strength of the approach undertaken by the C/G IWMP involved the delineation of four different watershed zones (Figure 4-6). This allowed the team to place a different management emphasis across the watershed by developing detailed zone-specific guidelines that more accurately reflected localized conditions such as terrain suitability and historical land use. However, the concept of developing alternative strategies was not used.

Develop a Range of Alternatives

Are alternatives that are substantially different in scope or approach developed?

For all intents and purposes, the C/G IWMP process focused on the development and review of a single watershed management alternative. However, during the period of public and agency review of the 1994 Draft Plan, two additional alternatives – generally referred to as "more development, less conservation" and "more conservation, less development" – were sketched out *for discussion purposes only* (B.C. MELP/MOF, 1996). These alternatives were developed by simply tweaking the details of the various management guidelines (e.g., decreasing average cutblock size from 10 hectares to 8 hectares), rather than by developing watershed management alternatives that were substantially different in scope or approach.

Figure 4-6: C/G IWMP Watershed Resource Management Zones



Use Competing Hypotheses to Develop Alternatives

Are management experiments identified that are capable of testing alternative hypotheses? Are models used to pre-test hypotheses?

Although competing hypotheses about system functioning were not formally developed and debated by the C/G IWMP team, there were a number of management experiments identified for implementation as part of the WRP (see details under section 4.3.6 below). The Plan also identifies the development and use of a "GIS analytical model". To date, both the management experiments and GIS model remain as ideas and concepts yet to be developed.

Example 3: Developing and Structuring Alternatives

This example builds on the C/G IWMP approach to grouping individual options (i.e., management guidelines) by resource sector, and describes how a range of well-structured higher-level watershed management alternatives might have been developed.

Examples of the types of management guidelines included in the Plan are given in Table 4-4. This small subset of management guidelines provides an indication of the extent and detail that is included (the full set of management guidelines covers forty pages).

The proposed approach to developing watershed management alternatives has two broad steps. In step one, the plausible range of possible management action is brainstormed (Table 4-5). For each resource sector or 'option class', a range of implementation is identified. For example, for timber harvesting the spectrum can range from a complete ban on harvesting, through an identified 'low volume' harvest and up to a 'high volume' harvest (with harvest levels stated on an AAC basis). Within the broad implementation range, further detail can be provided by considering both the techniques to be applied, and the areal extent of the management action. In the case of the C/G IWMP, the planning team did identify acceptable techniques and the areal extent of implementation by establishing four different watershed zones.

Table 4-5 contains several classes of options that were not directly considered by the C/G IWMP team, largely because it was outside of their mandate and terms of reference. Options for 'Fisheries', 'Water Supply' and 'Water Treatment' are included to reflect specific objectives that were stated within the C/G IWMP. The value-focused thinking approach (Keeney, 1992), here considered as a decision analysis tool, suggests that given the interests in providing a quality community water supply and preserving fisheries in the system that options that specifically address these objectives should be included.

Table 4-4: Selected Examples of C/G IWMP Management Guidelines[37]

Sector	Resource Management Guidelines
Forestry	▪ "ECA (equivalent clearcut area) for any sub-basin not to increase by more than 1% per year" ▪ "average cutblock size to be 15 ha" (zone 4: valley slopes) ▪ "a 200 - 400 m timbered buffer to be maintained between openings" ▪ "restocking of existing not sufficiently restocked (NSR) lands is to be a priority in the watersheds" ▪ "new roads are not to be located in riparian zones or the Forest Ecosystem Network (FEN) without the approvals of the BCE FES and MOF FE" ▪ "roads, drainage structures and ditch lines to be checked in spring, fall, after storm events and at regular intervals for immediate repair of deficiencies"
Recreation	▪ "low impact recreational activities will be maintained but not intensified" ▪ "any trails developed by BC Parks to be positioned away from all watercourses and wetlands" (zone 1: watershed conservation area) ▪ "C/G WRP to provide signage at entry points to the watershed" (zone 4: valley slopes)
Mineral Exploration and Development	▪ "prompt surface rehabilitation and revegetation to occur following exploration ground disturbances" ▪ "the management of potential acid rock drainage will be consistent with current provincial policy and regulations respecting prediction, prevention, and treatment to ensure that water quality in Chapman and Gray Creeks is not diminished" ▪ "permit conditions and financial securities to ensure mitigation of disturbances to a pre-determined condition" (zone 4: valley slopes)
Utilities	▪ "utility corridors not to be expanded" ▪ "30 m fertilizer-free zone to be maintained along all watercourses" ▪ "implement a community watershed erosion control program"

[37] Table 4-4 presents merely a subset of the many management guidelines stated in Chapter 4 of the Plan.

Broadening consideration of the options available to meet the planning team's *fundamental* objectives could open the door to better all-around options. Such options would likely require the involvement of more parties or be outside the scope of the C/G IWMP as currently defined. However, an exploration of options at a feasibility stage might result in decisions to expand scope or involve more parties in order to realize more attractive solutions.

The second step involves combining individual options into strategies that represent alternative management approaches. The development of these strategies can be facilitated with the use of a Strategy Table (Table 4-6). In complex land use planning exercises it is often beneficial to develop a 'base case' or 'do nothing' alternative as a starting point (e.g., the B.C. *Land and Resource Management Planning* process uses such an approach). For the C/G IWMP, consider the development of two additional strategies:

The Restoration Strategy: This strategy strives to return the watersheds to their original pre-development condition, while accommodating low-impact resource development and recreation opportunities. The overall emphasis is on options from the 'watershed restoration' category, along with compatible options included from forestry, fisheries and recreation.

The Mitigation Strategy: This strategy allows for more forest and mining resource development, while recognizing that additional measures may be required for both water supply and fisheries protection. This strategy includes options from the waterworks, water treatment and fisheries categories, along with more intensive options from forestry and mining.

The shaded boxes of Table 4-6 provide an example of a hypothetical restoration strategy. From a forestry perspective, it includes an advanced level of silviculture, a low level of harvesting and maintenance of the status quo for roads. For recreation, the status quo is continued. Watershed restoration activities would be implemented at the highest level for all categories, emphasizing the fundamental focus of this alternative. There would be a complete ban on any form of mineral exploration or development. From a fisheries perspective, hatchery operations would remain at the status quo while an enhanced program of habitat restoration was undertaken. Finally, both water supply and treatment options would hold at the status quo. Using this approach, alternative strategies would be developed by selecting different levels of implementation from each option class.

After a preliminary evaluation of these alternative strategies, the planning team could be encouraged to combine and re-create new alternatives that included any necessary compromises to satisfy all stakeholders. By starting with substantially different themes or approaches to developing alternatives, it is more likely that creative combinations of options will be developed.

It should be pointed out that there is a danger in generating alternatives in that the process may polarize stakeholders who anchor on a preferred alternative. It is essential to make sure that all stakeholders understand that the purpose of generating a wide range of alternatives is to generate creative ideas as a starting point for building a consensus alternative. Although evaluating several alternatives takes time and money up front, it may save in the long term through better public acceptance of the process and through the development of a more efficient plan.

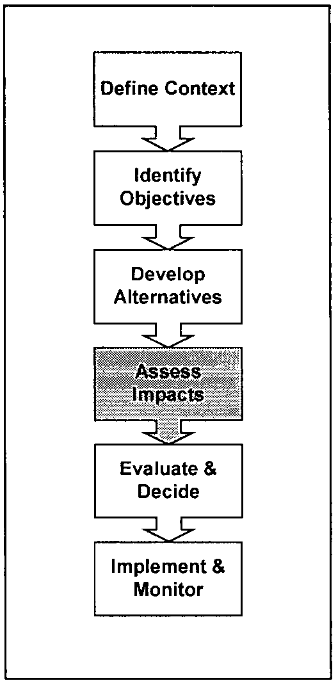
Table 4-5: Structuring Alternatives for Watershed Management

Option Class	Implementation Range	Detailed Considerations: Techniques	Areal Extent
Forestry Operations:			
Silviculture	Basic Advanced	E.g., Brushing, Weeding, Pruning, Planting and Underplanting	Watershed Wide By Zone (1, 2, 3, 4)
Timber Harvesting	Ban Low Volume High Volume	E.g., Clearcutting, Selection, Partial Cutting, Shelterwood	Watershed Wide By Zone (1, 2, 3, 4)
Roads	Status Quo Extended	E.g., Temporary, Seasonal, Permanent	Watershed Wide By Zone (1, 2, 3, 4) By Terrain Class (I-V)
Recreation:			
	Ban Status Quo Enhanced	E.g., Forest Service sites, Expanded Trails, Additional Cabins	Watershed Wide By Zone (1, 2, 3, 4)
Watershed Restoration:			
Streamworks	None Low Level High Level	*E.g., Bank Stabilization with Large Woody Debris & Bio-engineering, Diking, Channelization, Diversions*	By Stream Reach
Road Deactivation	None Low Level High Level	E.g., Full Contouring, Cross Ditching, Sidecast Pullback, Grass/Hydro Seeding	Watershed Wide By Zone (1, 2, 3, 4) By Terrain Class (I-V)
Erosion Control	Status Quo Reduced Enhanced	E.g., Drainage Structure Maintenance, Landslide Scar Treatments	Watershed Wide By Zone (1, 2, 3, 4)
Mineral Exploration and Development			
	Ban Exploration only Aggregates only Minerals only Comprehensive (all)		Watershed Wide By Zone (1, 2, 3, 4)
Fisheries			
Hatchery Operations	Status Quo Additional		By Location
Habitat	Status Quo Enhanced	E.g., Backwater Channels, Cold Water Siphoning	By Stream Reach
Water Supply			
Intakes	Status Quo Additional		At High Elevation
Storage	Status Quo Increased		At Intake At High Elevation
Water Treatment			
Filtration	Status Quo Enhanced		
Disinfection	Status Quo Enhanced		

Table 4-6: Strategy Generation: Hypothetical Example of a Restoration Strategy

	Forestry	Recreation	Watershed Restoration	Mineral Expl/Dev	Fisheries	Water Supply	Water Treatment	Others?
Base **Restoration** **Mitigation** **Others?**	**Silviculture** Basic Advanced **Harvesting** Ban Low Volume High Volume **Roads** Status Quo Extended	Ban Status Quo Enhanced	**Streamworks** Status Quo Low Level High Level **Road Deact.** None Low-level High-level **Erosion** Status Quo Reduced Enhanced	Ban Expl. only Aggs only Mins only Comp.	**Hatcheries** Status Quo Additional **Habitat** Status Quo Enhanced	**Intakes** Status Quo Additional **Storage** Status Quo Increased	**Filtration** Status Quo Enhanced **Disinfection** Status Quo Enhanced	

4.3.4 Assess Impacts



Estimate Impacts

Is the impact of each alternative on each fundamental objective estimated?

There were no formal attempts made to describe, quantitatively or qualitatively, what impact the proposed alternative (i.e., the complete set of management guidelines) would have on the objectives developed for the plan. In essence, the Plan contains a comprehensive set of management guidelines that were negotiated in the absence of explicit estimates of their potential impact on the stated objectives. Whether quantitatively or qualitatively, decision analysis suggests that reporting expected impacts is critical for making good decisions and generating widespread support for a plan.

However this is not to say that impact assessment information was totally absent from the planning process. The *Watershed Cumulative Effects Analysis* (WCEA) undertaken in 1993 (Hudson et al., 1993) provided important information that informed the ongoing negotiation of forestry related guidelines. The WCEA evaluated the type and extent of current water-related problems that exist in the watersheds, and provided recommendations on harvesting levels and road deactivation on a sub-drainage basis. The report provided timely direction to the IWMP team regarding the potential hydrologic impacts of future harvesting activity, and largely formed the basis of the forestry related guidelines included in the plan.

Nonetheless, within the plan itself, there are no final quantitative estimates or qualitative statements regarding the effects of the complete set of management guidelines on water quantity, water quality and timing of flow, which are the stated primary objectives of the Plan. Stakeholders are left to assume that the guidelines would result in future water quality and quantity lying within some unstated acceptable range. Similarly, there are no stated outcomes of what the management guidelines would achieve with respect to other objectives such as protection of biodiversity, conservation of wildlife resources and reducing recreation impacts. For example, although meeting the biodiversity emphasis targets as stated within the FPC Biodiversity Guidebook is a stated objective of the plan, there is no reporting, either qualitatively or quantitatively, of the degree to which the guidelines developed achieve this end.

Analyse Uncertainty

Has the uncertainty associated with each alternative been described for each outcome of interest? Are any tools such as sensitivity analyses, decision trees, or expected value of information calculations applied?

A review of the plan and related documentation uncovered no attempts to formally assess the impact of uncertainties as part of the planning and decision making process.

Example 4: Use of Decision Trees

This example demonstrates the use of decision trees as a means of incorporating uncertainty into decision making. As is often the case with analytical tools of this type, they are often best applied toward resolving a technically-oriented sub-problem of the broader planning process (Walker, 1996). Finding resolution to such sub-problems can be extremely important as a means of avoiding technical debates that could threaten the progress of the entire planning process.

In this hypothetical example, the basic management problem is captured by the question, "what is the best use of Watershed Restoration Program funds?" Assume there is $100,000 of program funds available and two investment options: i) gully/landslide scar rehabilitation, and ii) road deactivation. Assume further that managers are able to provide the information in Table 4-7, including estimates of the amount of sediment originating from the proposed treatment sites and the estimates of the efficiency of proposed treatments to be applied in each case.

Therefore, in the case of the gully/landslide scar rehabilitation program, managers estimate that 10,000 tonnes/year are released on average, and that implementing techniques such as removing debris jams from gullies and applying silt fencing and hydro-mulching on landslide scars would be 80% effective at reducing this source of sediment delivery. The resultant "expected reduction" in sediment delivery for this option is 10,000 tonnes/year x 80% = 8,000 tonnes/yr. At a cost of $100,000 then, this option costs $12.50 per tonne of reduction in long term sediment delivery.

In the case of the road deactivation program, managers estimate that 1,000 tonnes/year are released from the road surface itself, and an additional 15,000 tonnes/year on average are released in mass wasting events associated with road condition. Using a standard set of road deactivation techniques, managers estimate that they can be 80% effective at reducing road surface erosion, and 50% effective at reducing mass wasting events associated with roads. The resultant total "expected reduction" in sediment delivery for this option is 8,300 tonnes/yr. At a cost of $100,000 then, this option costs $12.05 per tonne of reduction in long term sediment delivery.

Based on this information, with such a small difference in cost, managers would likely be indifferent between the two program options.

Table 4-7: WRP Deterministic Decision

WRP Program Option	*Source* *(Avg Tonnes/Yr)*	*Treatment Efficiency (%)*	*Expected Reduction (Avg Tonnes/Yr)*
Gully/Landslide Scar Rehabilitation • debris jams • slit fencing • hydro-mulching • etc.	10,000	80 %	8,000
Road Deactivation • cross-ditching • sidecast pullback • seeding • re-contouring • etc.	Road surface 1,000	80 %	800
	Reduced Mass Wasting 15,000	50%	7,500 Total = 8,300

Now assume that instead of making deterministic estimates, managers decide to take into consideration uncertainties in their original estimates. They replace their original single point estimates for source tonnes and treatment efficiencies for each option with a plausible range of high and low value estimates, and associated probabilities of each value being correct. The decision tree in Figure 4-7 graphically displays how an expected value of sediment reduction can now be calculated for each program using the additional information provided.[38]

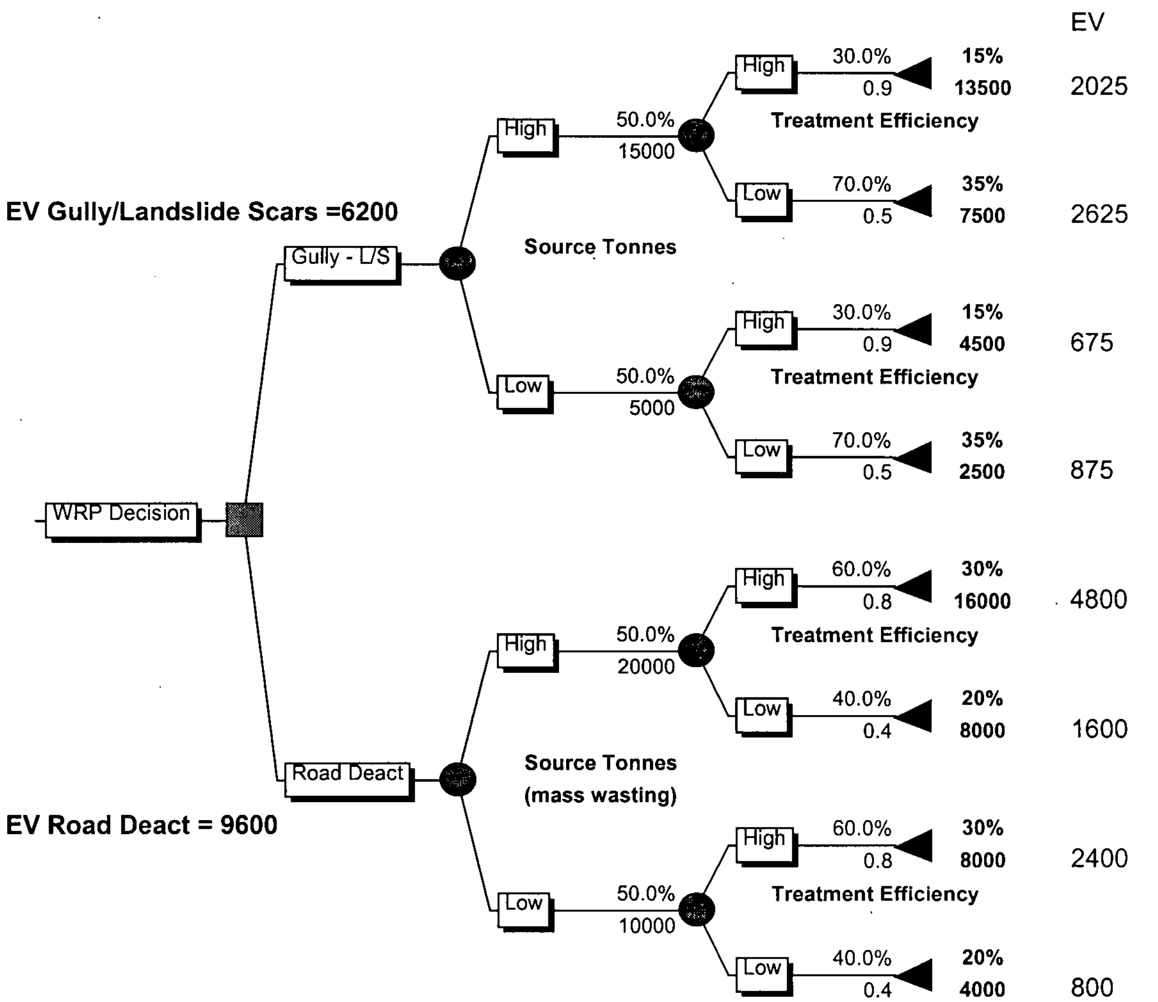
Within the structure of the decision tree, a square is used to represent a 'decision node' and circles are used to represent 'uncertainty nodes'. In this case the decision shown on the left hand side of the diagram is to select between the gully/landslide scar rehabilitation program and the road deactivation program. The two sources of uncertainty are shown branching out from left to right, represented by high and low values for source tonnes and treatment efficiencies for each program. At the end of each branch of the decision tree, the expected value (EV) of following the particular decision path is calculated as the product of the cumulative probability and cumulative outcome to that point. For example, following the uppermost branch of the decision tree, we find that for the gully/landslide scar rehabilitation program the first uncertainty is estimated as a 50% chance of the source sediments being as high as 15,000 tonnes per year. The second uncertainty is estimated as a 30% chance of the treatment efficiency being as high as 90% effective. By multiplying all cumulative probabilities by all values along this branch of the decision tree we find that the expected value of the outcome is a reduction of 2,025 tonnes/year.[39]

[38] For simplicity, this decision tree example will focus on the potential reduced mass wasting component of the road deactivation program and ignore the much smaller potential road surface erosion component.
[39] For more information on the mechanics of developing decision trees, see Clemen (1991). Here the focus is on providing a conceptual understanding of how they might be useful in planning and decision making.

By summing all possible branch results for the gully/landslide scar rehabilitation program, we find the total expected reduction in sediment delivery, taking into consideration the uncertainties shown, is 6,200 tonnes. At a cost of $100,000, the unit cost is $16.13 per tonne of reduction in long term sediment delivery. For the road deactivation program, the expected reduction is 9,600 tonnes leading to $10.42 per tonne of reduction in long term sediment delivery. With these results managers would clearly prefer the road deactivation program, which on an expected value basis, delivers greater sediment reduction at lower unit cost. That is, it has a higher probability of achieving a greater sediment reduction resulting in a lower unit cost.

In this hypothetical example, a very simple analysis, using managers' experience and judgment to be explicit about uncertainty, leads to a different and more effective decision than when point estimates are used.

Figure 4-7: Decision Tree Example



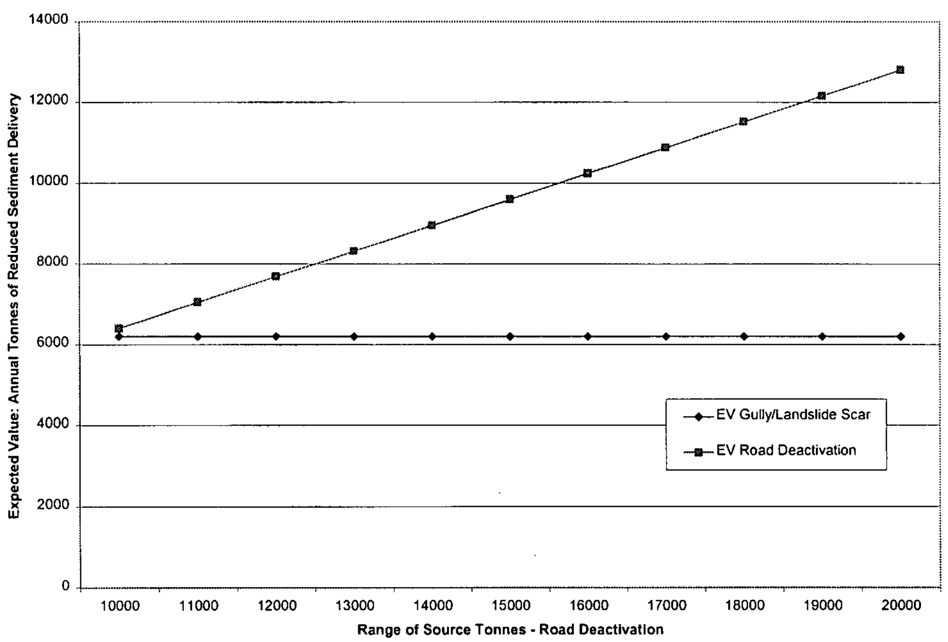
Example 5: Sensitivity Analysis

This example builds on the previous example to show how simple sensitivity analysis can provide managers with more confidence in decisions taken using uncertain information.

Making decisions on an expected value basis as in Example 4 is not always intuitive for managers. Sensitivity analysis is an alternative technique for examining the effect of uncertainty. Suppose a manager concludes that s/he expects road deactivation to lead to a reduction of 15,000 tonnes from mass wasting, but that the plausible range of reductions could be as low as 10,000 tonnes or as high as 20,000 tonnes. Sensitivity analysis is conducted by varying the value for estimated tonnes from road deactivation sites across the entire range of values, while holding all other variables constant (Figure 4-8). What this figure demonstrates is that within the range of values considered plausible by managers, the expected reduction in sediment delivery for the road deactivation program is always greater than that for the gully/landslide scar rehabilitation program. The decision is said to be insensitive to the uncertainty in the effect of road deactivation.

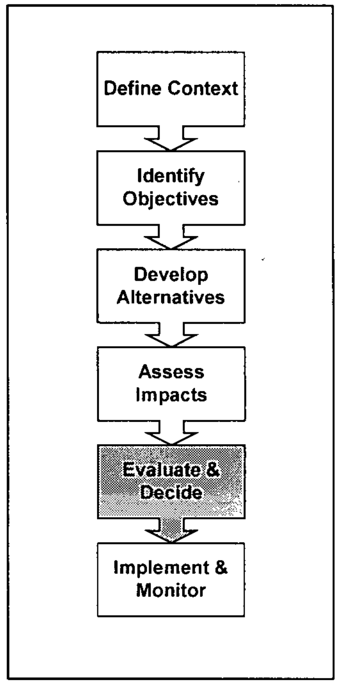
In the absence of analysis of this kind, it is possible that stakeholders could waste time in debate over the relative merits of both programs, and/or spend money on additional studies to confirm which is better. But in this case (valid only for the assumptions used in this hypothetical example), it is shown that no more study is needed – within the range of values considered plausible by managers, the decision is not affected.

Figure 4-8: Example Sensitivity Analysis



In cases where the decision is found to be sensitive to the specified range of values, managers can review how sensitive the result is, and decide whether there is merit in collecting better information before making a decision. In either case, managers are making more informed decisions in full recognition of the uncertainty inherent in their information and estimates.

4.3.5 Evaluate and Decide



Use a Multi-Attribute Evaluation Framework

Is a structured evaluation framework used to summarize the consequences of each alternative with respect to each objective? Does the framework help to clarify the differences between "facts" and "values"?

At the very outset, the Plan states that "decisions were made by weighing and comparing differing values regarding the acceptability of economic, social and ecological risks, costs and benefits" (B.C. MELP/MOF, 1998: i). However, analysis of the report uncovers no explicitly stated 'risks, costs or benefits', and no indication of the process used to 'weigh and compare' different values. Instead, the evaluation of specific management guidelines occurred through an unstructured process of negotiation and information review leading toward decisions that had varying degrees of consensus support.

Assess Preferences

Are formal preference assessment techniques used? Are multiple methods used? Are stakeholders/decision makers given opportunities to revisit their stated preferences?

No formal attempts at preference assessment were done. The process did indirectly incorporate the values of the stakeholders via the consensus-based approach. Nonetheless, because formal preference assessments were not made or incorporated into decision making, there is no guarantee that stakeholder values were applied rationally and consistently to make key tradeoffs. Instead, tradeoffs on any given strategy/guideline were implicit and may have been affected by personalities, negotiating skill, balance of power, and a number of other factors.

Example 6: Use of a Multi-Attribute Evaluation Framework

Decision analysis stresses the use some form of multi-attribute evaluation framework as a means of facilitating an effective process of evaluation and decision making. In this example, a Multiple Accounts Evaluation (MAE) – a common framework used in many instances in British Columbia – is described that relies on the objectives and decision criteria as structured in the example in Step 2 above and on the alternatives as structured in Step 3 above.

An MAE is a matrix that lists the fundamental objectives (or "accounts") on the vertical axis and management alternatives on the horizontal. The performance of each alternative with respect to each objective, as assessed in Step 4, is shown in the cells of the table using the decision criteria.

The value of the MAE format is that it helps to identify key trade-offs, either within a single alternative or among several alternatives. Stakeholders can quickly see trade-offs between water quality, economic development opportunities, environmental quality, and other objectives. The MAE can also highlight alternatives that do not meet critical constraints (e.g., budgets, regulations, etc.) or that are outperformed in all respects by other alternatives.

Once the alternatives are identified and characterized in an MAE, the need for a formal decision making process can be assessed. It may be that one alternative is clearly better than the others in all respects. In such a case, there is no need for a costly and time consuming decision process. Alternatively, there may be difficult trade-offs that need to be made, necessitating a structured approach. In either case, the MAE provides a useful summary of information to decision-makers and stakeholders.

Figure 4-9 shows an example of a multiple account evaluation using a subset of the objectives and decision criteria outlined in Example 2.[40] The entries in the table are the "facts" about the expected consequences of each alternative. Where there is uncertainty in these figures, a range of values may be shown. When stakeholders hold profoundly different views about underlying assumptions, a separate MAE table may be shown for different scenarios (where a scenario constitutes a set of assumptions).

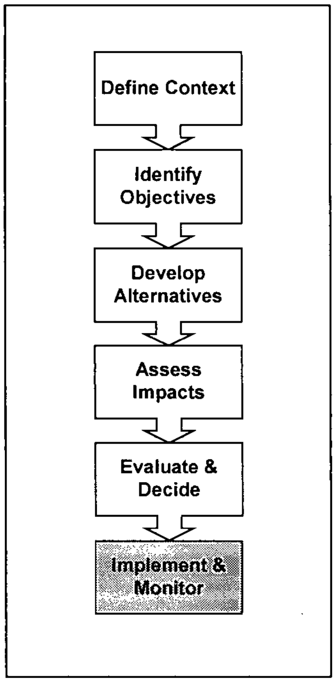
Once the consequences of different alternatives are clear, preference assessment techniques can be used to clarify the preferences of stakeholders for different outcomes. The MAE, however, does not make a decision. It simply presents information in a way that clarifies key consequences and trade-offs. This better prepares stakeholders to make decisions, whether through a holistic assessment, a quantitative decision modeling technique, or bargaining and negotiation.

Figure 4-9: Multiple Account Evaluation Framework

Account	Decision Criterion	Base	Mitigation	Restoration
Community Water Supply				
▪ Water Quality	▪ suspended sediment (tonnes/yr)	5,000	5,500	4,500
▪ Water Quantity	▪ avg. summer low flow (litres/second)	300	300	400
Economic Development				
▪ Timber Supply	▪ AAC (m^3)	50,000	70,000	30,000
▪ Forestry, fisheries, mining	▪ no. of jobs (direct and indirect)	300	400	300
Environment				
▪ Biodiversity	▪ forest ecosystem network area (ha)	6,000	5,000	7,000
▪ Wildlife Habitat	▪ suitable habitat (ha)	3,500	3,300	4,000
Social				
▪ Flood Risk	▪ annual # floods > 40 m^3/year	20	20	20
▪ Recreation	▪ total user days/year	5,000	5,000	5,000

[40] Note that it is usually useful to add some text that qualitatively describes or qualifies the figures shown in the table.

4.3.6 Implement & Monitor



Design Formal Management Experiments and Monitoring Systems

Do the management experiments adhere to the principles of experimental design: randomization, replication, blocking and representation?

There have not yet been any formal attempts at conducting management experiments as part of the C/G IWMP. However, the Plan states a number of studies will be undertaken as part of the Watershed Restoration Program's water monitoring program, including:

- determination of the effects of logging on creek hydrology and water quality using a paired catchment study approach;
- determination of the effects on water quality of converting alder stands to coniferous stands in riparian areas using a paired catchment study approach;
- determination of the sources, characteristics and possible options for dealing with aluminum;
- manipulation of stand characteristics to accelerate the development of old seral stage attributes within the forest ecosystem network.

Any one of these studies could be designed as an adaptive management experiment that adheres to the principles of experimental design. Since the Plan has yet to be approved and formally enter into implementation, one can only speculate on the degree to which this may occur. Given the limited remaining budgets and timeline of the existing WRP, it is unrealistic to expect that comprehensive and detailed management experiments will be developed without additional WRP or research funding being obtained.

Are monitoring systems developed up-front? Are suitable statistical tests and methods used to validate the confidence, power and relevance of monitoring results? That is, can causation be determined?

Implementation of the water quality/quantity monitoring program under the WRP provided an important source of baseline data that both benefited the ongoing development of the plan, and established recommendations upon which an ongoing monitoring program can be developed. The first year of the program used a flexible, reconnaissance approach to baseline monitoring that was particularly effective at narrowing in on key water management issues. The originally stated goals of the program (B.C. MELP/MOF, 1996: background report 7) were to:

- develop a reliable data base on water quality and discharge for the watersheds;
- monitor the effect of watershed restoration project activities;
- focus efforts to address anticipated short, medium and long term management problems; and
- ensure that the monitoring program has a life beyond that afforded by the project.

The program has largely achieved the first three of these goals, while success at achieving the fourth remains unknown.

The WRP water quality/quantity monitoring program has focused on developing a database of water quality and discharge baseline data. Analyses have also been undertaken to determine seasonal trends, correlations between turbidity measurements and total suspended sediments, and the relative proportion of organic versus inorganic suspended sediments. Finally, initial investigations were started into more specific water quality/quantity problems such as low flows, organic and inorganic sediment sources, high temperatures and pH.

The WRP water quality/quantity monitoring program has largely been a data gathering and summarizing exercise. The application of suitable statistical tests and methods has therefore not been considered warranted to date. Interestingly, however, the latest summary report of activities to date (Carson, 1998) does probe various cause and effect relationships (e.g., the relationship between natural organic matter and forest harvesting), based on the data gathered and summarized to date. However, more detailed understanding of such relationships could only be achieved through the careful design of adaptive management experiments coupled with the statistical analysis of monitoring results.

Evaluate and Adjust

In the short term, are monitoring results used to adjust ongoing implementation activities? Are they used to fundamentally change management decisions made with previous information?

As the Plan has yet to enter the implementation phase this question is not applicable. However, looking ahead, it is not clear how new information resulting from implementation could be used in on-going management. For example, if new information comes in from future WRP studies, how will this information be used? Is it realistic that the guidelines negotiated through seven years of planning will be changed without reconvening the stakeholder group? Should MOF/MELP be empowered to unilaterally change guidelines if new information challenges previous assumptions? Or should stakeholders be asked to come back to the table to re-negotiate? From a stakeholder perspective, both options may be seen to show a lack of respect for the planning process – the first because it weakens the commitment to implement the negotiated agreement as is, the second because it asks stakeholders to reconvene relatively soon after they have just made significant commitments and tough compromises in order to reach agreement once already.

In a multi-stakeholder process such as the C/G IWMP, the AM protocol of encouraging managers to make ongoing adjustments to implementation activities thus presents a possible dilemma.

In the longer term, are monitoring results used to update system characterizations, research hypotheses and experimental designs? Are they used to re-examine objectives?

Again, as implementation of the entire Plan has not yet started, these questions remain mostly inapplicable at this time. Interestingly however, results from the WRP water quality/quantity monitoring program provide some insight into the potential updates to system characterizations possible through a formal adaptive management approach. Although original understandings of the biophysical system were not stated explicitly as such, it is clear that certain 'hypotheses' evolved as a result of the improved understanding gained through comprehensive monitoring (Table 4-8).

Table 4-8: Changing Hypotheses Through WRP Implementation

Original Hypothesis		New Hypothesis
Inorganic sediments are the dominant source of turbidity	→→→	Organic sediments may dominate
Roads are the major cause of turbidity and sedimentation	→→→	Most turbidity/sedimentation is from streams and creeks
Most organics originate from high elevation bogs	→→→	Many originate from lower elevation riparian areas

These types of learnings could be applied directly toward changes in management strategies. For example, learning that turbidity may be primarily affected by sediments delivered from streams and creeks rather than roads may lead to decisions to reduce effort directed at road deactivation. In a formal adaptive management program, experiments would be designed to compare the effects to ensure that changes in turbidity resulting from a new management emphasis could be measured and verified, with statistical confidence. Paired watershed studies, for example, would allow comparison of a management program targeting sedimentation from roads and a management program targeting sedimentation from streams and creeks.

Example 7: Expected Value of Information Calculation

In this example, analysis is conducted to provide information to help assess whether the cost of conducting trials to generate improved information is warranted.[41]

In Figure 4-10, the decision tree from Example 3 is repeated in simplified form, focusing on the uncertainty regarding the estimated treatment efficiencies for techniques to reduce sediment delivery from gully/landslide scar sites and road deactivation sites respectively. This figure shows that in the absence of improved information, the road deactivation program is the preferred option. Assume now that adaptive management trials have been proposed as a means of generating improved information for the treatment efficiency estimates. The estimated cost of these trials is $20,000. The question is whether or not the potential benefits of improved information outweigh the cost of the trials.

The expected value of information is calculated by adding another branch to the original decision tree for the treatment efficiency trials (Figure 4-11). The new branch leads to an uncertainty node that has four possible results, covering the various combinations of high and low treatment efficiencies for both programs (i.e., High-Gully-L/S & High-Road Deact.; High-Gully-L/S & Low-Road Deact; Low-Gully-L/S & High-Road Deact; and Low-Gully-L/S & Low-Road Deact.). Here, the expected value of sediment delivery/reduction with new information is

[41] Note that this analysis could also be conducted during the Evaluate and Decide step of the planning process.

calculated by assuming the best outcome branch for each possible result, multiplying by the probability associated with that branch, and summing over all four possibilities.[42]

In this case, the expected reduction of sediment delivery if the decision is made after implementing a set of adaptive management experimental trials is 9,750 tonnes, an improvement of 150 tonnes over the expected reduction when the decision is made without the benefit of the information gained through trials. Remembering cost considerations, the road deactivation program yielded an efficiency of $100,000/9,600 tonnes = $10.42 per annual tonne of sediment delivery reduction. For the new option (implementing the road deactivation program *after* the trials) the cost efficiency becomes ($100,000+$20,000)/9,750 tonnes = $12.31 per annual tonne of sediment delivery reduction.

So do the benefits of the trials outweigh the $20,000 investment? The EVSI does not definitively answer the question. But it does provide two important pieces of information that could help managers answer the question: the expected incremental amount of sediment reduction and the change in the cost per tonne of reduction. Managers now need to evaluate whether the incremental sediment reduction (150 tonnes per year on an *expected* basis) is worth the $20,000 up-front cost. Another option is to consider whether a similar expected value of information calculation regarding possible source sediment surveys would be warranted to address the second major uncertainty affecting the decision. Finally, managers may also consider whether there are other options for reducing sediment delivery that can be achieved at less than $12.31 per tonne.

[42] For more information on the calculation of EVSI using decision trees, see Clemen (1991). Here, the focus is on providing a conceptual understanding of how the calculation might be useful in planning and decision making.

Figure 4-10: Simplified Decision Tree

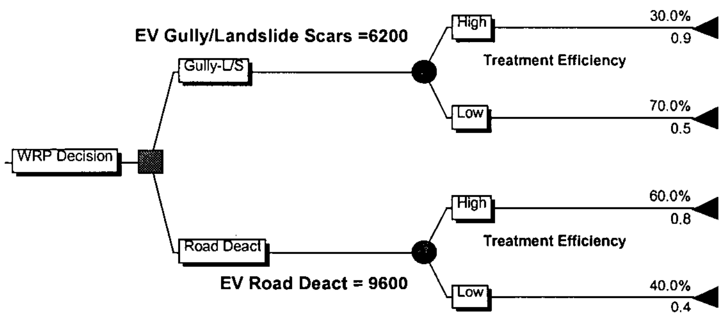
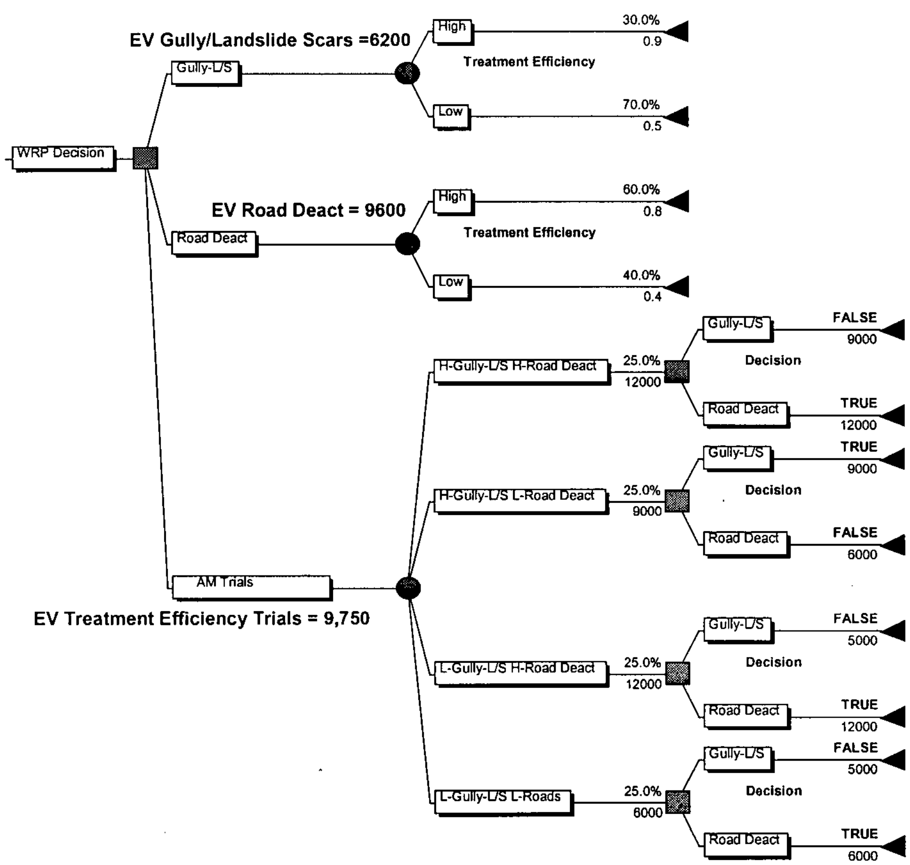


Figure 4-11: Expected Value of Information Calculation



4.3.7 Potential Impact of AM and DA on the Current Status of the Plan

The C/G IWMP was an intense and lengthy planning process staged in a situation with a long history of community grievance, chronic resource shortages and serious and prolonged resource-use conflicts. Committed attempts were made to use good science where possible and to collect improved information to inform the planning and negotiation process – the WRP project being the best example.

At the time of writing, several of the C/G IWMP planning team participants have not agreed to sign the plan and thus commit to its content or implementation. It is impossible to state whether the application of the tools and principles of adaptive management and decision analysis could have overcome all of the challenging aspects of this complex planning process. From the context of the analytical framework developed in this thesis, it appears that the current stalemate over approval of the Plan is caused primarily by a failure of the planning team to apply some of the actions suggested by decision analysis. Specifically, more effort or a different approach was required to better focus on and deal with fundamental objectives and differing stakeholder values. In the particular circumstances of the C/G IWMP, the adoption of a more rigorous approach to adaptive management is unlikely to have contributed much in terms of gaining consensus. AM's likely contribution is in providing a means of improving the quality of management decisions over time. Based on the preceding analysis, the key missed opportunities that might have avoided or alleviated some of the planning process challenges include:

1. Focusing the process with well-structured objectives;
2. Measuring results with decision criteria, both qualitative and quantitative;
3. Creating alternatives that represented a wider range of stakeholder values and focused on fundamental "ends"; and
4. Developing an agreement to learn over time as a means to breaking gridlock caused by uncertain future outcomes.

All this suggests that a more strategic-level plan, rather than a detailed set of implementation guidelines, may have been more appropriate and may have better addressed stakeholder issues. A plan of this type would have more clearly structured efforts around the heart of the negotiations, which very simply centre on the interrelationship between water quality protection and regional economics effects. By focusing efforts at the management guideline level, it was nearly impossible to cope with the more fundamental issue at hand.

Had an approach been applied that incorporated some of the elements suggested by the analytical framework in this thesis, it is conceivable (but far from certain) that the outcome, in terms of gaining consensus on the Plan, would have been different.

Of the tools demonstrated in this section (Examples 1 through 7), the structuring elements (objectives hierarchies, strategy table, multi-attribute evaluation framework) would likely have had the greatest impact. Simple analytical techniques (sensitivity analysis) may have a large potential for use by watershed managers and can be understood by a wide range of stakeholders. However decision trees and expected value of information calculations, which require an intuitive understanding of "expected value" and a rather detailed technical treatment, are less likely to be useful to either stakeholders or managers in IWM processes.

5 Conclusions and Recommendations

5.1 Summary of the Potential Contribution of Adaptive Management and Decision Analysis to Integrated Watershed Management

Integrated watershed management is a challenging soft systems problem. Attempts to manage the three interrelated and overlapping biophysical, socio-economic and institutional systems must address key issues such as reconciling conflicting objectives, managing watersheds as complete ecosystems, and facilitating meaningful stakeholder participation. Moreover, coping with inherent uncertainty and pervasive complexity is an overriding challenge.

Table 5-1 summarizes the potential contribution of AM and DA to the soft systems challenges of IWM. Box 5-1 explains the ratings provided.

In sum, AM and DA offer an overall philosophy and approach, as well as a set of tools that may help to address some, but not all, of the intractable characteristics of IWM.

Adaptive management offers a path to learning. With respect to the soft systems nature and challenges of IWM, it may help to:

- simplify the problem by focusing on key uncertainties;
- improve quality of information over time and hence the understanding of ecosystem function;
- break multi-stakeholder gridlock over controversial facts and assumptions by committing to a program of structured learning and continual adjustment.

Decision analysis offers a structured way to attack complicated problems. It may help to:

- improve understanding of the relationships between objectives, alternatives and consequences;
- increase the transparency of decision making by breaking complex problems into manageable sub-components, structuring information and focusing on key trade-offs;
- break gridlock over facts and values by demonstrating how (if at all) uncertainty affects the ranking of alternatives.

Limitations of AM and DA for resolving the soft systems nature of IWM problems include:

- Cross-boundary impacts and influences remain fundamental issues not directly addressed by AM or DA. They suggest a need for reform of institutional systems.
- The potential for escalation of conflict stems from deeply rooted values and vested interests. These will be only indirectly affected by AM or DA, and suggest a need for an assessment of the tools and techniques of facilitation, mediation, bargaining and negotiation.

Table 5-1: Summary of Potential Contribution to IWM

Soft Systems Characteristic	Adaptive Management	Decision Analysis
Ambiguous Boundaries / Complex Linkages		
Cross-boundary impacts	□	▪
Cross-boundary influences	□	▪
Cross-disciplinary scope	▪	▪
Difficulty with Objectives, Alternatives and Consequences		
Unclear objectives	▪	■
Complicated alternatives	▪	■
Inherent conflict	□	■
Data overload	■	■
Pervasive Uncertainty		
Uncertain ecosystem relationships	■	▪
Uncertain socio-economic relationships	□	■
Evolving institutional and legislative bounds	□	□
Multiple Stakeholder Conflict		
Gridlock over facts and values	■	■
Potential for escalation of conflict	□	□
Lack of transparency in decision making	▪	■

Key: ■ Significant contribution
▪ Some contribution
□ No or limited contribution

Box 5-1 Rationale for Table 5-1 Ratings

Ambiguous Boundaries and Complex Linkages

Cross-boundary impacts: DA can help participants in or observers of a planning process to better understand impacts on other sectors or jurisdictions by reflecting them in decision criteria that report cross boundary impacts. In the C/G IWMP for example, fears over impacts on harvesting quotas in other jurisdictions would be either confirmed or alleviated based on reported data, rather than left as an uncertain impact. Although AM promotes a systems approach, the complexities of cross-boundary impacts and inter-jurisdictional planning and decision making remain largely unaddressed through either AM or DA.

Cross-boundary influences: IWM processes are often plagued by uncertainty about influences that are beyond the jurisdictional authority of managers. DA can help to characterize the impact of uncertain external influences on decision making through scenario analyses. Decision makers can explore and exercise their risk preferences by seeing how (if at all) external influences affect the ranking of alternatives. Nonetheless, DA does not reduce the dependence of IWM processes and outcomes on provincial, national or global political and economic trends.

Cross-disciplinary scope: Through value-focused thinking, DA encourages exploration of creative alternatives that explicitly recognize linkages up and downstream of the watershed. For example, by focusing on the objective of quality of drinking water at the tap, DA might identify a new alternative that included "more logging, more water treatment", and compare this with "less logging, less water treatment". We cannot assume these would be better alternatives. However, DA encourages these linkages to at least be examined. AM encourages the kind of multi-disciplinary teamwork that would facilitate greater collaborative planning/implementation.

Difficulty with Objectives, Alternatives and Consequences

Unclear objectives: Through an emphasis on value-focused thinking (which requires clear articulation of a concise set of objectives) and the use of decision criteria, DA can help enormously in clarifying objectives and using them to create a framework for evaluating alternatives. AM encourages learning objectives to be set and thus helps to institutionalize a process of continual improvement.

Complicated alternatives: The structure of DA facilitates the development and evaluation of complex, interrelated alternatives. DA advocates clearly defining a set of distinct alternatives. These may be combinations of smaller projects, initiatives or standards. The process of structuring and iteratively refining alternatives can be an important element of stakeholder interaction leading toward consensus. AM facilitates the reduction of uncertainty over time by implementing a range of alternatives that test different hypotheses of ecosystem functioning.

Inherent conflict: DA clarifies what the trade-offs are. When only a single decision maker is involved, it also offers tools for making trade-offs (e.g., MATA, etc.). When multiple stakeholders with diverse values are involved, as in IWM, DA can help all stakeholders understand the values of other stakeholders, and to pinpoint where differences are creating conflict.

Box 5-1 Continued...

Data overload: From an ecosystem inventory, modelling and analysis perspective, AM focuses attention on the key uncertainties, management actions and ecosystem responses and therefore minimizes unnecessary or irrelevant data. From a decision making perspective, DA focuses on the use of a handful of decision criteria and helps to structure otherwise complex decisions.

Pervasive Uncertainty

Uncertain ecosystem relationships: AM is designed specifically to reduce uncertainty about functional relationships, and offers considerable potential to do so. DA offers no means of *reducing* uncertainty, but helps to clarify the range of possible outcomes and their potential effect on decisions to be made.

Uncertain socio-economic relationships: Considering socio-economic systems as well, DA helps to clarify the range of possible outcomes and to understand the effect (if any) on the decisions to be made. Although in theory AM could be used to help reduce uncertainties in socio-economic aspects of resource management, it has not been applied for this purpose.

Evolving institutional and legislative bounds: IWM in BC is definitely a victim of this soft systems problem. AM and DA may improve the ability of planners to undertake IWM, but in BC at least, it is not clear through what mechanism IWM planning for community watersheds will occur and / or how it will link to other provincial planning and regulatory initiatives. No amount of AM of DA is likely to resolve this problem.

Multiple Stakeholder Conflict

Gridlock over facts and values: DA can help decision makers to clarify their values and apply them consistently. By focusing on values up-front, and insisting that a range of alternatives be generated and evaluated, it can offer greater potential that creative win-win solutions will be offered. In the C/G for example, DA may have created a wider range of alternatives that reflected a wider range of values, rather than the single alternative that included detailed prescriptions but reflected a relatively narrow range of values. AM can break gridlock over uncertain facts by committing to a program of structured learning and continual adjustment. If stakeholders understand that a program is in place to improve the quality of information and decisions over time, they may be more willing to accept decisions made under uncertainty.

Potential for escalation of conflict: In highly confrontational or politicized situations, quality of data and technical understanding may not be the limiting factors in reaching agreement. In the worst case, some of the tools and approaches of DA and AM may even be viewed as techniques to delay or otherwise cloud the difficult decisions to be made.

Lack of transparency in decision making: By structuring information, providing a clear evaluation framework, and helping decision makers clarify the values of all stakeholders, DA introduces transparency into decision making. In the case of a decision maker with sole decision making authority, DA introduces accountability for incorporating stakeholder values. AM encourages resource managers to state assumptions that underlie choice of management action.

5.2 Conclusions on Specific Aspects of Adaptive Management and Decision Analysis

1. ***The structure provided by a DA approach is likely to have widespread application in IWM.***

   In its simplest form, DA requires four steps: i) set clear, concise and measurable objectives; ii) develop a range of distinct alternatives; iii) clearly show the impact of each alternative against each objective to illustrate tradeoffs; and iv) ask decision makers to clearly state their preferences for different outcomes. It is clear from the C/G case study that this is not always done in IWM.

   Following these simple steps, in whatever level of quantitative or qualitative detail possible will result in a clearer understanding of the potential costs and benefits of alternative courses of action. The degree of quantification may vary according to the availability of existing (or easily obtainable) tools and information, and/or the capacity of stakeholders to absorb complex technical information. DA suggests an emphasis on quantifying impact information. However, the process of structuring the decision, even without quantification, will likely help stakeholders focus on the key trade-offs.

   Even if no further steps are taken after objective-setting, this step alone should help planners focus on key outcomes, stakeholders focus on common interests, and resource managers make rational, consistent, and transparent decisions.

2. ***Simple uncertainty analysis can improve IWM decision-making and guide management activity.***

   Uncertainty analysis can be sophisticated and costly. However, at the most basic level, it involves simply stating ranges of possible values for an uncertain parameter (rather than a single guess at a "most likely" value) and exploring the range of impacts that result. This is well within technical capability of IWM processes and should have a negligible impact on budgets.

   The results of doing this may be significant, including:

   - different decisions could be made because decision makers who are averse to riskier plans (i.e., plans that have a better "most likely" outcome, but significant down-side potential) can become better informed;
   - stakeholders who would otherwise reject an entire analysis because they don't agree with an assumed value may be more comfortable with the analysis and any decision(s) that result;
   - the need for additional data collection may be eliminated (for example, if decision makers are uncomfortable with a decision because it relies on uncertain assumptions about the value of a given variable, sensitivity analysis may show that under a plausible range of values for that variable, which all stakeholders agree to, the decision would not change.);
   - the need for additional data may be highlighted, and decision makers have a basis for allocating additional funds or effort to resolving uncertainty over time; and /or

- the need for more sophisticated analysis may be indicated (usually by the revelation that there are multiple uncertainties which interact in complex ways, that there are significantly conflicting views on the range of or probability of outcomes, or that the uncertainty could affect the ranking of alternatives).

3. ***Specific quantitative DA tools can be useful in clarifying sub-problems, but have relatively limited application.***

   The C/G case study identified several sub-problems for which the use of decision trees, expected value of information calculations, and other tools offer the potential to improve information on which decisions are based. Such tools can require time, money and technical expertise, resources that may not be available in many IWM processes. Further, as illustrated by the C/G case study, detailed evaluation of sub-problems will not salvage a planning process that has failed to set clear objectives and evaluate a range of alternatives against them.

4. ***Setting an explicit learning objective and developing a formal learning plan is an easy and effective way of institutionalizing adaptive management.***

   Many managers are convinced that AM has merit, but either believe they are already doing it (via trial and error learning) or believe they cannot do it (because they don't have expertise in detailed experimental design.)

   In fact, there is a middle ground that involves setting a formal learning objective.[43] By stating that learning is an explicit goal of management, managers are forced to focus on key uncertainties without allowing those uncertainties to handcuff them. It also forces them to think about how to resolve them over time.

   The danger is that managers will use this as a justification for an extensive program of scientific research, generating a lot of data, but not necessarily useful information that will improve management and decision making. To avoid this, the learning objective must be backed up by a formal learning plan that includes:

   - which uncertainty(ies) will be reduced or resolved;
   - what the current hypothesis is (the assumption on which current planning is based);
   - specifically what decisions, management plans or activities are expected to change as result of reducing the uncertainty;
   - which data will be collected and how results will be presented;
   - minimum conditions or criteria for the results to be accepted by all stakeholders as the basis for making changes to management actions.

   Even if formal experimentation (i.e., active adaptive management) is not implemented, the process of defining clear learning objectives will result in more strategic allocation of resources to monitoring and improve the relevance of monitoring to future decision making.

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[43] See McDaniels (1995) for a good example of how a learning objective can be integrated into a multiple objective decision analysis.

5. ***An IWM Plan developed through a multi-stakeholder process will need to develop a formal protocol for incorporating new information into management and planning.***

   Adaptive management suggests that experiments be ongoing and learning be incorporated over time. However, if a planning process has been developed through a multi-stakeholder process requiring stakeholders to make large time commitments and come to tough trade-offs and compromises, it is difficult to suggest that the plan can then be simply changed as new information comes in. What new trade-offs need to be examined as a result of new information? How would stakeholders value those trade-offs? In establishing a formal protocol for how new information will be incorporated, consider:

   - Are there relatively minor adjustments that could be made at the discretion of management as part of on-going operations?
   - Can key triggers or hurdles be identified beyond which management would need to seek new input from stakeholders before modifying previous commitments?

6. ***The active adaptive management process is unlikely to be practical in a majority of IWM processes due to limitations on quantitative modeling capability, the availability of technical expertise, and financial resources.***

   Designing statistically powerful management experiments capable of confidently differentiating between the ecosystem response to various management interventions requires a significant commitment of time, expertise and money. The same may be true in some cases for passive adaptive management since a high level of technical expertise and financial resources may still be required to implement conclusive monitoring programs.

7. ***There are synergies between AM and DA that suggest strategic joint implementation of both may be particularly effective.***

a) DA can provide a strategic framework for AM. For example, DA establishes clear planning objectives and can help identify which uncertainties are significant from a planning and decision making perspective. In this context, an AM program can be established that is focused on delivering information that will be useful in future decision making. Joint implementation will help to avoid two problems encountered in AM experience:

   - lack of support from management because of failure to demonstrate how the AM program will address management priorities;
   - waste of resources in conducting studies that do not provide useful information for management.

b) If experiments are designed to test alternative management actions, then it will be useful to have a clear framework for evaluating experimental results. This can be provided by the use of measurable decision criteria. Decision criteria may affect both the design of the experiment and the interpretation of the results. They become the basic experimental response measurement set. Indeed, Walters (1995), recommends that AM questions be framed as "will policy A do better than policy B in terms of performance measure C?" to avoid expending effort on resolving uncertainties that will not affect policy or management decisions.

c) AM may be a logical next step after application of DA. That is, when DA is applied to analyze uncertainty, it often confirms that an uncertainty, within plausible ranges, does not affect the decision to be made. But what if it does? What if the uncertain parameter or relationship is a key driver of the ranking of alternatives? By applying both DA and AM, planners can work logically and thoroughly through uncertainties by:

- screening out non-critical uncertainties;
- defining hypotheses for critical uncertainties;
- designing experiments to test hypotheses; and
- answering the question, how much should be spent getting better information?

d) AM may involve risks to fundamental objectives in order to improve learning. These are not risks that should be judged by scientists alone. DA provides a framework for allowing multiple stakeholders to consider risks associated with experimentation and make explicit trade-offs between what may be gained through increased learning and what may be lost as a result of experimental impacts.

8. Decision analysis must be designed as a complement to, not a replacement for, facilitation, mediation, bargaining and negotiation.

Decision modeling techniques (e.g., MATA, etc.) can be used to find an optimal solution in situations where there is only one decision maker or when decision makers share similar values. It can inform decision makers about the preferences of stakeholders. However, it offers little guidance on how to proceed when different stakeholders or decision makers hold fundamentally different values.

As a result, facilitation, mediation, bargaining and negotiation will remain fundamentally important in IWM planning processes. Although these tools cannot resolve fundamental value differences or rights disputes, they can contribute to positive outcomes by building mutual respect, minimizing the escalation of conflict, finding practical (if not optimal) solutions, and facilitating participatory decision making. DA should be used to support principled negotiations by providing clear information on the impacts of proposed strategies with respect to agreed-upon fundamental ends – including information about uncertainties and their potential impact.

5.3 Recommendations for Integrated Watershed Management Planning for Community Watersheds in British Columbia

The legislative and planning framework for IWM in British Columbia, and for IWM in community watersheds in particular, is in a state of flux. Although there are no immediate plans to develop a new framework, it appears likely that renewal in some form may be on the horizon. If changes are made, the following are suggested by this research.

1. ***The renewed community watershed IWM planning process should be designed primarily to address strategic issues.***

   In the current situation, strategic-level issues for community watersheds are supposedly addressed within higher level plans such as provincial Land and Resource Management Plans (LRMP). Unfortunately however, LRMP processes are not yet completed across the entire province, and are at too coarse a scale to offer useful guidance to any given community watershed that falls under its jurisdiction. On the other hand, the community watershed guidebook of the FPC overlooks strategic level issues and jumps directly into operational level planning. In short, planning for strategic issues within community watersheds in B.C. is falling through the cracks.

   Any new planning process for community watersheds should remain at the local planning level within the broader provincial land use planning framework (Table 4-1). However, unlike the current IWMP process, which over time has evolved toward an operational focus, the new process should instead incorporate elements more commonly associated with the strategic level of planning.

2. ***The renewed community watershed IWM planning processes should be given a mandate to address a wider range of alternatives, including water treatment options, as a means of achieving optimal solutions.***

   The complexity of fully integrating the engineering side of community water supply planning into the land-based watershed management planning process is likely not feasible. Nonetheless, water purveyors should be encouraged to bring water supply planning expertise and options to the table as a means of more fully considering the fundamental objective, which is clean water at the tap.

3. ***Guidelines for multi-attribute evaluation should be developed and issued as guidance for the process.***

   The use of multi-attribute evaluation frameworks are common to many planning processes in B.C. For example the B.C. Crown Corporations Secretariat (1993) have developed "Multiple Account Evaluation Guidelines" to guide the development of all major plans and projects by B.C. Crown corporations. Similarly, the provincial LRMP process incorporates a multiple account procedure into their social and economic impact assessment guidelines (Province of B.C., 1993). Most recently, the Province's Water Use Plan Guidelines (which govern the process for relicensing water control facilities) were issued in December 1998 and require setting objectives, using performance measures, developing alternatives, conducting a trade-off analysis and demonstrating the effect of uncertainty on trade-offs (Province of B.C., 1998).

These examples point to a growing trend toward the use and acceptance of multi-attribute evaluation frameworks to guide planning processes in B.C., and offer a foundation upon which to develop guidelines specific to the needs of community watershed IWM planning processes.

The IWM guidelines should at minimum, require the development of measurable objectives and a range of alternatives, and the use of decision criteria (or performance measures) to report the performance of each alternative on each objective.

4. ***The renewed community watershed IWM planning processes should direct the development of an explicit learning plan.***

   It is unrealistic to expect that each individual community watershed IWM planning process will have the resources or need to undertake full-scale adaptive management. Nonetheless, the adaptive management principle of structured learning over time is universally applicable, and can be captured by directing planning teams to develop explicit learning plans as part of their efforts (see conclusion 4, Section 5.2).

5. ***The active adaptive management process should be utilized for problems of provincial significance.***

   Designing and implementing powerful adaptive management experiments and monitoring programs is a costly and time consuming endeavour. Nonetheless there are circumstances where the effort is justified. One example of this situation is evident in the Chapman/Gray case study. Effort is currently being undertaken to better understand the sources of organics, and their role as precursors within treated surface water supply system. The C/G IWM team (and others like them) likely don't have the resources to do a comprehensive AM program. However if the results of a study or experiment could help to understand processes at many watersheds throughout BC, it may be a candidate for Provincial support and coordination.

   Criteria for Provincial support for comprehensive AM experimentation should include:

   - Over the range of values considered plausible for the uncertain variable, is the choice of management action sensitive to the uncertainty?
   - Are stakeholders or decision makers prepared to support a change in management action on the basis of the information to be generated?
   - Is the new information to be gained likely transferable to other IWM or similar planning processes?

6. ***The process should be supported by a neutral facilitator.***

The potential for escalation of conflict and the complexity of issues to be addressed in most community watershed IWM processes are too great to have a member of the planning team appointed as chair or facilitator of the process. In most cases it will be essential to have a professional facilitator involved, at least at critical stages of the process. The facilitator should have the following skill set and knowledge base:

- multi-stakeholder facilitation;
- participatory decision making and consensus-building;
- negotiation, mediation and conflict resolution;
- experience in integrated resource management planning processes; and
- familiarity with the principles and tools of adaptive management and decision analysis, particularly as to how they can support the consensus-building process.

5.4 Recommendations for Further Study

The research focus of this thesis has been on the fields of adaptive management and decision analysis. Many aspects of these fields overlap to some extent with other fields and/or could be complemented with other fields. Three areas of further research stand out.

1. ***Explore the roles of mediation, negotiation and bargaining and the interaction between decision analysis and collaboration theory.***

One of the conclusions of this thesis is that in an IWM process, decision analysis can be a complement to, not a replacement for, stakeholder negotiations. This opens the door to consideration of how the analytical framework developed for this thesis could be strengthened through formal integration with the fields of bargaining, negotiation and collaboration theory.

Two of the key references used in this thesis provide a starting point toward this research. Keeney's *Value-Focused Thinking: A Path to Creative Decisionmaking* (1992) has several sections devoted to the linkages between decision analysis and negotiation processes. Similarly, Lee's *Compass and Gyroscope: Integrating Science and Politics for the Environment* (1993) emphasizes how the art of negotiation and conflict resolution can pragmatically bound and advance the institutional aspects of complex environmental management problems.

In addition to these, two references that serve to describe specific work that has already gone on in this area include:

- Maguire and Boiney (1994) develop a framework that interweaves the qualitative techniques for conflict resolution with the quantitative analyses of decision analysis. In their work, they show how relatively minor compromises on the part of one or more interest groups may lead them to recommend the same action, thereby resolving a conflict.

- Keeney and Raiffa (1991) describe how the preparation for multi-issue negotiations can be greatly improved through systematic introspection using the various decision analysis tools discussed in this thesis.

2. ***Explore the linkages between institutional learning and adaptive management***

This thesis has mentioned but not elaborated on the institutional challenges associated with adaptive management. Recent literature emphasizes that these may be the key barriers to its implementation, and/or that AM may in fact be a tool for enhancing institutional effectiveness.

For example, Lee (1993) discusses institutional conditions for success in applying an adaptive management approach. He highlights the social dynamics and institutional rigidities that complicate the adaptive management approach. This may be linked with the literature on "learning organizations" to better understand barriers and opportunities.

The best starting point the exploration of the linkages between institutional learning and adaptive management is in the book *Barriers and Bridges to the Renewal of Ecosystems and Institutions* by Gunderson et al. (1995). This work sets out to simultaneously answer two interrelated questions: Do institutions learn?; and, How do ecosystems respond to management actions? Drawing heavily on both the ecological and social sciences, the book examines a common pattern of pathology in managed ecosystems, whereby resource exploitation leads to ecological, social, and institutional breakdown, followed by crisis and, in some examples, reform and learning.

3. ***Explore the linkages to Ecological Risk Assessment***

Ecological risk assessments (ERA) are quickly becoming a popular approach to support policymakers with complex problems involving ecological risks. The *Guidelines for Ecological Risk Assessment* developed by the United States Environmental Protection Agency (1998) are rapidly becoming accepted as the seminal work in the field. The guidelines are being used by many agencies in order to provide i) a quantitative basis for comparing ecological risks, and ii) a systematic means of improving the estimation and understanding of those risks. Ecological risk assessments are structured to provide information concerning "assessment endpoints" and "measures of effect" that are what policymakers or the public care about. This is analogous to the discussion of fundamental objectives and decision criteria as described in this thesis, suggesting that there are parallels between the two approaches.

Interestingly, integrated watershed management is one of the focus areas of the USEPA in attempting to promote their ERA approach (USEPA, 1999). This is because ERA offers a framework for bounding complex regional-scale ecosystem management problems, and it offers a much needed avenue toward the quantification of non-financial objectives.

Two potential weakness areas in the ERA approach could serve as a focal point for research exploring the possible linkages with decision analysis and adaptive management:

- ERAs are limited to a focus on ecological endpoints. Most ecosystem management problems however must also balance financial, recreation, aesthetic or other objectives as well. Applying the DA approach as developed in this thesis could help to expand the applicability of ERA to IWM.

- By definition, an ERA has a focus on *assessment* (i.e., what is the problem), leaving aside the bigger – and likely more difficult – questions of *management* (i.e., what can be done about it). Adaptive management as discussed in this thesis is specifically designed to move forward with management in an ecologically responsible manner.

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Appendix A: A Summary of Techniques for the Treatment of Uncertainty

(adapted from Morgan et al. 1984)

The treatment of uncertainty can be performed with greater or lesser degrees of analytical rigour depending on both the nature and the magnitude of the uncertainty itself (Morgan et al., 1984). The following table characterizes the options available for the treatment of uncertainty across a continuum based on the nature and magnitude of the uncertainty.

Technique	Description
Deterministic	When uncertainty is small and functional relationships among the variables are well known, single value point estimates representing the best estimate of the value of the variables can be used.
Value Ranges	A range of values (usually high, medium and low) are assumed for an uncertain variable. Outcomes are calculated for each value assigned in the range. If the outcomes are not substantially different from the outcome calculated using the average, then the average can be substituted for that variable and a deterministic approach adopted. If the outcome is substantially different, more rigorous analysis of the variable may be warranted.
Constructed Scenarios	Value ranges are used for several variables simultaneously. Assumptions about value ranges are based on plausible scenarios of how one variable varies with respect to another. This approach can be useful for testing best and worst case scenarios.
Point Probabilities	If sufficient data on the variable exist, a probability for the likelihood of the assumed value occurring can be developed using classical statistical techniques. If no or insufficient data exist, subjective expert judgements can be used in a Bayesian approach. Calculations can then be made of the "expected value" of each outcome based on the assigned probability.
Continuous Probability Distributions	Continuous probability distributions replace point probabilities across the range of uncertainty, using either a classical or Bayesian statistical approach. Continuous probability distributions are normally developed through a structured framework of elicitation (e.g. see Morgan and Henrion, 1989). Probability distributions provide statistically valid information about the mean value of the variable and its standard deviation, which can be used to calculate outcomes.
Combined Probability Modelling	This sophisticated approach is applicable only to complex situations where several uncertain variables require simultaneous treatment. In this case, the probabilistic mean values and standard deviations for each variable are statistically combined using a "Monte Carlo" simulation modelling technique that develops an estimated mean value for the overall outcome.
Bounding Analysis	When uncertainty becomes too large or too complicated for reasonable analysis, the best approach is to perform order-of-magnitude bounding analysis (Morgan et al., 1984). This approach does not produce "answers", but rather estimate bounds on the range of possible answers.

Appendix B A Summary of Preference Assessment and Tradeoff Techniques for Decision Making

There are a number of qualitative and quantitative approaches to identifying decision makers' preferences and thus making tradeoffs. The following table lists some of the more common techniques roughly in order of increasing rigour and complexity.

Technique	Description
Overview Assessment	Decision makers' preferences are not identified explicitly or systematically, thus tradeoffs are made implicitly. Alternatives are ranked based on an overview assessment of the structured objectives and alternatives alone.
Goal Setting	This approach is common in engineering and similar technical management decision situations. Goals, which are often based on performance standards and/or constraints, are used to establish fixed criteria upon which to evaluate the alternatives. Preferences are thus based more upon "technical" efficiency than on value judgments.
Weighted Averaging	Preferences of decision makers' are initially identified through relative weights applied to the stated objectives. The consequences of each alternative on each objective are then assigned relative rates, usually based on technical or expert estimates. An additive function is then used to derive a "score" upon which the alternatives can be ranked (e.g. Ax + By + Cz = Score).
Swing Weighting (Simplified Multi-Attribute Rating Technique)	This approach begins by specifying the plausible range (from "most" to "least" desirable) of each consequence for each objective. Decision makers' then rank the importance of objectives by indicating which objective they would move from its least to most desirable state first. The highest ranked objective receives a weight of 100 (or some other number representing the top of the scale) and other objectives are weighted as a percentage of this highest objective. The plausible ranges are further developed into unitless "single attribute utility functions". Finally each alternative is rated along the utility functions and combined with the swing weights to obtain a final utility score.
Multi-Attribute Utility Technique	With the help of a skilled decision analyst, decision-makers explicitly state how much of one objective they are willing to trade off for a specified change in another competing objective, and the results are modelled as continuous utility functions. This is done across the range of objectives, and the results are developed into a "multi-attribute utility function" that is used to calculate the utility of each alternative under consideration.