MULTIPLE ACCOUNT EVALUATION OF AN URBAN LAKE REHABILITATION AND MANAGEMENT PROPOSAL: A CASE STUDY OF DEER LAKE, B.C

by

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B.A SIMON FRASER UNIVERSITY, 1990

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF

THE REQUIREMENTS FOR THE DEGREE OF MASTERS OF ARTS

IN

THE FACULTY OF GRADUATE STUDIES

(The School of Community and Regional planning)

We accept this thesis as conforming

to the required standard

THE UNIVERSITY OF BRITISH COLUMBIA

AUGUST 1996

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Date April 29/96.

DE-6 (2/88)

ABSTRACT

Lakes in Canada's rapidly growing urban areas have reached a critical state, and decisions about the best way to protect, manage, and rehabilitate urban lakes are a planning priority. Lakes are important parts of the urban landscape that have provided local communities with a wide variety of recreational opportunities. Deer Lake is an eighty-six acre lake located in the central portion of the City of Burnaby, British Columbia. The relatively small shallow lake has provided swimming and fishing opportunities for local residents since the 1950s. For the past forty years, the aesthetic qualities of Deer Lake have progressively deteriorated to the point where aquatic, and terrestrial recreational activities are being compromised. Burnaby's urban planners have been asked to maintain the aesthetic and biological integrity of Deer Lake. At the same time, the planners are asked to accommodate the recreational needs of a growing urban population. The Deer Lake Restoration and Management Committee have relied on scientists and engineers to find the best technological alternative to restore the lake's water quality to some pre-urban condition. Despite numerous scientific reports, city planners, and politicians are undecided on a preferred technological water treatment alternative for Deer Lake. Controversial and complex environmental issues, high costs, technological uncertainty, and differences in stakeholder values have stalemated the decision making process.

The current Deer Lake planning process lacks an organizational structure that can incorporate different stakeholder values and represent complex information in a clear and understandable way. Value-focused thinking and multiple account analysis offers urban lake planners an integrated planning framework that can accommodate many of the complexities involved in planning for the restoration and management of urban lakes. Multiple account analysis assumes that economic, social and environmental objectives should be explicitly considered in the decision making process. The crucial first step in a multiple account evaluation is to develop and articulate a set of objectives that can then be used to create a set of plausible alternatives.

The purpose of this thesis is to conduct a policy analysis for Deer Lake restoration alternatives. The thesis employs the principles of "Value Focused Thinking" to identify, and structure the objectives of the Deer Lake Restoration Committee. Value-based objectives are used to develop a set of alternatives. The impacts of the selected lake restoration and management alternatives are assessed using a multiple account analysis.

First, the problem is described, and structured with all aspects of the decision that merit consideration. Next the process assesses the impacts of the alternatives being considered by combining the best scientific, technical, environmental, and financial information that is available. This information is used to assess how well the selected alternatives achieve the desired objectives.

The Deer Lake case study illustrates the benefits of using value-focused thinking and multiple account analysis as a comprehensive decision making framework for urban lake restoration projects. One new alternative has been created as a result of this process, and the impacts of all the proposed alternatives have been measured with respect to the stated objectives. On the basis of available information, this analysis predicts the probability of achieving the desired water quality standards over the short term and long term. Perhaps the greatest analytical strength of applying this combined approach to the Deer Lake issue is the ability to simplify complex information, and at the same time retain enough detail to support the decision making process. Intangible social and environmental aspects of the decision are explicitly incorporated. In the end, a compact, complete statement of objectives and alternatives is derived from this information, which in turn provides a platform for good communication and constructive stakeholder negotiation.

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CHAPTER ONE

INTRODUCTION

Lakes in Canada's rapidly growing urban areas have reached a critical state, and decisions about the best way to protect, manage, and rehabilitate urban lakes are a planning priority. Canada has the largest inventory of fresh water lakes in the world, and the vast majority of them have not been seriously threatened by non-point source agricultural and urban pollution. In the more heavily populated southern urban areas, lakes have suffered the negative impacts of increased levels of suspended solids, nutrients, and toxic chemicals from storm water discharge (Cooke 1993).

Along with accommodating diverse recreational opportunities, urban lakes and their watersheds provide habitat for a variety of fish and wildlife. Lakes help control storm water run-off and act as a bio-filter for chemical and bacterial contaminants contained in urban run-off. Today's city planners are challenged to provide local recreation opportunities, while at the same time conserve and protect urban lakes and their watersheds. Accelerated population growth in many urban areas has increased the demand for local fresh water recreational opportunities. Urban growth and increased day to day human activity within watersheds has contributed to the near destruction of many urban lakes. Decision makers are asked to provide opportunities for increasing residential and commercial densities, and at the same time politicians and planners are expected to anticipate, and prevent environmental problems associated with accelerating urban growth. Limits on public spending have greatly restricted the ability of local governments to meet these two challenges.

Historically, decision makers have consulted with scientists and engineers to find the best technological alternative to improve the quality of water in urban lakes. In this approach experts are defacto decision makers, and impacts of the proposed alternatives are often viewed in terms of only the physical sciences. This emphasis is unbalanced. Technical analysis is, of course, essential for understanding the important effects of a regulatory action. However, the importance of various effects is itself a value judgment (Dryzek 1987).

Point source, and non point source pollution control technologies for lake management and restoration, are still relatively new, and have a number of drawbacks associated with them. Unwanted side effects, questionable performance, and poorly defined costs, are a few of the uncertainties that decision makers have found hard to reconcile in deciding the most appropriate technological alternative (Cooke 1993). Professional biases of experts, and differences in stakeholder values regarding these uncertainties, often result in disagreements about which management alternative is the best. This leads to value based disputes about future consequences, which impairs decision making. A more balanced approach would consider these differences in values, and concerns about future consequences as the aspects of decision making (Keeney 1992).

"Value focused thinking essentially consists of two activities: first deciding what you want and figuring out how to get it" (Keeney 1992, 4). This is accomplished by first identifying a set of value based objectives, systematically structuring these objectives, and then specifying a set of attributes to measure the degree to which each alternative course of action achieves the stated objectives. Structuring a set of objectives is the first step in this multiple account evaluation process. Objectives such as minimizing environmental impact or minimizing costs are the type of evaluation accounts that are employed to judge the most suitable alternative. "Multiple account analysis entails the systematic documentation and assessment of the financial, environmental and other relevant implications of alternative plans and projects in order to determine the advantages and disadvantages they entail" (Crown Corporations Secretariat 1993, 8).

A combined approach of value focused thinking and multiple account analysis provides a systematic procedure that can assist decision makers in making choices in the presence of uncertainty, risks, and conflicting objectives. This is a decision making approach that can orderly identify and evaluate the impacts of alternative actions. The complicated nature of lake restoration and management decisions, makes them useful case studies for the application of value-focused thinking, (VFT) and multiple account analysis (MAA).

Deer Lake, located in the center of the City of Burnaby British Columbia, suffers from polluted urban storm water discharge. As part of Burnaby's natural heritage, Deer Lake is a valued community resource that has reached a critical point in its ecological health. The City of Burnaby is currently trying to find the best way to reverse the damage done by questionable land use practices in the Deer Lake watershed.

In his 1991 master's thesis John Kirbyson (a director with the Burnaby Parks and Recreation Department) undertook a cost benefit analysis of the Deer Lake Restoration and Management proposal. In his final recommendations, Mr. Kirbyson suggested the need for a "comprehensive decision-making framework" to assist the City in reaching a final consensus on how to best continue with the project (Kirbyson 1991).

1.1 Purpose

Experience has shown that one of the most difficult problems in the formulation of public policy is the translation of values held by various sectors of the public into successful choices between possible alternatives. This is exactly the problem that Mr. Kirbyson and other members of the Deer lake Restoration Committee have referred to as a stumbling block in the formation of a restoration and management strategy for Deer Lake.

> "Values are what we care about. As such, values should be the driving force for our decision making. They should be the basis for the time and effort we spend thinking about decisions. But this is not the way it is. It is not even close to the way it is. Instead, decision making usually focuses on the choice among alternatives. Indeed, it is common to characterize a decision problem by the alternatives available. It seems as if the alternatives present themselves and the decision problem begins when at least two alternatives have appeared. Descriptively, I think this represents almost all decision situations. Prescriptively, it should be possible to do much better"(Keeney 1992, 3).

The purpose of this thesis is to apply aspects of value focused thinking, and multiple account evaluation as a basis for a comprehensive decision making framework for the planned restoration and management of Deer Lake. The current Deer Lake restoration proposal involves the application of two uncertain and potentially risky restoration technologies. By explicitly focusing on stakeholder values, and incorporating existing case study information within a MAA framework, a more informed and thus justifiable decision regarding the rehabilitation of Deer Lake can be made.

The objectives of this thesis are to:

1) explicitly articulate objectives for the Deer Lake Restoration decision;

2) use VFT to structure these objectives in a clear and logical manner;

3) develop new and possibly better alternatives;

4) using MAA measure the impacts of each selected restoration and management alternative in terms of the stated objectives;

5) based on existing information, try to determine the best alternative.

1.2 SCOPE

The Deer Lake restoration initiative and decision making process has been going on for a number of years with no final resolution in sight. Focusing on values within a MAA framework will help the City of Burnaby recognize and define the decision problems. This should help the Deer Lake Restoration Committee **(the committee)** to move forward with their decision making process. The scope of the thesis includes the identification of the committees fundamental objectives. The emphasis is on structuring the decision such that the committee can consider the current alternatives in terms of their stated objectives. This should help in broadening the decision, and as such provide a means of developing better alternatives.

The City of Burnaby has commissioned numerous technical and scientific studies addressing lake management and restoration issues. Within the framework of a MAA the impacts of different alternatives are assessed using this existing information.

1.3 ORGANIZATION OF THE THESIS

This thesis consists of seven chapters. Following the introduction in chapter one, chapter two starts with a discussion of urban lake planning issues. This includes a summary of some of the problems associated with past and current planning processes. Chapter two also introduces VFT and MAA as a comprehensive decision making tool for urban lake planning, and includes sections on the theory and methodology of both VFT and MAA. Chapter three begins the case study by defining the problem and providing a decision context. This chapter also includes a description of the research undertaken to identify the objectives of the committee. In chapter four, the decision is structured with the fundamental objectives of the committee. These fundamental objectives are organized hierarchically, and graphically represented as a common value tree. The value tree delineates the relationship between value

statements at the bottom of the tree (or trunk), with the measurable attributes at the top (or twigs) of the decision tree. The fifth chapter defines the alternatives that are currently being considered by the City of Burnaby, and introduces one new alternative. Using existing information, chapter six models the impacts of three alternatives. Chapter seven provides a summary of the decision making process thus far, with some conclusions and recommendations. The last section of chapter seven, presents an appraisal of VFT and MAA as it pertains to this case study.

CHAPTER TWO

VALUE FOCUSED THINKING AND MULTIPLE ACCOUNT ANALYSIS: A FRAMEWORK FOR URBAN LAKE PLANNING DECISIONS

Chapter two is divided into two major sections. Included in section one is a general discussion of lakes and their value to urban populations. This is followed by a historical perspective on how urban planners, have addressed issues of lake restoration and management. The final part of section 2.1 offers some insights into the complexity of urban lake planning, concluding with seven recommendations on how to improve the current planning process. Section 2.2 briefly describes the theory and methodology of VFT used for the case study of Deer Lake and the method used in this thesis.

2.1 Planning For Urban Lakes

Lakes are large bodies of standing water that occupy natural or man made basins. Water enters a lake as precipitation, surface run-off, and ground water seepage. The ecology of lakes is dominated by events in the watershed. Streams and creeks deposit sediments, fertilizers, and pesticides from farms, residential areas, and forests. The general chemical and biological health of a lake are a reflection of the environmental health of its watershed. "Lakes seem, on the scale of years of human life spans, permanent features of the landscape, but they are geologically transitory, usually born of catastrophes, to mature and die quietly and imperceptibly" (Cooke 1993, 1). In densely populated urban areas, lakes are often overwhelmed by the concentrated activities of people. An urban lake differs from other lakes by use only. Reeve has defined an urban lake as one that lies within the "municipal boundaries of an urban area ... irrespective of how much development has taken place in the watershed" (Reeve 1987, 11).

Lakes are important parts of the urban landscape. Historically lakes have provided a source of potable water and are valued for the recreational opportunities that they offer to an urban community. Humans use this resource for irrigation, power, drinking water, and often rely on lakes as a source of food. Swimming, fishing, hiking, canoeing, picnicking and nature viewings are a few of the many

recreational activities that take place on and around lakes. As receptacles and retention basins for urban storm water discharge, lakes act as a natural flood control mechanism and provide biological controls for pollutants in the air and water. Chemical and photosynthetic processes in a lake can neutralize toxic chemicals, as well as bacterial and viral pollutants found in storm water discharge. As conservation areas, lakes are important to the ecological and spiritual health of an urban community. A range of aquatic and terrestrial ecosystems provides habitat for a diverse number of valued plants and for unique varieties of birds, insects and terrestrial as well as aquatic invertebrates. Aesthetically lakes are valued for their passive visual qualities. Looking at, or being close to a clean and healthy lake can be a "morally uplifting" experience (Reeve 1987, 12). Lakes offer a contrast to the stark urban landscape, providing a local escape for people seeking the comfort of more open spaces. These values are underscored by the "promise that whatever it is that people have enjoyed in these natural features will be available to their children and their children's generations" (Lant 1991, 459).

A current challenge for urban lake planners is to maintain the aesthetic and biological integrity of a lake, while at the same time meeting the demands for increased urban densities within the watershed. There is often a cause and effect relationship between development, and the degradation of natural aquatic systems. Decision makers are asked to consider the tradeoffs between increased development and improving or maintaining natural systems.

With maintaining the natural character of a lake, "the most obvious and persistent, and pervasive water quality problem is that of eutrophication" (Cooke 1993, 2). Through a series of positive feedback loops, water quality and lake aesthetics, are degraded as a result of multipurpose activities that go on within the watershed. As an example, eutrophication is the natural process of nutrient enrichment that causes high productivity of biomass in an aquatic ecosystem (Cooke 1993). When this process is accelerated by human activity it is refered to as cultural eutrophication. Without control measures cultural eutrophication proceeds much faster than the natural phenomenon. The main source of nutrient enrichment comes from the extensive application of phosphorous and nitrogen based fertilizers in the watershed. Over-fertilization stimulates algal and macrophyte growth in the receiving waters of a storm

sewer system. Water plant populations increase, taking advantage of surplus nutrients stored in lake sediments. These surplus fertilizers stimulate the increased growth of macrophytes which in turn, at an increasing rate, recycle more of the surplus phosphorus into the lake, which ultimately encourages more unwanted algal blooms. This is a type of positive feedback loop that is a common problem for lakes which have high inputs of nutrients. As a result of this process, lakes become unattractive for bathing, boating and other water oriented recreation.

Accelerated sedimentation and the rapid unnatural in-filling of lakes are other symptoms of urbanization. Hard impervious surfaces in urban areas have replaced the porous natural surfaces of meadows and forests. The use of asphalt, concrete and roofing materials within the watershed has contributed to a general increase in the velocity of storm water discharge. Faster flowing creeks and streams have encouraged the rapid erosion of their banks, which in turn dramatically increases the amount of suspended solids that reach urban lakes.

Human activities within a watershed contribute to the deposition and accumulation of potentially toxic pollutants on roads, lawns, and parking lots. Toxic chemicals from non-point sources of pollution washed into the storm water system during major storm events ultimately drain into lakes or other receiving bodies. Some common contaminates in untreated urban storm water include: pesticides; lead; zinc; mercury; oil; biological wastes; fecal bacteria; and viruses. Point source pollution from industrial areas and leaking sanitary sewer connections also contribute to the pollution of natural waters. The US Environmental Protection Agency (EPA) estimates that 2 million ha (5 million acres) of lakes and reservoirs in the US are threatened or impaired by toxins and by point and non-point sources of nutrients, silt and organic matter (Cooke 1993, 2, 6).

Lake problems associated with cultural eutrophication and point sources or non-point source pollution have been addressed by lake managers as issues of lake restoration and management. In the literature there is a distinction made between these two terms. Cooke et al., define restoration as "any

active attempt to return an ecosystem to an earlier condition following degradation resulting from any kind of disturbance"(Cooke 1993, 9).

> "Restoration involves repair of ecological damage, a return of species and processes to their former states, and is holistic in its approach to returning the lake and its watershed (including surrounding wetlands) to an approximation of pre-disturbance conditions. Management involves an attempt to remedy, or improve, or change conditions, usually of some specific lake component, often with human use in mind. Management is not necessarily involved in returning the lake or reservoir to some earlier, or pre-disturbance conditions but is directed towards amelioration of one or more specific problems" (Cooke, et al 1993 p.9).

A common first step in the urban lake planning is to identify potential or existing water quality problems. Following, is a search for alternatives that can effectively, and efficiently address the water quality issues. The third step in the process is to gather enough relevant scientific and technical information to support the decision making process. The emphasis is on finding the best scientific or technological solution. Technical experts commissioned to do the scientific or technical analysis present their findings and advise the decision makers as to the best restoration or management alternative. Due to the complexity and voluminous nature of the technical and scientific reports, experts in many respects become the decision makers. As a result, stakeholders with a legitimate interest in the decision are left out of the process. Exclusion from the decision making process can lead to post decision stakeholder disagreements over the legitimacy of scientific information. Ethical concerns about the final decision result in battles over the content and procedural methodology of the urban lake planning process (Gregory and Keeney 1992).

More open urban lake planning processes include the interests of relevant stakeholders from both the public and private sector. Involving stakeholders helps to avoid confrontation. Authoritative decisions behind closed doors are becoming an increasingly unpopular approach for planners tasked with decisions of public interest. The incorporation of conflict resolution techniques, and including relevant stakeholders in the planning process, are two important improvements to the traditional approach to urban lake planning (Reeve 1987).

Greater emphasis is now placed on consensus-based decision making, which has brought its set of problems to the already complex planning process. Understanding scientific reports, and technologically novel and imprecise restoration alternatives, provides a formidable challenge to urban lake planners. Compounding this challenge is the inclusion of different stakeholder groups who often interpret information with a slant that suits their self interest. Stakeholder involvement has meant that post project adversarial interaction, has been replaced with in-process stakeholder disagreements (Andrews 1992). Current public processes often lack an organizational structure that can incorporate different stakeholder values and represent complex information in a clear and understandable way (Keeney 1992).

Finding creative solutions to controversial complex problems with uncertain consequences is a major challenge for urban lake planners. The more complex the problem is, the more difficult it is to come up with a decision that acknowledges the values of the stakeholders interested in the decision. Good science is fundamental to effective urban lake planning. However, scientific and technical information is often presented in a format which planners and stakeholders find hard to understand. Decisions regarding important environmental issues are stalemated because of disagreements about facts, yet these positional disagreements are often a result of fundamental differences in stakeholder values. Controversy, "adversarial interactions and win-lose outcomes encourage the use of information as a weapon rather than as a tool, and cause stakeholders to posture from extreme positions rather than look for mutually beneficial middle ground" (Andrews 1992, 185,186).

Uncertain consequences with substantial environmental risk can fuel the positional debate between poorly informed adversarial stakeholders. Two kinds of uncertainty contribute to, and amplify the debate. Accurately predicting the reaction of a natural system in response to a proposed course of action requires enough data to accurately model the outcome. "Event based uncertainty" refers to the lack of such data. Making judgments with incomplete data sets often leads to an erroneous understanding of how complex feedback mechanisms in natural systems will behave if disrupted. "Knowledge based uncertainty" refers to the incomplete expert understanding of how these natural systems will work when put under stress.

Experts asked to evaluate scientific data often disagree on the interpretation of the information and the probable range of impacts expected from a proposed action (Gregory 1992).

Controversial and complex environmental issues, positional stakeholder disagreement, combined with event based and knowledge based uncertainty often result in the delay of the decision making process. The dynamic of a natural system defies the complete understanding of how an ecosystem will respond if disturbed. This kind of event based uncertainty stimulates the search for more information, and more studies often lead to more confusion and further delays in the planning process. The development of a complex interactive planning process that supports the input from a variety of stakeholders has made some positive contributions to understanding problems associated with urban lake planning. However, what appears to be missing as part of the planning process is an open, and logical decision making framework that can:

1) **accommodate the competing interests of different stakeholders groups;**

2) **create new and better alternatives;**

3) **represent complexity in a simple and meaningful way;**

4) **distinguish facts from values;**

5) **represent uncertainty in a simple yet straight forward manner;**

6) **measure the impacts of each alternative in terms of the desired objectives;**

7) **through good communication facilitate negotiation, and ultimately consensus on a preferred planning strategy.**

As a planning tool, the combination of VFT and MAA offer a decision making strategy that can help stakeholders overcome these barriers. It is a framework that can deal with controversy by incorporating all the concerns of interested parties. Considering expert judgment and available data, uncertainty is dealt with by explicitly representing the probable impact of a proposed action. Both subjective and objective assessments are accommodated in this combined decision making framework. The analytical strength in VFT and MAA is the ability to simplify complex issues and communicate at a level that lay persons can understand.

2.2 THE THEORY AND METHODOLOGY OF VALUE FOCUSED THINKING AND MULTIPLE ACCOUNT ANALYSIS:

2.2.1 The Theory of Multiple Accounts Analysis

Principles, policies and standards for MAA were first developed in 1969 by the U.S. Water Resources Council. This multi-objective decision making framework for water resource and land use planning was officially adopted by the U.S. Water Resource Council in 1973. "The multiple accounts method is based on the assumption that economic, social and environmental factors should be given equal consideration in project evaluation" (Gunton 1991,Vol. 2, 3). In Canada, MAA has been used by a number of different government agencies, including the Canadian Department of Fisheries and Oceans in 1985 and British Columbia Hydro in 1976. "MAA incorporates cost-benefit analysis and supplements it with a multiple account framework to display and compare the effects of undertaking alternative courses of action" (Gunton 1991, Vol. 1, 18). The original four accounts used for evaluation included a cost-benefit account, environmental quality account, regional economic development account, and a social effects account. Current MAA guidelines encourage the use of other accounts that may be more suitable for specific decision problems. Multiple project accounts including the attributes used for the analysis of the alternatives are integrated into a single table which indicates the impacts of each alternative. The decision makers then compare the plan options and choose the one that maximizes project objectives (Gunton 1991 Vol. 2).

In 1993, the British Columbia Crown Corporations Secretariat (C.C.S) developed multiple account guidelines to assist government agencies "in systematically identifying and evaluating the implications and relative merits of alternative plans and projects" (B.C. Crown Corporation Secretary 1993, 1). Four basic principles are the foundations of MAA guidelines. First "the evaluation process must...be seen as part of an integrated planning framework" (B.C. Crown Corporation Secretary 1993, 1). Project objectives must meet with the broader strategic goals of the corporation. Second, a full range of alternatives must be considered. "The evaluation of an incomplete or inappropriate set of alternatives, no matter how sophisticated, will not generally assist in identifying the best course of action"(Crown Corporation Secretary 1993, 2). Third, for projects considering a range of diverse objectives, there is no single best measure of net benefit. Multiple account "evaluation may not determine which of a set of

alternatives is unequivocally preferred. However, that is not the goal. Rather, the goal is to clearly identify advantages and disadvantages, and the trade-offs that different alternatives entail--to inform and assist decision-making not to supplant it" (B.C. Crown Corporation Secretary 1993, 2).

The crucial first step in this process is to define a decision context, and identify all relevant project alternatives. The next step is to assess the alternatives for their advantages and disadvantages. "Evaluation accounts define the range of criteria by which the relative advantage or performance of alternative plans and projects can be judged" (Crown Corporation Secretary 1993, 8). The C.C.S suggest a number of ways of generating a set of project alternatives. This includes collaboration with a diverse group of stakeholders and the brainstorming of project alternatives. However the C.C.S falls short of offering a systematic method of structuring objectives and developing new alternatives. Keeney prescribes the use of "value focused thinking" to guide the decision making process. Values are the reasons for being interested in a decision and as such should be considered before alternatives are selected. Traditionally, obvious alternatives are selected to deal with the problem and then assessed in terms of the most accessible hard scientific data available. Keeney argues that this kind of process has a number of deficiencies. Firstly, values, which should provide guidance for all the effort on a problem are considered separately and after alternative solutions have been selected. The relationship between values and the choice of alternatives is ignored (Keeney 1992, 29). The set of objectives for the decision is often left incomplete because of the search for scientifically verifiable alternatives. For the purposes of this thesis Keeney's approach to structuring objectives is employed for the Deer Lake Restoration and Management Decisions.

2.2.2 The Theory Of Value Focused Thinking

Values are the "principles used for evaluation. We use them to evaluate the actual or potential consequences of action and inaction, of proposed alternatives and of decisions. They range from ethical principles that must be upheld to guidelines for preferences among choices"(Keeney 1992, 7). By concentrating on values Keeney maintains that more informed and thus more defensible decisions can be made. The principles outlined in Keeney's book Value Focused Thinking are the foundation used to guide the first two steps of the Deer Lake case study.

Keeney suggests that values should play a pivotal role in structured decision making processes. Rather than taking the traditional approach, of thinking only about choices between the most obvious decision alternatives, a less constrained approach would be to concentrate on values first. Articulating values should help to generate a broader range of decision alternatives.

> "If in fact, we begin with values, we might not even think of situations as decision problems, but rather as decision opportunities. Periodically, we might examine achievement in terms of our values and ask, can we do better? The thinking process might suggest creative alternatives that result in increased achievement of our values. This should be a better allocation of our time than spending most of it choosing among readily apparent alternatives in decision problems" (Keeney 1988, 466).

In a structured decision making process values are defined and made operational in organized objective statements.

Value focused thinking is useful for uncovering hidden objectives by providing decision makers with an opportunity to think about what the essential considerations are for a given decision. Values provide the context for guiding information collection. By focusing on values, limited time and scarce resources, can be directed towards gathering only the relevant information that is required to assess proposed alternatives. "For most public problems, values rather than facts, are the aspects of the problem about which many members of society will have knowledgeable viewpoints" (Keeney 1992, 25). Incorporating values into the decision making framework provides a common language that bridges the communication gap between technical experts and laypersons. VFT helps interested parties communicate about project objectives in an effective and honest way. Gaining insight into interests provides an opportunity to distinguish facts from values, assess conflicting objectives, and identify the tradeoffs between different alternatives. VFT is a procedure that decomposes the preferences of decision makers into their constituent parts, which in turn allows for the analysis of each part. The preferences of decision maker's are explicitly represented, by reconfiguring the individual components of a decision into a well organized and understandable analytical model. This comprehensive statement of objectives provides a tool for the development of better alternatives.

2.2.3 The Method

There are three major steps involved in the Deer Lake MAA. In step one, the problem is contextualized, and structured regarding all aspects of the decision that merit consideration. Using the principles of VFT, value based objectives that frame the decision are identified and represented graphically in a hierarchical decision tree. Attributes that measure how well a prescribed alternative achieves a stated objective are also identified in this stage of the analysis. This first step is often repeated such that a final set of values representing all the concerns of the interested parties can be found. "The finished value's hierarchy may have components using causal models, economic models, influence or means end-diagrams, and so forth showing the linkages between specific measures at the bottom and the abstract attributes (*objectives)* at the top" (Gregory, Lichtenstein, and Slovic 1993, 23).

Step two of the process assesses the possible impacts of the alternatives being considered. To accomplish this, MAA facilitates the combination of the best scientific, technical, environmental and financial information that is available. "Evaluation accounts define the range of criteria by which the relative advantage or performance of alternative plans or projects can be judged" (Crown Corporation Secretary 1993, 8). For the Deer Lake Case Study, the fundamental objectives identified in the first part of the decision making process become the evaluation accounts. The accounts used in this analysis include the costs, environmental impacts, aesthetic impacts and recreational benefits. Existing information is used to assess how well the selected alternatives achieve the desired objectives. Uncertainties regarding the impacts of alternatives are represented by probabilities. For each account, the processed information is condensed into a compact tabular representation of the performance of the selected alternatives. "In multiple account analysis it is explicitly recognized that not all benefits and costs can be expressed in dollar terms" (Crown Corporation Secretary 1993, 9).

In step three a compact and complete summary matrix highlights the advantages and disadvantages of the different alternatives. This matrix can be used as a tool to assess the tradeoffs between alternatives.

Value focused thinking has been criticized on a number of different levels. The ability of VFT to improve decision making has been questioned. Some argue that the decomposition and recomposition of a problem may result in "the suppression of soft or fragile considerations" (Howard 1979, 4). On an ethical level, the process has been challenged as having an anthropocentric bias. The most common complaint leveled against this type of decision making, is that the process simply takes too long. McDaniels maintains that "even a few hours spent probing a problem, focusing on the nature of the problem, the objectives of different groups, and the potential for new alternatives can pay dividends" (McDaniels 1992, 51). He also points out that this kind of analysis is flexible enough to be iteratively refined, which fits the type of incremental planning approach favored by many planners.

The combined approach of VFT and MAA offers planners a methodology that can accommodate many of the complexities involved in planning for the restoration and management of our urban lakes. This chapter has presented a brief discussion of the value of urban lakes, with a summary of how planning has been done in the past and how planning processes can be improved in the future. By applying the principles of VFT and MAA to the Deer Lake case study, it may be possible to gain some insights into how urban lake planning processes can be improved.

CHAPTER 3

THE DECISION CONTEXT FOR THE RESTORATION AND MANAGEMENT OF DEER LAKE:

"The decision context defines the set of alternatives appropriate to consider for a specific decision situation" (Keeney 1992, 30). The intent of this section is to provide a context for the Deer Lake Case Study. Chapter three consists of seven sections, including a brief geographical and historic viewpoint on Deer Lake, a problem statement, and an outline of the source of water quality problems. Next is a discussion of the recreational activities affected by the decline in water quality. An outline of the alternative treatment options currently being considered and an assessment of the costs and risks involved is presented. Section 3.6 provides a summary of the technological uncertainty of the proposed restoration alternatives. The final section of the chapter reviews the decision process to date.

3.1 SIGNIFICANCE OF DEER LAKE

Deer lake is an eighty-six acre lake located in the central portion of the City of Burnaby, British Columbia. The relatively small shallow lake has provided a variety of recreational opportunities for local residents since the 1950s. Swimming, fishing, hiking, and nature viewing are some of the more popular activities in Deer Lake Park. (See figures 1 and 2) "Besides being a significant part of Burnaby's natural heritage, cultural, aesthetic, and recreational values of Deer Lake and the surrounding park have made the lake an important asset to the residents of Burnaby and the region for generations" (Johnston 1991, 1). Deer Lake is described by experts as hyper-eutrophic or in an accelerated state of eutrophication.

> "Eutrophic lakes are richly supplied with plant nutrients and support heavy plant growths. As a result, biological productivity is generally high, the waters are turbid because of dense growths of phytoplankton, or contain an abundance of rooted aquatic plants; deepest waters exhibit reduced concentrations of dissolved oxygen during periods of restricted circulation. Eutrophic lakes tend to be shallow with average depths less than 10 meters (33 feet) and maximum depths less than 15 meters (50 feet) (Beak 1982, xv).

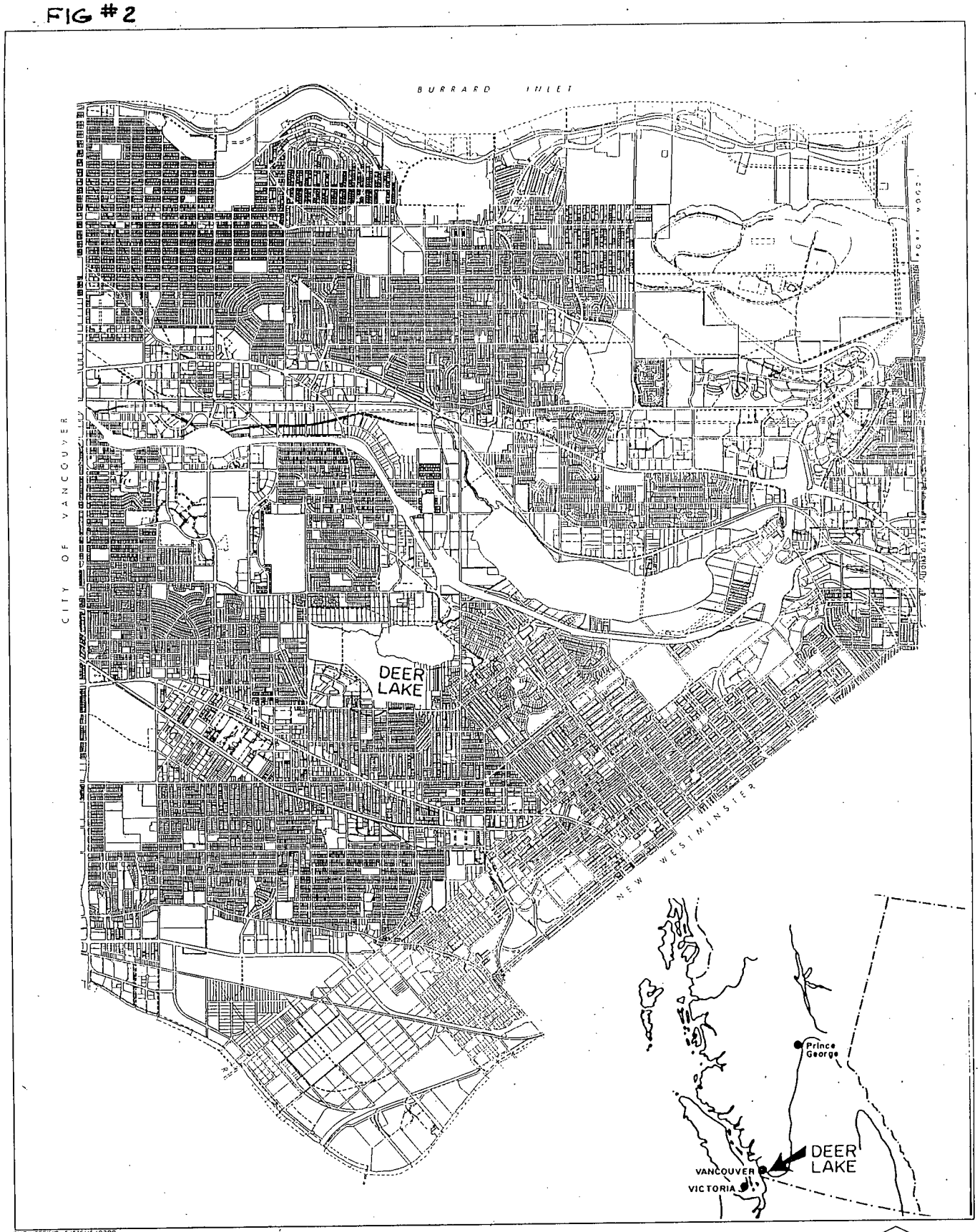
City officials want to select the most appropriate way of dealing with high coliform counts and increasing levels of phosphorus.

3.2 PROBLEM STATEMENT:

For the past forty years the water quality of Deer lake has progressively deteriorated to the point where aquatic and terrestrial recreational activities are being compromised. Summer blue green algal blooms, abundant weed growth, low water transparency, high water temperature, low oxygen levels, and high fecal coliform counts, are some of the most significant symptoms of the lake's declining trophic state. Declining water quality has had the most impact on swimming, and fishing activities. To reverse this process, technical experts maintain that the phosphorus load into the lake has to be reduced from a current level of 636 kg per year to a minimum level of 353 kg per year. In addition fecal coliform counts will have to be reduced to less than 200 organisms per 100 ml if they are to meet current health board standards for swimming (EVS 1990).

FIGURE # 1 DEER LAKE
BURNABY B.C. 1995

FIG #2



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3.3 PROBLEM SOURCE:

The eighty-six acre lake has suffered the impact of rapid urbanization within its 2038 acre watershed. Phosphorus contained in many lawn fertilizers reaches the lake directly through Burnaby's storm water system and through ground water discharge. Storm water also carries pet wastes into the lake, which contributes to the unhealthy concentrations of fecal coliforms. Other sources of coliform include, waterfowl, illegal sanitary sewer connections in the watershed, and leaking septic systems on the south side of the lake.

External phosphorus loading from non-point sources in the watershed has over fertilized the lake water, resulting in the accelerated growth of nuisance weeds and algae. Weed growths around the perimeter of the lake have compounded the nutrient problems in the lake, by acting as phosphorus pumps that recycle fertilizer contained in the lakes' sediments. (See fig. # 1) "Excessive growth of macrophytes will cause recreational hazards and may eventually choke the lake" (Beak 1981 4-36).

Storm water discharge has supported the rapid sedimentation of the lake and the growth of unnaturally high populations of aquatic plants and algae. The in-filling of Deer Lake, is in part, a natural process, which in time, happens to all lakes. The term eutrophic is a descriptive scientific term, which does not necessarily refer to the aesthetic quality of a lake. "The perceived quality is a human judgment based upon needs and expectations" (Cooke 1993, 35). Eutrophication accelerated by human activities is often described as "cultural eutrophication". This is perceived as an unnatural process, deemed to be unacceptable due to the negative impact that it has on human recreational opportunities. Many of the water quality reports commissioned by the City of Burnaby suggest that Deer Lake was well on its way toward an advanced state of eutrophication before the urbanization of the city. However, concern for the degradation of the lake is relatively new.

Deer lake receives storm water from seventeen creeks that drain the 2,000 acre watershed (see appendix # 2). Six of these creeks are identified as major sources of phosphorus and suspended solids. Consultants estimated that creek 3 contributes 25% of Deer Lake's total nutrient budget, creeks 11,12, and 13 contribute 23%, while creeks 15 and 17 add an additional 16%. Internal loading from sediments is about 3 %, and from macrophytes 14%, with ground water, precipitation, and diffuse inputs, making up the remaining 35% of nutrient and sediment loads (EVS 1990).

3.4 RECREATIONAL ACTIVITIES AFFECTED BY DECLINING WATER QUALITY:

Until the 1980s, Deer Lake has provided cold water trout fishing and summer time swimming opportunities. Increased sedimentation has contributed to a general warming of the lake and a reduction in dissolved oxygen. In recent years surface water temperatures have sometimes reached 25 degrees Celsius and 15 degrees at the bottom. High water temperature and low oxygen concentrations make Deer Lake an unsuitable environment for preferred cold water rainbow trout, thus changing recration opportunities associated with the lake (Beak 1982).

A warmer lake has encouraged an increase in the population of less desirable coarse fish, at the expense of the more valued trout species. An oversupply of phosphorus has encouraged the growth of aquatic plant life, which in turn has attracted large populations of birds. The high productivity of the lake has in an indirect way contributed to an increase in coliform levels. These levels now exceed BC public health standards for class C water use. Acceptable standards for fecal coliform densities may not exceed running log mean of 200 per 100 ml, or 400 per 100 ml in more than 10% of the samples in a 30 day period (Beak 1982).

FIGURE # 3 DEER LAKE
BURNABY B.C. 1995

Waterfowl are partially credited with the increase in coliform levels, which has forced the health department to close the lake for swimming. "An estimated 300 birds reside at the western end and eastern end of the lake in the winter, totaling approximately 600 birds. This number is reduced by about one half or more in the summer. A rough estimate of 8.0×10^8 million fecal coliform bacteria are discharged directly or indirectly into the lake on the western and eastern shore by waterfowl each year" (Beak 1982, 4-47). To recover fishing and swimming opportunities, and to enhance lake aesthetics, the City has patiently investigated solutions to the coliform problem, including a bird management program.

3.5 TREATMENT OPTIONS CURRENTLY BEING CONSIDERED BY THE CITY

Burnaby is considering four expensive and relatively new treatment options. Dredging is expected to reduce the internal phosphorus loading from aquatic plants. The construction of nutrient sink ponds should reduce the external phosphorus loading, and reduce coliform concentrations contained in storm water that discharges into the lake. As a treatment alternative the city wants to use these two technologies in tandem to maximize the improvement to water quality. Besides these two technological alternatives, the City has already implemented a watershed management program within the Deer Lake catchment area. This project includes increased street sweeping, a public information campaign, a pest management strategy for municipal park lands and a storm drain marking program.

3.6 UNCERTAINTY REGARDING THE PROPOSED RESTORATION AND MANAGEMENT OPTIONS:

Restoring a complex natural system like Deer Lake to some pre-urban condition involves substantial uncertainty. The restoration alternatives currently being considered by the City of Burnaby involve the application of an unproved, and potentially hazardous technologies. Sinkponds and dredging might have a negative as well as positive impact on water quality. Scientific studies to date have failed to provide a comprehensive, well structured, and predictable picture of how certain proposed technologies may affect the lake's aquatic, and terrestrial ecosystem. The uncertainties involved in the decision are underscored

by the often conflicting stakeholder values regarding the use and maintenance of the lake and it's surrounding park and watershed.

Consultants' reports estimated that dredging the lake, and the construction of one sink pond large enough to handle fifty percent of the inflow would cost the municipality more than 2.5 million dollars. Dredging costs were originally estimated at 1.6 million dollars and represent the most expensive of these two treatment technologies (EVS 1992). A number of studies commissioned by the City have concluded that both of these technologies have significant risks and uncertainties associated with them. Test samples indicated that the some of the lake sediments contained significant concentrations of toxic metals and pesticides. De-watering this material on site could present some local environmental risk to valued park land. City officials are advised that, decontaminating toxic dredge waste is costly and if the levels of toxicity are above a certain standard, disposal sites for the material may be difficult to find.

In the literature there are mixed reviews about the performance efficiency of constructed wetlands (Moshiri 1993). The construction of artificial wetlands (sink ponds) to treat storm water discharge is a recent technological innovation that has had variable success in removing fertilizers and contaminates from storm water. The overall efficiency of sink ponds is dependent on a number of environmental factors, including local soil and weather conditions. Constructed wetlands are also vulnerable to single event contamination in the upland watershed. To get a better idea of how local conditions may affect a full scale sink pond, the City has constructed a pilot project. To date, the test sink pond has had fluctuating success in controlling phosphorus and TSS (total suspended solids). In 1993 EVS reported that, the test sink pond had reduced total phosphorus concentrations by more than 50%, and TSS by 33% - 90%. In 1994 "structural problems with the constructed wetland have apparently affected wetland performance and make it difficult to interpret monitoring data. ...Water quality parameters were fairly constant from inflow to outflow during each survey. ... during the 1993/94 monitoring season" (EVS 1994, ii). Consultants hope that source controls within the watershed will help the performance of a full scale wetland project. However, the City has not been monitoring the results of their watershed management program. There is no way of knowing how much these strategies will help enhance the performance of

the proposed sink ponds. Despite the inception of the watershed management programs in 1988, coliform and phosphorus levels have remained above the recommended standards.

Budget considerations, potential impacts on recreational opportunities, environmental concerns, and the technological and event-based uncertainties of the various rehabilitation and management proposals have all contributed to a protracted decision making process which at the time of this case study was still underway.

3.7 THE DECISION PROCESS TO DATE:

A decision problem was recognized when Burnaby's Health Department closed the lake for swimming in the late 1980s. This action soon became a political issue, which in turn resulted in the formation of the Deer Lake Restoration Committee. The mandate of the committee was to advise council on how to best restore the lake's water quality, so that recreational activities could be resumed. To date, the committee has spent considerable time and resources on considering the combined alternative of dredging, and constructing a sink pond on one of the major inlet streams. To secure council's approval, the committee commissioned a number of scientific studies that were to verify the effectiveness of the constructed wetlands and dredging. Besides the two studies done before 1986, the committee has since commissioned consultants to provide seven more scientific reports addressing water quality issues.

This process parallels what Keeney describes as "alternative focused thinking." A process in which a decision problem is identified because of some "dissatisfaction" with the current situation. In the search for a cure all alternative, the City of Burnaby since 1979 has incrementally tried to resolve the Deer Lake decision by commissioning one scientific study after another. To date there is still no clear resolve on how to best continue with the restoration of the lake.

As an alternative to this kind of process, Keeney suggests that the decision be framed with the fundamental objectives that one wishes to achieve. These objectives should be based on the values of the decision makers and what they think is important. This kind of decision strategy can then be used to guide the process of information gathering. To restructure this problem with value based objectives a series of interviews was conducted with each member of the committee. These interviews provided the foundation for recasting this decision in terms of what objectives the Committee wished to achieve. Chapter four presents a detailed description of this first part of the decision making process.

CHAPTER FOUR
OBJECTIVES FOR THE DEER LAKE RESTORATION AND MANAGEMENT PROPOSAL

The first step in the Deer Lake case study is to define a relevant set of objectives. This chapter, using the methods outlined in chapter two, structures a set of fundamental objectives for the restoration and management of Deer Lake. The fundamental objectives described in the following sections are the accounts used to assess the impacts of selected alternatives. Section 4.1 describes the interview procedures as well as strategies used to obtain these objectives from the committee and from related documents. Section 4.2 describes the structuring process. The overall strategic objective is presented in section 4.3. The last five sections of this chapter provide a descriptive and graphical representation of the four fundamental objectives used for this multiple account analysis.

4.1 Committee Interviews

Deer Lake restoration and management objectives are derived from existing reports, inter-office memos and committee interviews. The interview process consisted of meeting separately with each member of the committee. Of the five interviews conducted, each lasted between 1.5 to 2.5 hours. Except for one telephone interview, each personal meeting was conducted in an informal manner, with the respondents being previously presented with a list of interview questions.

Five individuals with different educational and professional backgrounds make up the committee. As stakeholders in this project, each committee member represents the concerns of different departments within the City. John Kirbyson is a superintendent with the Parks Department and has a Masters Degree in Natural Resource Management from Simon Fraser University. Dr. Sarah Groves, an Ecosystem Planner, and Basil Luk Sun, a Long Range Planner, are members of Burnaby's Long Range Planning Department. Dipac Dattani is a Public Health Inspector and a member of the Cities Environmental Health Department. Vic Weibe is a professional engineer and represents Burnaby's Engineering Design

Department. Each member of the committee brings to the process, professional expertise as well as a different set of values.

Each interview took the form of a general discussion on relevant issues. Previously providing each respondent with a questionnaire acted as a springboard for discussion, and seemed to help overcome the interviewer's inexperience. Keeney (1992), discusses in detail, the strategies for eliciting fundamental objectives from a group of stakeholders. Questions for the interview were in part derived from Keeney's "Value Focused Thinking"(1992). Each member of the committee was asked to think beyond the set of questions and bring up any issues that they thought would be important for this decision. A total of eleven questions were asked, some of which required multiple answers. (See table 1)

TABLE 1

INTERVIEW QUESTIONS:

1) If there were no limitations at all, what would your objectives be for the Deer Lake Restoration decision?

2) Considering the current alternatives as:

a) rehabilitating through dredging, diversion and the construction of nutrient sink ponds.

b) a combination of rehabilitation through source control, dredging and the construction of sink ponds

c) do nothing about improving water quality in the lake or watershed
What is good or bad about each alternative?
Are there limitations in considering any alternative thus far?
Are there uncertain consequences?

3) What concerns do you have in choosing either of the three options? For example, are there issues of fairness or equity involved, if so state to whom, and what you consider is fair.

4) What are the distinguishing features that make one of the alternatives listed in question two better than the others?

5) What are the desirable or undesirable features of each of the three alternatives being considered?

6) What needs to be changed from the status quo to make the restoration of Deer Lake a reality?

Table #1 Continued

7) Given the alternatives considered thus far are there any consequences that you feel are unacceptable?

8) What is an undesirable future for Deer Lake and why would it be undesirable?

9) What if any are the constraints in this decision?

!0) Within Burnaby's stated strategic objectives of creating a healthy community, how do the alternatives considered thus far help contribute to the fulfillment of this vision?

11) For public sector decision makers there is a set of generic objectives that often have to be considered. These are:

a) economic impacts

b) health and safety considerations

c) environmental impacts

d) socio-economic impacts

e) political impacts

Comment on the relevance, of each of these generic objectives within the Deer Lake decision context.

In many situations the questionnaire did not produce a satisfactory first time response, and it was necessary to pursue the issue by asking a more specific question. For example, one response to question 2.1 (what is bad about constructing nutrient sink ponds) was that they occupy considerable amounts of valuable park land. This response prompted the question, why is it important to protect this park land? The respondent replied, that the only park land available for sink pond construction was valued by park nature viewers for its unique aquatic and terrestrial habitat.

Often, elements in a committee member's response required further elaboration. For example, commenting on the relevance of economic impacts, committee members often replied that the project must be cost effective. The term "cost effective" required clarification and in many cases it meant different things to different people. For one committee member, costs are defined for long term

maintenance costs, technological reliability, and the effectiveness of the different treatment options. Short term costs, like construction or dredging costs, did not seem to be much of an issue for this person. In contrast, another committee member wanted questions of cost effectiveness to include an accounting that would consider a dollar value for intangible environmental costs. Examples of intangible costs include, the destruction of valued habitat, or the value of losing an endangered bird. A professional engineer defined cost effectiveness in terms of the tradeoff between benefits and costs. Minimizing both short term start up costs, and long term maintenance costs had to be balanced off against the lost opportunity costs of realizing certain water sport recreational benefits.

One of the drawbacks to this type of questioning is that it often requires a considerable amount of time to complete. The first set of interviews took approximately one week. Members of the committee gave generously of their time. However, I found it necessary to supplement the data from the interview process with some secondary sources of information. These sources included, commissioned consultants' reports, and internal interdepartmental memos concerning the Deer Lake project. Relevant value statements pertaining to the objectives of the project were extracted from these reports and memos. Objective statements from both sources facilitated the development of a comprehensive list of objectives to use as the foundations of this analysis. As a check for any errors and omissions, a preliminary list of objectives was presented to the Committee leader. This helped to ensure that as many objectives as possible where considered for the structuring process. For the final stage of analysis all members of the committee should be consulted to verify the completeness of the set of objectives.

4.2 STRUCTURING THE OBJECTIVES

Once the elicitation of objectives was complete, the next step was to separate means from ends, consolidate, and structure the objectives into a well-organized representation of what is important to the Committee. "An objective is a statement of something that one desires to achieve. It is characterized by three features: a decision context, an object, and a direction of preference" (Keeney 1992, 34).

To illustrate how the objectives hierarchy was created from both the primary and secondary sources of information, part of the consolidation process is summarized. For example, question seven of the interview questionnaire dealt with the consequence of the dredging alternative. Some typical kinds of statements made regarding this issue were; "de-watering the dredge spoils would have to take place on park land, and this may adversely affect park activities by creating an unsightly and smelly mess!" ; "dredging the lake may create a sterile aquatic environment!" From these kinds of overt statements more structured or focused objective statements such as 1) minimize the impact on the aesthetic features of the park, and 2) minimize the impact on valued aquatic ecosystems in the lake; are derived. For each of these two objectives, the decision context is rehabilitation and management of Deer Lake. The object in 1, is impact on aesthetic features, and the direction of preference is less impact. Table two contains the completed list of objectives used as the foundations for this multiple account analysis.

TABLE 2

COMBINED LIST OF OBJECTIVES FROM THE INTERVIEWS AND FROM RESEARCH DOCUMENTS COMMISSIONED BY THE CITY AND FROM INTERNAL MEMOS:

2-A OBJECTIVES FROM THE INTERVIEW PROCESS:

1) Minimize the impact of urbanization on the Deer Lake Watershed.

2) Maximize opportunities for ecological stewardship within the Deer Lake Watershed.

3) Minimize any alteration to the trophic structure of the lake.

4) Minimize any further damage to the natural terrestrial ecosystems surrounding Deer Lake.

5) Maximize the opportunity for source controls within the watershed.

6) Maximize the natural character of Deer Lake.

7) Maximize the opportunity for bird watching activity.

8) Minimize the number of algal blooms in the lake.

9) Maximize improvement to Deer Lakes water quality.

10) Maximize political and public support for the restoration and management of the Lake.

11) Maximize the cost effectiveness of the project.

12) Minimize the risk and uncertainties of the different treatment options.

13) Increase the number of public information programs.

14) Maximize pollution point source control programs.

15) Maximize street sweeping activities in the watershed.

16) Minimize any alteration of the parks valued natural landscape.

17) Minimize the population of aquatic birds in the park.

18) Maximize the recreational opportunities in Deer Lake.

19) Decrease the lakes current rate of eutrophication.

20) Establish an integrated pest management program for the lake's watershed.

Table # 2 continued

21) Maximize the long term effectiveness of the rehabilitation and management proposal.

22) Maximize the opportunity for the resumption of full water contact activities in the lake.

23) Maximize the recreational benefits from the dollars being spent.

24) Maximize the use of scarce tax dollars.

25) Do not make Deer Lake a sterile environment.

26) Maximize the rural character of the lake and surrounding park land.

27) Minimize the loss of existing wetlands.

28) Maximize the opportunity for learning about lake rehabilitation.

29) Minimize the impact on day to day park activities.

OBJECTIVES FROM MEMOS AND SELECTED REPORTS:
(Selected objectives taken from the (SOER) report)
(These objectives are an edited selection from The Statement Of The Environment Report (SOER) For Burnaby. The use of these objectives was suggested by Committee member Basil Luk Sun as a representation of what he thought were the important issues for the Deer Lake decision problem)

30) Maintain and improve forested areas, clean air, fertile lands and ecological diversity.

31) Maximize the opportunities for thoughtful decision making.

32) Minimize the production of toxic waste.

33) Anticipate and prevent environmental problems.

34) Maximize preservation and enhancement of natural areas.

35) Maximize the quality of urban storm runoff.

36) Maximize public awareness of environmental issues through public education.

37) Maximize the opportunities for backyard stewardship.

(OBJECTIVES TAKEN FROM THE DEER LAKE PARK STUDY 1978)

38) Maximize the variety of recreational activities that will accommodate a broad range of individual choice among park users

39) Preserve and enhance the cultural and natural resources of the site for recreational, scientific, educational, scenic, historical and interpretative purposes.

40) Improve water quality of Deer lake as a fish habitat and as a focus for public use.

Table # 2 Continued

(OBJECTIVES STATEMENTS TAKEN FROM REPORT MEMO H65-38 JULY 1991)

41) Maximize the aesthetic and recreational attributes of Deer Lake.

42) Maximize the natural character of Deer Lake.

43) Maximize the opportunities for boating, walking, nature viewing, swimming and fishing.

44) Minimize health and safety risks.

45) Minimize short term and long term environmental impacts.

46) Minimize short term and long term costs.

47) Maximize positive impacts to the lakes water quality

48) Minimize impact to the site's ecology, aquatic as well as terrestrial.

4.3 STRATEGIC OBJECTIVE FOR THE DEER LAKE MULTIPLE ACCOUNTS ANALYSIS

"Every individual and every organization have strategic objectives. Although they are often not explicitly written down, these objectives are intended to guide all decision making. ...The strategic objectives should provide common guidance to all decisions and to all decision opportunities" (Keeney 1992, 41).

During the interview process a number of issues surfaced that were relevant to building a value model. Question # 6 from the interview questionnaire asked "what needs to be changed from the status quo to make the restoration of Deer Lake a reality?" All the committee members agreed that a political champion is necessary to make this project a reality. After the lake was first closed for swimming in the late 1980s there was a political initiative to clean up the lake. This initiative was championed by one of the members of City council. Much of the work done to date is directly attributable to the leadership and direction of former council member Joan Sawicki. In 1991 Mrs. Sawicki moved on to provincial politics and much of the momentum for a final restoration decision has diminished. From discussions with the

committee members it became apparent that to make this project happen any decision making framework would have to re-kindle this lost political will.

On a number of occasions both politicians; and committee members, have acknowledged the need for a public process, regarding the Deer Lake decision. A common desire of the Committee was to come up with a decision process that would anticipate public concerns for the project, and in part help to facilitate a future stakeholder interaction. From both of these observations it was decided that the overall fundamental objective for this MAA should be to "Make the best decision regarding the future of Deer Lake." This objective represents the committee's overall reason for being interested in this decision, and defines the boundaries of the committee's mandate.

4.4 BUILDING A COMMON VALUE TREE

Constructing a final value tree that would represent all the stakeholders' interests would involve a series of iterations and is beyond the scope of this paper. The purpose of this first run analysis is to find a set of value based objectives that the committee can agree on and use as a framework for a final decision making process. A structured set of fundamental objectives should provide the decision makers, and the public with a clear and concise understanding of all the important aspects of this decision.

Besides facilitating communication about values, structured objectives provide the basis for quantitative modeling. "The fundamental objectives hierarchy indicates the set of objectives over which attributes should be defined" (Keeney 1992, 64). The first task in this part of the process is to consolidate the list of objectives in table # 2 into a concise representation of what the committee members think is important. At this point, means objectives are separated from the ends such that a compact statement of the fundamental or value based objectives can be produced.

Keeney describes the distinction between a means objective and a fundamental. A means objective is a way to achieve a desired end, and the desired end or fundamental objective is based on what is important for this decision. There are two recommended strategies for identifying fundamental objectives. One strategy is to separate the means objectives from the fundamental objectives by asking why is it important to choose a specific objective. This is described as a continual process of "linking objectives through means-ends relationships"(Keeney 1992, 65). For example, objective # 15 from table # 2 is to maximize street sweeping opportunities. This statement is perused by asking, why is it important to maximize street sweeping opportunities? The answer is that street sweeping will help improve water quality in the lake. Within the context of this decision, improving water quality is important, because we want to maximize the opportunity for water contact sports. For this decision, maximizing the opportunity for water contact sports may qualify as an essential reason for being interested in the rehabilitation and management proposal. Therefore, maximizing recreational opportunities could be a candidate for a fundamental objective. In this example improving water quality is a means of achieving water contact recreational objectives.

Breaking down a stated fundamental objective into more specific value statements is another way of confirming a fundamental objective. For example, minimize environmental impact is made more specific by asking "what environmental impacts should be minimized?" The answer might be to minimize long term and short term impacts, which is further broken down into long-term aquatic impacts, and long term terrestrial impacts. Deriving broader objectives from more specific ones, is the same process, only in reverse. "The process of structuring objectives helps identify missing objectives in both the objective's hierarchy and the objective's network" (Keeney 1992, 69). Fundamental objectives are derived from the interview process, and from the statements contained in the City of Burnaby's reports and memos. For the most part, objectives contained in the reports and memos required very little alteration or analysis. In contrast, the interview statements required the use of both previously described specification strategies to structure and organize these statements into clearer objective statements.

After consolidating all the fundamental objectives for this decision context, the next step in the process is to organize a hierarchical value tree. The trunk of the Deer Lake tree structure is the overall

strategic objective and the fundamental objectives are represented by the major branches, with each descending branch representing a more specific objective. Opposite the terminal twigs of the tree are the attributes used to quantify each of the selected alternatives. The tree structure is set up such that there is a distinct relationship between each descending level of the objective's hierarchy.

To summarize, each lower level objective clearly describes or defines the upper level objective, and these lower level objectives should be "mutually exclusive and collectively should provide an exhaustive characterization of the higher-level objective." The process begins with the declaration of the overall strategic objective. The decision tree is concluded at the point where "reasonable attributes can be found" (Keeney 1992, 78). A certain amount of personal judgment is involved in the creation of a value tree, and for the set of fundamental objectives. Keeney suggests that any set of fundamental objectives should possess nine important qualities. Objectives should be; 1) essential, 2) controllable, 3) complete, 4) measurable, 5) operational, 6) decomposable, 7) non-redundant, 8) concise, and 9) understandable (Keeney 1992).

A fundamental objective is essential if each alternative being considered affects the achievement of that objective. An objectives hierarchy is controllable if it relates to the outcome of each of the alternatives that are being considered. A complete set of objectives should speak to all the possible consequences of each alternative. These first three properties help guide the consolidation of the objective's hierarchy by providing a context for judging the unedited set of objectives.

An objective has to be measurable with the attributes that relate, and define the consequences of the alternatives being considered. An objective is operational, if it is possible within a reasonable amount of time to gather enough data to ascertain the outcome of a considered alternative. This information is easier gathered when the objectives are decomposable. This means, that the aspects of consequences relating to one attribute can be considered independently of the aspects of consequences relating to other attributes. Objectives must also be non-redundant to ensure that no double counting occurs during the final phase of the analysis when alternatives are numerically assessed with their individual attributes. An objectives hierarchy should provide a complete, concise, and understandable representation of what

the Committee thinks is important. A compact value tree model reduces the amount of data necessary to facilitate a final decision. This supports the notion of an objective being comprehensible, which in turn should help the Committee to communicate the important issues to the decision makers. All of the nine properties mentioned above, were considered in the construction of the value tree model for the Deer Lake Restoration and Rehabilitation project.

The objectives hierarchy depicted in figures # 4 through # 9, and derived from table # 2, represents the values of the committee. Figure # 9 shows the overall relationship between objectives, with each number corresponding to an objective statement in figures # 4 to # 8. The committee needs to bring forward a set of objective statements that communicates to City Council all the aspects of the decision that merit consideration. A well organized and precise objectives statement should help council facilitate the proposed public process that is the next step in the evolution of this decision making process. "This step is crucial for a number of reasons: structuring public debate, identifying areas of agreement and disagreement, fostering negotiation and building a more open and defensible public decision process" (McDaniels 1992, 42). Objectives # 2 through # 5 outline the major categories that reflect the general concerns of the committee. The four fundamental objectives for this analysis are to 2) minimize costs, 3) minimize environmental impacts, 4) maximize aesthetic benefits to the lake, 5) maximize recreational benefits. (See fig # 4) These four fundamental objects, and their attributes are the accounts used for quantifying the impacts of the proposed alternatives in section six.

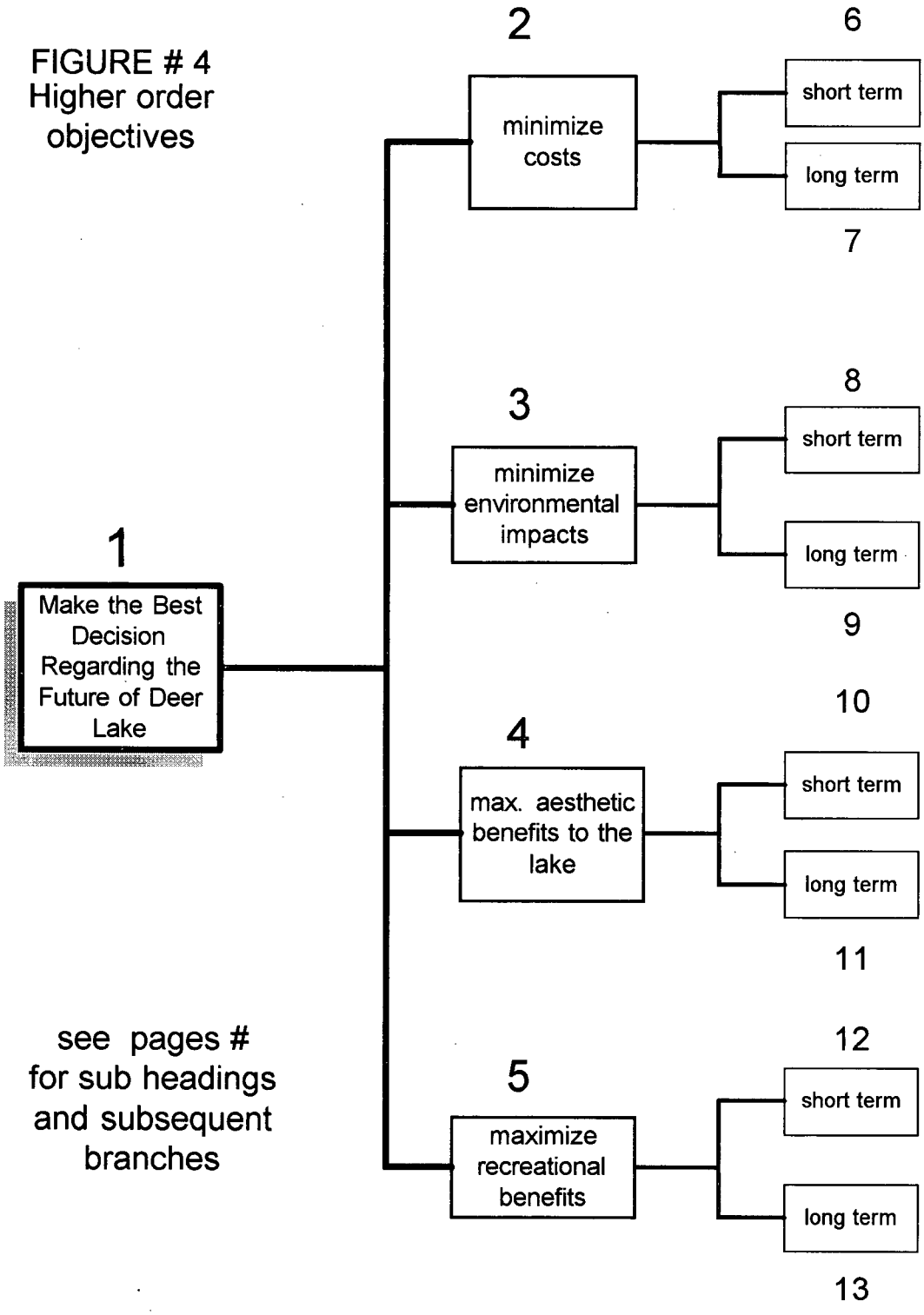
4.5 FUNDAMENTAL OBJECTIVE #2: MINIMIZE COSTS.

The two objective statements listed below have been taken from Table # 2 and represent objectives # 24 and # 46. These are the cost issues that the committee members feel are important for this decision.

1) **Maximize the use of scarce tax dollars; # 24**
2) **Minimize short term and long term costs; # 46**

Rather than use a generic category of economic impact that would include both the costs and benefits, minimizing cost seemed to better fit with what the Committee thought was important. For the three alternatives being considered in this case study. Both politicians and taxpayers interested in the economic implications of the project would be primarily concerned with the short term direct capital costs, the long term annual and remedial maintenance costs, and the long term lost opportunity cost of not being able to use the lake for swimming and fishing.

FIGURE # 4
Higher order objectives



see pages # for sub headings and subsequent branches

In a cost benefit analysis, the costs of each different alternative would be balanced against a dollar value for the benefits of the same alternative. The option with the best benefit to cost ratio is selected. Finding accurate ways of assigning a dollar value to intangible benefits, such as swimming and fishing opportunities, makes cost benefit analysis very difficult. In his 1991 Cost Benefit Analysis of the Deer Lake Restoration Project, John Kirbyson has argued that a dollar value can be placed on intangible recreational benefits. The long term, and short term costs of the project can be balanced against the dollar value of the expected recreational benefits. However, all committee members agreed that before potential recreational benefits are assigned a dollar value, there needs to be some way of estimating the probable effectiveness of the proposed alternatives. Therefore, it seemed logical to address the probability of achieving the recreational objectives before trying to assign a dollar value to the benefit of an unsure outcome. The probable achievement of desired recreational benefits is explicitly addressed by objective # 5 (maximize recreational benefits). However, without any rehabilitation effort it is very likely that there will be a continuation of lost swimming and fishing opportunities in Deer Lake. For this reason, it is logical to use Kirbyson's dollar value for recreational benefits as estimates of the lost opportunity cost (LOC) of potential fishing and swimming opportunities. Therefore, estimated recreational benefits in Mr. Kirbyson's Cost Benefit Analysis could be counted as the long term cost of an unsuccessful rehabilitation program for Deer Lake. Alternatively these estimates could also be used to assess the expected dollar benefits of a successful rehabilitation.

In the short term there are direct capital costs for sink pond construction, dredging, diversion, and sediment removal. There is some uncertainty over the ability of the various treatment-options to maintain the initial gains in water quality improvements. To retain long term performance, consultants have recommended that the City include an annual and remedial maintenance program for the dredging, and sink pond proposals. Yearly maintenance for dredging includes the removal of macrophyte re-growth. Annual maintenance for sink ponds involves the harvesting of part of the yearly aquatic plant growth. The recommended ten-year remedial maintenance program includes, the re-dredging of portions of the lake, and the removal of toxic sediments from the constructed wetlands. Figure # 5 below represents the graphical representation of the cost branch of the decision tree.

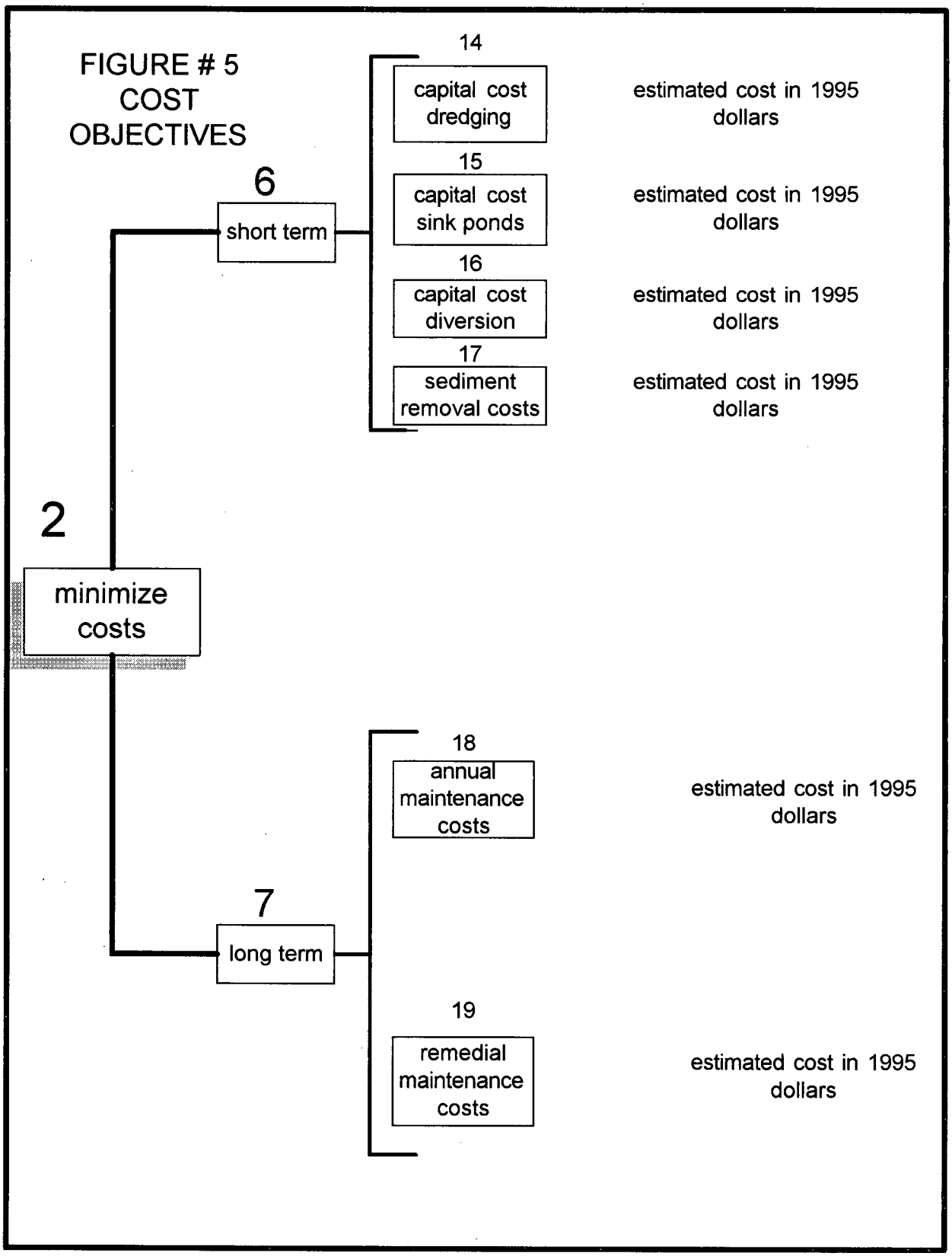


FIGURE # 5
COST
OBJECTIVES
2
minimize costs
6
short term
14
capital cost dredging
estimated cost in 1995 dollars
15
capital cost sink ponds
estimated cost in 1995 dollars
16
capital cost diversion
estimated cost in 1995 dollars
17
sediment removal costs
estimated cost in 1995 dollars
7
long term
18
annual maintenance costs
estimated cost in 1995 dollars
19
remedial maintenance costs
estimated cost in 1995 dollars

4.6 FUNDAMENTAL OBJECTIVE # 3: MINIMIZE ENVIRONMENTAL IMPACT.

The five fundamental object statements taken from table # 2 and listed below, have been consolidated into the fundamental object of minimizing environmental impact.

1) Do not make Deer Lake a sterile environment; # 25

2) Minimize the loss of existing wetlands; # 27

3) Maximize preservation and enhancement of natural areas; # 34

4) Minimize short term and long term environmental impacts; # 45

5) Minimize impact to the site's ecology, aquatic as well as terrestrial; # 48

Fundamental objective # 3 considers the long term terrestrial and aquatic impacts, as well as the short term terrestrial impacts on the park. There is concern about the potential impact that dredging, sewer diversion, and sink pond construction will have on different species of plants and animals in the park. There is also interest in the short term air quality impacts, and noise levels that would inconvenience park users during the construction phase of the project.

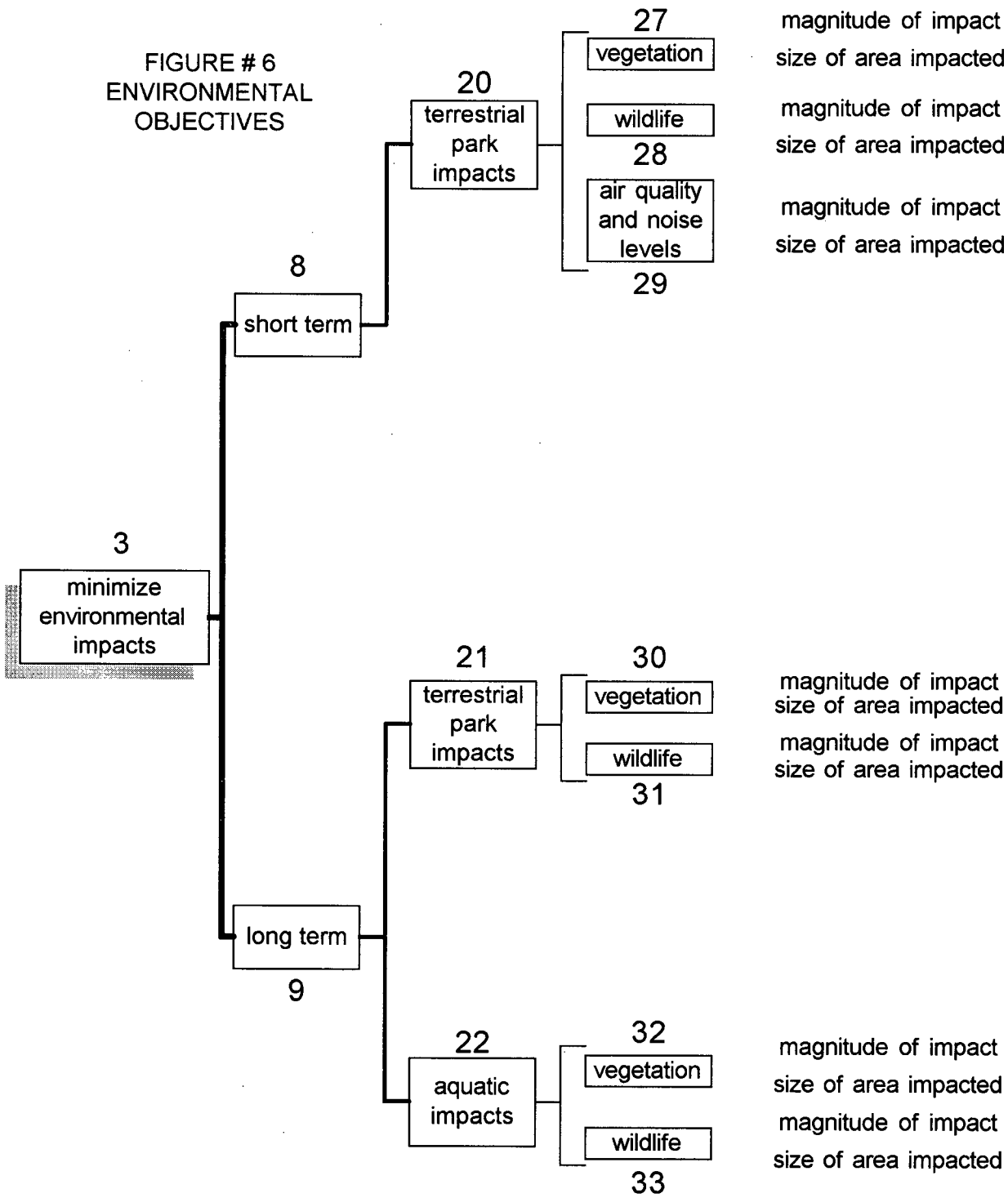
Dredging is one of the major components of the two proposed restoration alternatives for Deer Lake. It could take up to five months to complete the project, and would involve the removal of 135,000 cubic meters of dredge spoils to some other location. Previous studies, including the most current one done by E.V.S. Consultants, have indicated that the sediments in the lake contain varying levels of toxic material. Samples of mud taken from the lake bottom contain pesticides from the Oakalla farm lands, and heavy metal contamination from forty years of storm water discharge into the lake. The Committee has expressed concern over how to deal with both the on site, and off site removal of toxic dredge spoils. Concern about the environmental impacts of de-watering the toxic dredge spoils within the park has delayed lake rehabilitation. The 1990 E.V.S. Report points out that dredging and dewatering the dredgate in the park, could re-release a whole array of toxic chemicals and heavy metals back into the lake.

The construction of sink ponds, the diversion of creeks # 11, # 12, and # 13 into creek three, and the diversion of creeks # 16 and # 17 into the outlet channel (see appendix # 3) are the remaining components of alternatives considered in this analysis. These projects will involve the alienation of native plant and animal species, in the short term, and in the long term. The amount of land required for sink pond construction is one of the recognized disadvantages of employing this technology. Currently the only site available for this sink pond construction, is in the west side of the park. This part of the park is regarded as a significant part of a valued forest, grass and wetland ecosystem.

The sink ponds and the storm water diversion project will have some local short term impacts on air quality and noise levels in the park. Consultants have recommended that the optimum time to start construction would be in the early spring extending into the summer. This however, is a time when the park, and lake is used the most. Construction during this time could delay or compromise the scheduled spring and summer recreational activities in the park. Restricted access, construction noise, and dust would likely have the most impact on park users. In addition, to the inconvenience to park users, the dust and noise will also have a significant impact on park flora and fauna. The committee regarded park patron inconvenience, and the disturbance of valued natural assets as an important local issue and a significant part of this decision.

Most of the environmental impact assessments (EIS) done to date have focused on the site specific environmental impacts to the park, and the lake. The downstream impacts of dredging and the diversion project, are issues that still need to be addressed. There are preliminary environmental impact assessments that address downstream concerns. However, "a complete assessment should be undertaken once all the elements of a restoration project are detailed" (Kirbyson 1991, 84). The Provincial Environment Ministry and the City have informally agreed that there will be full environmental assessment of the downstream impacts before any restoration project begins. Information from a future EIS could be incorporated into the final iteration of this MAA framework. At this time, however, only the site specific impacts will be considered as part of this first Stage of the analysis. Fig # 6 below represents all the important environmental objectives considered to date.

FIGURE # 6
ENVIRONMENTAL
OBJECTIVES



4.7 FUNDAMENTAL OBJECTIVE # 4: MAXIMIZING AESTHETIC BENEFITS TO DEER LAKE:

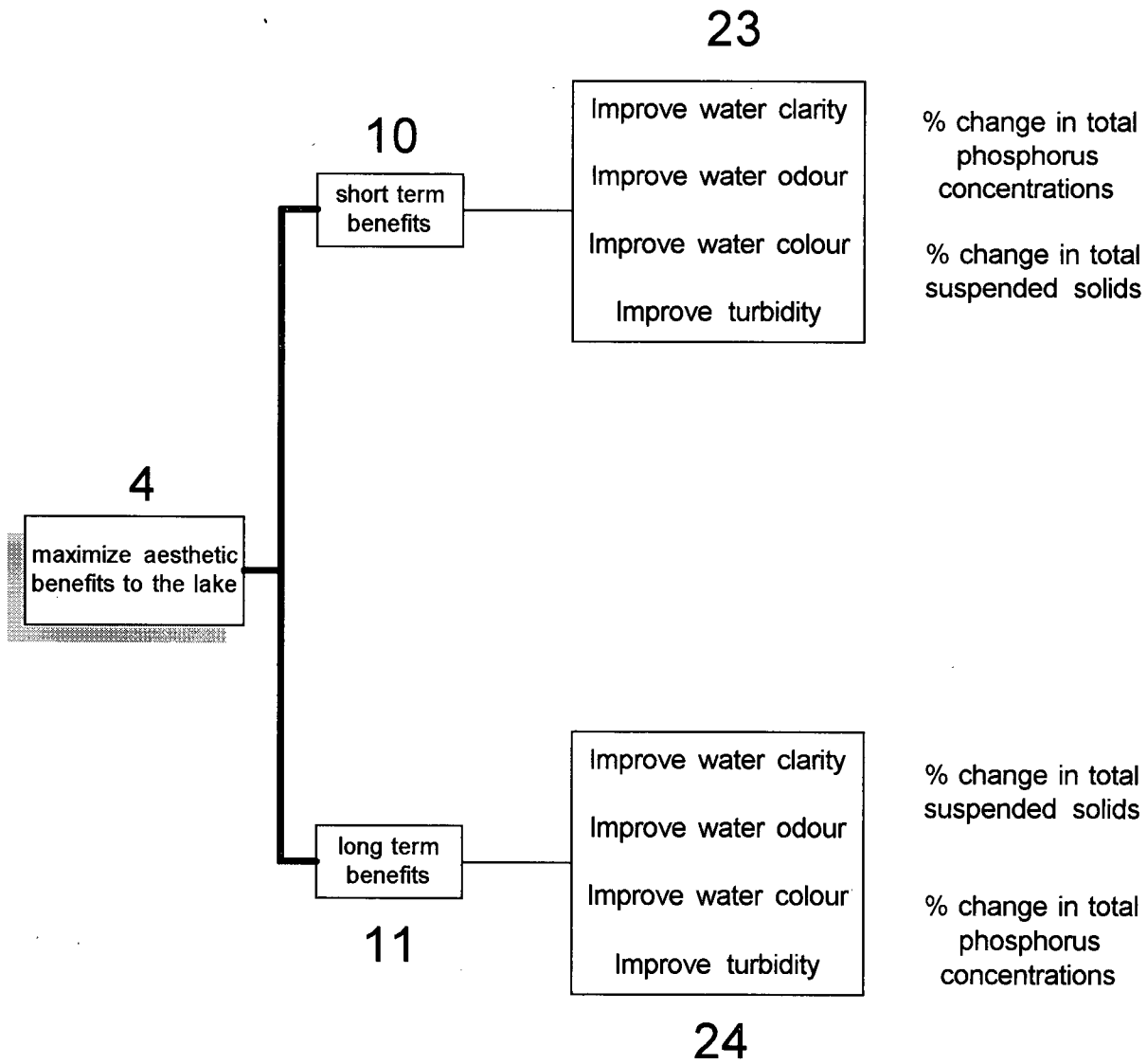
These five original objective statements listed below and extracted from table # 2, in whole or in part represent the desire to improve and maintain the aesthetic qualities of Deer Lake.

1) **Maximize the natural character of Deer Lake; # 6**
2) **Minimize any alteration of the parks valued natural landscape; # 16**
3) **Maximize the aesthetic and recreational attributes of Deer Lake; # 41**
4) **Maximize the natural character of Deer Lake; # 42**
5) **Maximize positive impacts to the lake water quality; # 47**

Aesthetic benefits often have an intangible dollar value. People become aware of the aesthetic features of an ecosystem through their senses. Aesthetically speaking, water quality is judged for its odour, clarity, colour and turbidity. These aesthetic factors of a lake may or may not reflect its true biological or chemical health. Around urban lakes many passive forms of recreation including walking, sightseeing, photography and sun tanning, are often favored by park users. The individual's choice to partake in these activities can be affected by the perceived aesthetic qualities of the Lake. In a public survey conducted by Butler and Redfield, 62% of the respondents indicated that the aesthetic qualities of a lake were most important to them. "This finding reinforces the importance of visual or aesthetics as a key factor in lake enjoyment" (Butler and Redfield 1991, 607). Successful completion of the Deer Lake Project includes improving the aesthetic features mentioned above.

Consultants expect that the proposed restoration alternatives will show differential results from the short term to the long term (EVS 1990). Dredging for example should show some measurable post project improvements to turbidity. Sink ponds on the other hand may take a number of years to show any noticeable improvements to the aesthetic qualities of the lake. Fig # 7 below, presents the aesthetic branch of the objectives hierarchy

FIGURE # 7
AESTHETIC
OBJECTIVES



4.8 FUNDAMENTAL OBJECTIVE # 5: MAXIMIZE RECREATIONAL BENEFITS.

Committee members have agreed that restoring the valued aquatic recreational activities in the lake is a major reason for being interested in this restoration and management decision. The committee's objective statements presented below have been condensed into the fundamental objective of Maximizing Recreational Benefits.

1) **Maximize the recreational opportunities in Deer Lake; # 18**
2) **Maximize the opportunity for the resumption of full water contact activities in the lake; # 22**
3) **Maximize the recreational benefits from the dollars being spent; # 23**
4) **Maximize the variety of recreational activities that will accommodate a broad range of individual choice among park users; # 384**
5) **Maximize the opportunities for boating, walking, nature appreciation, outdoor swimming and fishing; # 43**

Fundamental objective # 5 was broken down into reestablishing fishing and swimming opportunities in the short term or the long term. The objective of maximizing water sport recreational benefits are directed towards the restoration and maintenance of these activities. At present, the renewal of contact water sport activities requires compliance with a specific Health Board standard for fecal coliforms. One of the more specific objectives of this section is to meet the minimum allowable standard for fecal coliform in the lake.

Experts have informed the City that the trophic status of the lake will have to be altered to provide acceptable habitat for salmonid sport fish. To accomplish this task, total suspended solids (TSS) contained in the storm water discharge will have to be reduced. In addition, phosphorus concentrations in the storm water will have to meet a standard that is acceptable for the desired trophic status. (See fig.# 8)

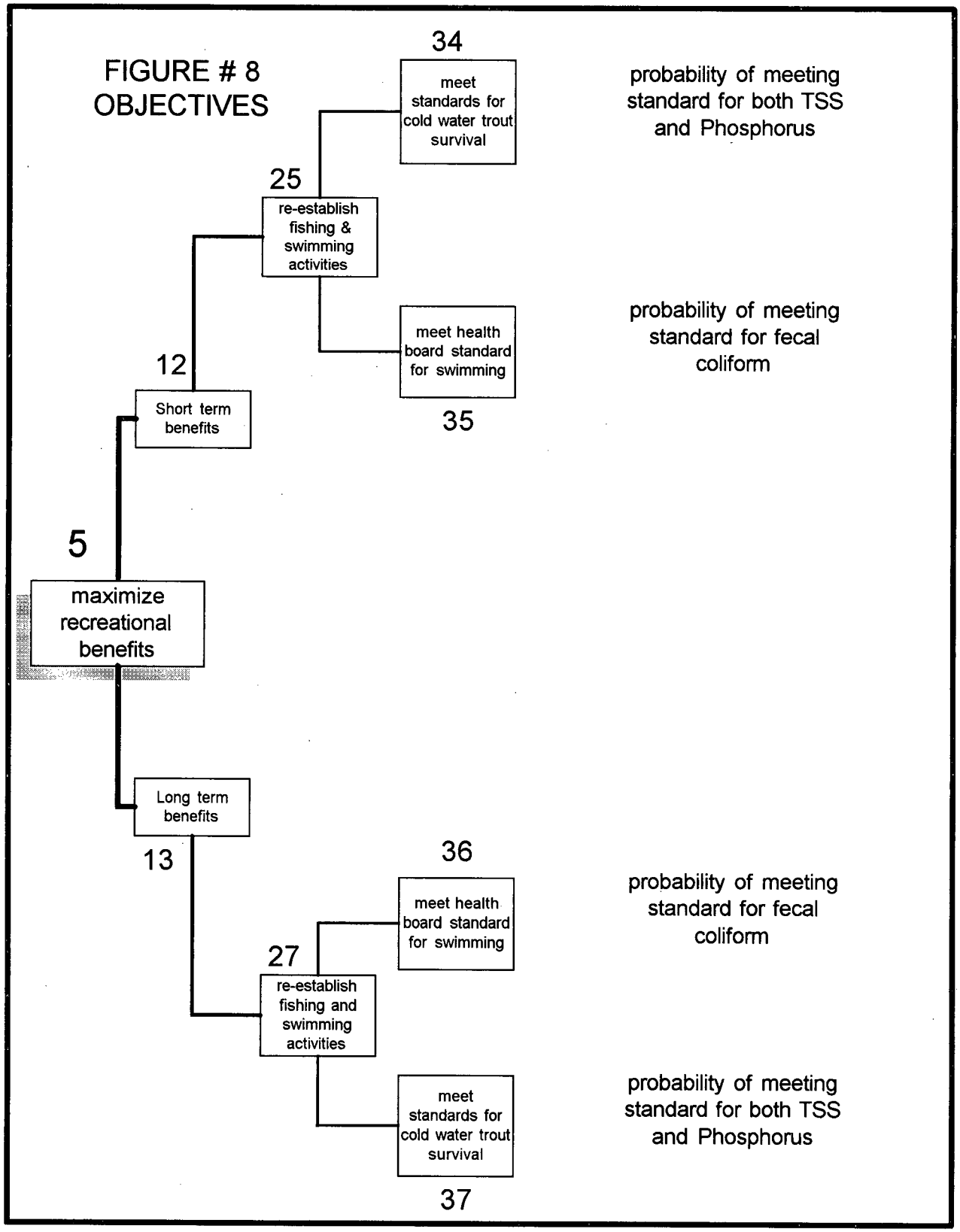


FIGURE # 8
OBJECTIVES
34
meet standards for cold water trout survival
probability of meeting standard for both TSS and Phosphorus
25
re-establish fishing & swimming activities
meet health board standard for swimming
probability of meeting standard for fecal coliform
12
Short term benefits
35
5
maximize recreational benefits
Long term benefits
13
36
meet health board standard for swimming
probability of meeting standard for fecal coliform
27
re-establish fishing and swimming activities
meet standards for cold water trout survival
probability of meeting standard for both TSS and Phosphorus
37

Recreational benefits considered for the purposes of this analysis, are fishing and swimming activities. Improving the quality of recreational activities, such as, canoeing, picnicking, jogging, walking, and sun tanning, are not considered as candidates for recreational objectives. The participation level for these activities can be influenced by a number of other amenities, besides water quality. Park facilities and services, the number of park users, and terrestrial aesthetics, could all influence user attitudes and participation in these recreational activities. These objectives are not essential nor controllable within the context of this decision and have therefore been omitted.

Fig # 9 presents a general survey of how all the parts of the objective's hierarchy fit together. All the twigs and branches are represented numerically and correspond to each of the number sequences on Fig # 4 through # 8. Fig # 9 below is the key diagram for this first stage of the Deer Lake multiple account analysis.

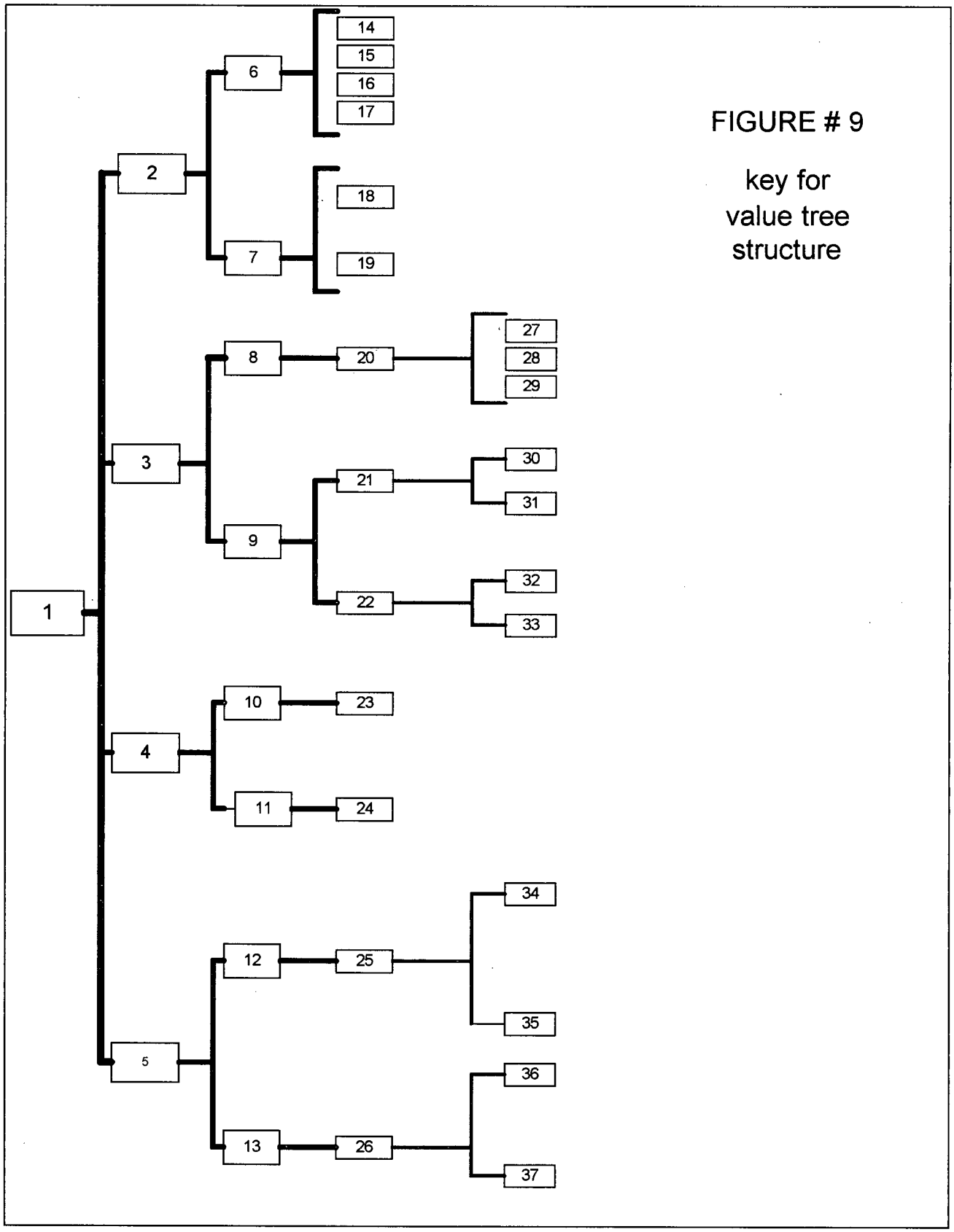


FIGURE # 9

key for value tree structure

The objective statements in chapter five are derived from committee interviews and from related project documents. All of these objectives are condensed and represented in table # 2. This list of objectives provides the foundations for the structuring process. The committee's four fundamental objectives, maximizing recreational and aesthetic benefit and minimizing cost and environmental impacts are expected to maximize public and political support for this project. These five objectives are graphically represented as a common value tree in sections 4.4 to 4.8.

CHAPTER 5

ALTERNATIVES FOR THE RESTORATION AND MANAGEMENT OF DEER LAKE:

The purpose of chapter five is to describe the origins of the three alternatives selected for this case study. A brief technical summary of the individual components of both restoration and management alternatives provides background information for the remaining two chapters.

5.1 ALTERNATIVES

Generating new and perhaps better alternatives is one of the strong points of value focused thinking. To date, one **restoration** alternative is being seriously considered by the City. From the interview process, and from reading the reports, it was possible to identify a number of other restoration and management alternatives. In practice, MAA often assesses which alternatives are better, given the decision context and a statement of objectives. Keeney argues that alternatives should be created after the stakeholders choose project objectives. By concentrating on stakeholder values first better alternatives can be produced.

Currently the City is assessing the impacts of a two staged restoration approach, which is intended to reduce both the internal and external sources of phosphorus. Alternative #1 involves selectively dredging the lake and building a sink pond on creek 3 (see appendix # 4). This alternative will be evaluated as part of this MAA, and is described in more detail in section 5.1

During the interview process it was possible to identify some new alternatives. These new options included alternative # 2, which is a staged restoration approach. Alternative # 2 includes the construction of a sink pond large enough to handle the storm water discharge from the diversion of creeks 3, 11, 12, and 13. Second, it is proposed that creeks 16 and 17 should be diverted into the lake out-fall (see

appendix # 3). As in alternative # 1, the third part of this proposal is to selectively dredge the shallow portions of the lake and remove nuisance aquatic plants.

Other alternatives suggested by different members of the committee, and in part rejected by the others, included the use of ultraviolet sterilizers, and a more extensive bird management program to control in-lake colifom levels. Aeration and ozonation are another restoration approach suggested by the Health Department representative. The addition of oxygen can help the survival rate of trout, and the application of ozone gas can reduce coliform levels. Diluting lake water with city water was suggested as a possible management option. This is an expensive treatment option that has had limited success in other parts of the Greater Vancouver Regional District. Other management and restoration options included, an annual aquatic plant control program, and the implementation of chemical as well as biological controls to reduce nutrient levels. All of these options were either put aside because of a lack of supporting data, or because they represented partial solutions only. As part of a final analysis, these alternatives may be reconsidered by the committee as part of new restoration alternative.

The third and final alternative, to continue with **water management programs only,** was in part acknowledged by members of the committee as a current reality of this decision making process. After twenty years of discussion and studies there is still no final decision on how to best approach the lake restoration issue. The first consultants report, regarding the water quality issues in Deer Lake was delivered to Burnaby by Northcote in 1978. Since then, there have been at least ten studies with numerous alternative water treatment recommendations. It is important to acknowledge the progress the City has made in the area of non-point source and point source phosphorus and coliform controls. Source control initiatives to date, include a bird management program (1988), a water quality brochure delivered throughout the watershed (1989), a nuisance plant removal program (1981), and a slope stabilization and sediment control initiative for creeks 17 and 11 (1981-1984), a storm drain marking program (1990), a pilot project sink pond (1992), and additional street sweeping in critical watershed areas. At the time of this study cost estimates for these programs were unavalilable. The impact of all of these source control projects on the lake's water quality is unclear. This in part is due to the lack of any comprehensive water quality monitoring program for the lake. There is no statistical evidence to support

or reject the effectiveness of these initiatives. The only credible observation, is that despite these source controls, high summer coliform counts have continued to keep the lake closed for swimming, and phosphorus and TSS concentrations have remained above acceptable standards. Intuitively, it seems that these kinds of source controls should have a positive impact on the lake's water quality. With the proper supporting evidence, source controls should be included as one of the alternatives considered in final multiple accounts analysis. For this first run analysis the water management alternative is retained as a method of assessing the continuation of the status quo, which is to further delay the decision until sufficient evidence can be found to support or reject any of the considered alternatives.

SEC 5.2 ALTERNATIVE # 1: DREDGING AND SINK POND FOR CREEK THREE

5.2.1 Dredging:

Dredging deepens a lake by removing a layer of bottom sediments. Four major objectives are accomplished by dredging a lake. First, removing shoals can enhance recreational opportunities, such as canoeing and sailing. A deeper lake is more likely to stratify during the summer months, and the decrease in water temperature provides a healthier habitat for preferred cold water sport fish. Second, sediment extraction is a means of removing toxic substances, including, copper, lead and zinc that enter a lake through the storm water system. Third, surplus phosphorus, nitrogen, and other nutrients contained in bottom sediments, are eliminated or reduced by dredging the lake. The fourth objective is to remove nuisance aquatic plants that diminish the lakes aesthetic appeal.

In 1989 Ceda Dredging submitted a proposal to the City of Burnaby to dredge the shallow regions of the lake, and remove 90% of the aquatic plants. The total volume of material to be removed was estimated at 135,000 cubic meters. The proposed dredge area represents about 30% of the total lake bottom. It was intended that the shallow parts of the lake be deepened by 3 meters. To remove the sediments Ceda planned to use a cutter head dredge and hydraulic suction technology. There are a number of problems associated with the use of these kinds of dredges. Finding a suitable site to de-water the dredge spoils is one of the more problematic issues that the City would face if it decided to accept

Ceda's plan. Using cutter head technology typically results in a dredge slurry with low amounts of solids, and a high percentage of water. "Most slurries from hydraulic dredges contain only 10% to 20% solids; 80% to 90% of the slurry volume is water. This means that relatively large disposal areas, with adequate residence times, must be designed to precipitate solids from the dredge slurry" (Cooke 1993, 463).

Alternative # 1 will require approximately 2.4 hectares of park land, and twenty-two weeks to de-water the dredge spoils. To neutralize the impact of phosphorus reentering the lake during the de-watering process, it was proposed that the slurry, and the lake be treated chemically with alum. The original estimated total cost of this project in 1989 dollars, excluding the cost of removing the dredge spoils, was about 1.16 million dollars. The Ceda proposal did not provide a cost estimate for dealing with the dried dredge solids. More recent studies done by EVS consultants have determined the relative toxicity of the material. These estimates are based on BC government standards for toxic soils. The 1994 EVS report has recommended that the City submit this information to the province and apply for a permit to dump the dredgate in the GVRD sanitary landfill. The cost will likely include transportation costs, and a disposal permits cost for dumping the material in the landfill.

5.2.2 Sink Ponds:

"A constructed wetland is defined as a designed, and human made complex of saturated substrates, emergent and submergent vegetation, animal life, and water that simulates a natural wetland for human use and benefit"(Hamilton 1992, 553). Constructed wetlands or nutrient sink ponds provide an enhanced natural way of treating different kinds of waste water including urban storm run-off. Aesthetically speaking, sink ponds provide all the benefits of a natural wetland, but are more efficient at processing nutrients, and degrading pollutants. By slowing down storm water flow, constructed wetlands take advantage of gravity to settle out suspended solids. Storm water solids often contain high levels of phosphorus, nitrogen, bacteria, viruses, heavy metals and organic contaminents (oil and greese). Sink pond sedimentation efficiencies are measured by the change in total suspended solids (TSS) coming into the sink pond and leaving the pond. Root systems of aquatic plants provide a mechanical means of filtering out solids left in suspension. Some heavy metal contamination is chemically precipitated by

combining with other insoluble compounds in the pond's substrate. Large water surface areas promote the decomposition of organic contamnants through ultra violet irradiation, and oxidation. Bacteria can oxidize heavy metals, and decompose organic solids. Bacterial reduction and absorption processes can be inactivated. "More emphasis is now placed on bacterial degradation processes in the water column, in wetland sediments, and on biofilms, although aquatic plants are critically important in providing a suitable environment for active microbial communities" (Hamilton 1993, 532). Hamilton describes biofilms, as integrated complex communities of bacteria. These bacteria, because of economies of scale, have a more efficient metabolic rate than planktonic bacteria. Increasing the metabolic rate of a bacterial community is one of the main reasons that constructed systems are more efficient than natural ones. Roots and stems of aquatic plants absorb, both microorganisms, and viruses. At the same time macrophytes provide needed oxygen to the substrate which in turn supports aerobic bacterial decomposition in an otherwise anaerobic environment. Certain aquatic plants absorb nutrients (nitrogen and phosphorus), heavy metals, and organic compounds, which can be removed from the system when the plants are harvested (Hamilton 1992).

There are two basic types of sink ponds, surface flow, and subsurface flow wetlands. In subsurface flow systems the water flow is through a bed of gravel that has plants growing on the top of it. These systems have a disadvantage of being hard to maintain but attract fewer nuisance insects, and tend not to cause as many odor problems as surface flow systems. The sink pond proposed for creek three alternative # 1, and for the alternative # 2, is a surface flow type. Surface flow sink ponds are shallow wetlands with many channels, and a variety of plants, including reeds, cattails, and bulrushes. All of these plants can decrease the rate of flow through the system supporting the sedimentation process. Seepage from the channel is reduced, by lining the bottom, and sides with clay or other semi impervious material. This prevents contamination of surrounding areas, and promotes the recycling, and further breakdown of nutrients within the system. The channel is partially filled with peat or soil to provide a medium for the root systems of aquatic plants. Efficiency of these systems depends on the amount of flow, the level of contamination, and the water temperature. Local environmental conditions also play a significant role in the overall performance of these systems. Site selection, configuration of the system, and the hydraulics of the watershed, are all important system design details. In a 1992 study, Cooke

significant role in the overall performance of these systems. Site selection, configuration of the system, and the hydraulics of the watershed, are all important system design details. In a 1992 study, Cooke dispelled the myth that sink pond efficiency rates decline over time. "His results suggest that the rate of P removal was sustainable, with P deposition being the main removal process" (Hamilton 1992, 533). Engineering consultants propose a series of sink ponds for creek 3 that will occupy a "total area of 4.5 ha." and will be located in the western portion of Deer Lake Park (EVS 1990, 7) (see appendix # 4).This represents approximately 2.5% of the total park area. Consultants have estimated that creek three, which has the largest watershed area, accounts for 25% of the total phosphorus budget for Deer Lake, with an annual contribution of 158 kg.

EVS in 1990, suggested that a combined approach (as in alternative # 1) of dredging a portion of the lake, and constructing a sink on creek 3 could reduce annual phosphorus loading by as little as 148 kg/yr. or as much as 211 kg/yr. To provide the desired changes in water quality and aesthetics, the annual phosphorus load into the lake would have to be reduced by at least 283 kg/yr. Even though alternative # 1 falls short of the phosphorus removal goal, dredging and a sink pond on creek 3 "may be sufficient to improve water quality considerably" (EVS 1990, 18). This prediction is predicated on the notion that there may be seasonal variations of phosphorus loading in the watershed, and that sink ponds may be more efficient than has been calculated.

Section 5.3 Alternative # 2 Dredging, Larger Sink Pond and Diversion

During the interview process certain committee members acknowledged the conclusion of the 1990 EVS report noted above. Anticipating that alternative # 1 may not improve water quality to public health standards, or facilitate the desired changes to trophic status of the lake, it was suggested that as a second alternative, an expansion of the project could be considered. Committee members suggested that this expansion should address, the nutrient, and coliform inputs from creeks 11,12, 13, 16 and 17 (See appendix # 3).

In total these creeks represent an additional 39% of the total phosphorus loading into the lake. In a 1982 water quality study for Deer Lake, Beak proposed a two part project. First they proposed a 50% larger sink pond than the one proposed for creek # 3, to be located in the south west corner of the park. Beak anticipated that this pond would occupy 6.75 acres, and efficiently handle all the inputs from creeks 11,12, and 13, as well as the inputs from creek 3. The second part of this project proposed the diversion of creeks 16 and 17 into the outlet channel of Deer Lake, which drains into Burnaby lake, and ultimately the Brunette river system. This two part storm water diversion had an estimated cost of 1.2 million dollars in January 1982 prices. The diversion system requires a 10 meter wide and 2.96 km long right of way. The average depth of the pipe would be about 3 meters. The diversion of creeks 11,12, and 13 plus the inputs from creek three, assuming a 50% efficiency rate in the constructed wetlands may reduce the annual phosphorus load by 112 kg (Beak 1981). The diversion of creeks 16 and 17 is expected to reduce annual phosphorus loading into the lake by 30-40 kg. In total this project could reduce phosphorus by 152 kg/yr. For the purposes of this paper the Beak proposal has been adopted as alternative # 2. The diversion recommendation in the 1982 Beak report was originally set aside by the City because of the costs involved, and the scale of the project. However, Beak does provide some interesting insights into what it might take to accomplish the fundamental objectives of the committee. The Beak report also conveniently provides a data set that can be used for the purposes of this first run analysis. Therefore, alternative # 2, includes diversion, the sink pond project proposed by Beak, and the dredging proposal

outlined in the 1990 EVS report. The three alternatives used for this first run analysis are summarized below.

Alternatives For This Multiple Account Analysis:

1) Alternative # 1: Limited Sink Pond and Dredging.

a) Construct a sink pond on creek three to handle storm water inputs from that section of the watershed.

b) Dredge a portion of the shallow regions of the lake.

2) Alternative # 2: Total Control Sink Pond, Diversion, and Dredging.

a) Construct a sink pond that will handle the storm water inputs from creeks 3, 11, 12, and 13.

b) Divert streams 16 and 17 into the lake outfall.

c) Dredge a portion of the shallow regions of the lake.

3) Alternative # 3: Water Management Programs.

During the interview process it was possible to reach a consensus on a new or a partially recycled alternative. All committee members agreed that alternative # 2 should be considered as lake restoration solution. The origins and specifics of all three alternatives including the water management programs are described in section 5.2 to 5.3. The impact of the three alternatives listed above are assessed in chapter 6.

CHAPTER 6
ASSESSING THE IMPACTS

The overall or strategic objective of this project is to make the best decision regarding the future of Deer Lake. Attainment of the overall strategic objective is assessed with four accounts. For this multiple account analysis the four objectives are to minimize costs, minimize environmental impacts, maximize aesthetic benefits, and maximize recreational benefits. These four objectives are the accounts used to evaluate the impacts of the three alternatives discussed in chapter 5. Costs are subdivided into long term and short term, and are assessed in 1995 dollars. Environmental impacts include the long term terrestrial and aquatic impacts, as well as the short term impacts. The attributes used to measure the achievements of the environmental objective are described as the magnitude of impact and the size of the area affected. Fundamental objective # 3 is to maximize the aesthetic benefits to Deer Lake. The achievement of aesthetic benefits is measured by the percentage change in certain water quality measures. Maximizing recreational benefits is the final fundamental objective, which is broken down into the short term and long term probability of regaining lost swimming and fishing opportunities. The recreational water sport benefits are assessed with the probability of achieving a prescribed environmental, and public health standard that would promote, or allow the resumption of these activities in Deer Lake. The proxy attributes used are, the probability of meeting standards for total suspended solids (TSS), phosphorus, and fecal coliform. All four of the fundamental objectives and the overall strategic objective are graphically represented in Fig # 4.

This chapter is divided into four sections. Each of the four accounts (represented by the four fundamental objectives) will be evaluated in order. Attributes are used to measure the performance of each of the three alternatives. The last section provides a graphic summary of all the impacts. The multiple account summary in table # 14 section 6.5, summarizes the impacts of each of the three alternatives.

6.1 Objective Minimizing Costs:

There are significant costs involved in all three of the proposed alternatives. Some of the costs are real, some are intangible, however, all costs can be described as either short term or long term expenditures. Cost estimates are based on the best information available at the time of this study. Unless otherwise noted, cost estimates for this analysis have been derived from John Kirbyson's 1991 Cost Benefit Analysis of the Deer Lake project. Many of the costs that Mr. Kirbyson used, were estimated by Burnaby staff or by consultants. Mr. Kirbyson's 1990 cost estimates were brought forward to 1995 dollars using CPI indexes.

The long term costs are considered for a fifty year period. According to Mr. Kirbyson, this is the more optimistic estimate of the project's longevity, and based on normal discount rates is the time at which "most costs and benefits become negligible"(Kirbyson 1991, 49). This fifty year period does not, however, reflect all expert estimates of the performance longevity of the different treatment options being considered.

In their 1990 report EVS consultants suggested that sinkponds could provide five years of optimal performance. Hamilton suggests that sinkponds with the proper maintenance can provide sustainable performance into the long term. For dredging, Cooke "points out that increased lake depths due to dredging can be reversed by sedimentation in as little as 10 years" (Cooke 1993, 452). EVS also suggests that dredging benefits, given the proper maintenance, could last longer than twenty years. John Kirbyson's cost benefit analysis was assessed for a fifty year and thirty five year time frame. This was done to provide an optimistic as well as a pessimistic view of the projects uncertain longevity. Sources that have been reviewed for this proposal, present inconsistent predictions regarding the longevity of either dredging or sink ponds. However, most experts agree that the success of a combined approach will depend on the conditions within the lake's watershed, and on how well inputs into the lake from the watershed are managed. To accommodate the uncertainty over the effectiveness and longevity of the treatment options, annual and remedial maintenance costs have been included. The remedial maintenance cost would include sediment and macrophyte removal from the lake, and from the sink

ponds. Remedial maintenance may be required every five or ten years depending on the need. For this multiple accounts analysis, remedial maintenance costs are based on a ten year schedule.

There are other tangible as well as intangible costs not included in this analysis. During the construction phase of the project there are expected inconveniences that will affect park users and residents within close proximity to the park. Intangible short term construction costs such as noise and dust are excluded. Members of the committee felt that these are short term inconveniences that are an expected part of any city construction project, and therefore do not need to be included. Due to a lack of data, previous expenditures on commissioned studies, pilot projects or source controls have also been excluded. The health costs of eating contaminated fish or illegally swimming in a polluted lake were not identified by the committee as being important, and as such have been also omitted from the analysis.

Tangible costs include trading what is now 4.5 ha. (See alternative # 1) and 6.75 ha. (See alternative # 2) of usable terrestrial park area for the construction of the two proposed sink pond options. It is possible to evaluate the dollar value tradeoff of exchanging 4.5 or 6.75 hectors of existing forest for newly created wetland habitat. The proposed constructed wetlands provide habitat for different kinds of aquatic flora and fauna. Species that are unique to wetland ecosystems are not well represented in the park and would be considered as appreciable assets gained from the construction of sink ponds. In the interests of promoting biodiversity, members of the committee felt that sacrificing a small portion of the parks forested area for wetland construction was an equitable tradeoff.

6.1.1: Cost of Alternative # 1 ; Limited Sink Pond and Dredging

The cost for alternative # 1 includes the long term remedial and annual maintenance costs for sink ponds and dredging. Annual maintenance for the periodic harvesting of aquatic plants, adjustment of water flow and the control of unwanted insects is included. Nineteen ninety-one yearly maintenance costs are estimated at $8,275 per year for dredging, and $33,586 per year for sink ponds. Remedial maintenance mentioned above, represents a system overhaul, and includes among other things, a cyclical re-dredging of the lake every ten years, and the periodic removal off sediments from the constructed wetlands. Estimated in 1991 dollars, the ten year remedial maintenance estimate for sink ponds was $66,970, and for dredging $202,500.

Short term costs include the direct capital cost of, dredging, sink ponds, and the removal of toxic dredge sediments. Dredging costs in 1991 dollars were estimated at $1.6 million. Sink pond construction costs were estimated at $1.2 million. Disposal costs for the removal of toxic dredge material to a sanitary land fill are estimated at $405,000. The short term capital costs for sink pond constructing on Creek # 3 were originally based on a single design, and construction proposal from Phillips Barrat Kiaiser Engineering in 1989. Dredging costs are derived from Ceda Dredging proposal estimates. Initially sediment removal costs were not included in the dredging estimate, because of the uncertainty regarding the toxicity of the lake sediments. In his cost benefit study Mr. Kirbyson anticipated that there could be additional cost not included in his study if lake sediments exceeded BC government guidelines for Class C toxic materials. Consultants determined that both copper and extractables (mineral oil and grease) have exceeded BC Ministry of Environment Level B remediation guidelines for residential or parkland sites (EVS 1993). However, samples taken do not meet or exceed Level C for remediation of commercial or industrial sites. This means that the City cannot however, decontaminate the dredge spoils on site but can apply for permits to remove the de-watered dredge material to a local sanitary landfill. Therefore, the original costs mentioned above, and estimated by Mr. Kirbyson, are appropriate for this analysis.

All the costs for alternative # 1 are presented in table # 3 below. For all three alternatives, capital costs are considered as a onetime expenditure. Remedial and annual maintenance costs are represented as present value (PV) using a discount rate of 8%.

Table # 3 Costs for Alternative # 1

	LONG TERM COSTS		SHORT TERM COSTS			
ALT. # 1	Annual Maintenance PV	Remedial Maintenance PV	Capital Cost of Dredging One time	Capital Cost Sink Pond One time	Sediment Removal One time	Total Cost for Alt #1
1995 $	**0.53 million**	**0.19 million**	**1.9 million**	**1.7 million**	**0.41 million**	**4.72 million**

6.1.2: Cost of Alternative # 2 :Total Control Sink Ponds, Dredging and Diversion:

There are two significant cost differences between alternatives # 1 and # 2. Alternative # 2 includes the diversion of a number of inlet streams, and the construction of a larger sink pond to accommodate the diverted storm water. Estimates for the diversion project are based on some preliminary figures assessed by Ken Priestman and Associates, and summarized in the 1982 Beak report. In this report it was estimated that a total of 1.2 million (January 1982) dollars would be needed to complete the proposed sewer diversion project. The Beak report included three options for the construction of the larger sink pond that would be required to handle the increased volume in storm run-off after diversion. Option three in the 1982 Beak report was "deemed to be the most practical when addressing purpose and cost" (Beak 1982, 7-12).

The cost of a total control sink pond including the cost of hauling away construction material was estimated at $1.8 million (1982 dollars). The sink pond for the Beak proposal is about 1.5 times the size of the one suggested in alternative # 1. Estimates for remedial and annual maintenance for the larger sink pond are taken from Mr. Kirbysons work. CPI figures are used to bring the 1982 costs up to 1995 dollars. Table # 4 below presents the 1995 dollar estimates for alternative # 2. An 8% discount rate was used to calculate present value.

Table # 4 Costs for Alternative # 2

	SHORT TERM COSTS			LONG TERM COSTS			
ALT. # 2	Annual Maint. PV	Remedial Maint. PV	Cap. Cost Dredging One shot	Cap. Cost Sink Pond one shot	Cap. Cost Diversion One shot	Sediment Removal One shot	Total cost Alt #2
1995 $ in millions	**0.74**	**0.22**	**1.8**	**2.0**	**1.8**	**0.41**	**6.97**

Section 6.1.3 Lost Opportunity Cost for Potential Fishing and Swimming Opportunities:

For this analysis, the lost opportunity costs (LOC) of fishing and swimming for 50 years into the future are the benefits of a successful restoration and management project. The LOC for these two recreations are assessed as the dollar benefits for all three alternatives. The assessed values for the LOC of these two recreational activities represent the benefit side of Mr. Kirbysons cost benefit equation. Mr. Kirbyson used previous Ministry of Environment, and City recreational user surveys to establish the number of expected fishers and swimmers that would use Deer Lake in the post restoration years. The estimates of swimmers include a high, low, and base estimate of 63,976; 47,600; and 55,788 respectively. Mr. Kirbyson set the number of expected swimmers at 50,000 per year. The two estimates for the annual number of angler days ranged from a low of 2,275 to a high of 20,000. For this study Mr. Kirbyson's base estimate of 15,000 angler days per year is the figure adopted for this study (Kirbyson 1991, 63).

To estimate the dollar value of a day of swimming, and a day of fishing Mr. Kirbyson used a number of different sources to establish a range of possible values. Estimates are derived from

Contingent Valuation (CV), Willingness to Pay (WTP), Compensation Demanded, and Travel Cost Method (TCM) studies done for other lakes in the US and Canada. For a detailed explanation of how these methods calculate a dollar value for these activities, the reader should refer to Mr. Kirbyson's work or to other sources in the literature. All of these methods depend on a considerable amount of subjectivity to express values in dollars.

There are no completely objective assessments of the true market value for a day of swimming or fishing. However, one market value estimate used in Mr. Kirbysons study for his low estimate of a day of fishing was derived from the cost of taking a fish from a U catch operation in Aldergrove. This cost a customer $13.56 including taxes, but excluding travel costs. The high estimate of $25.29 is based on the subjective studies mentioned above. For the purposes of this study, a day of fishing in Deer lake has an estimated value of $20.00 (Kirbyson 1991, 70). This figure represents the rounded off average of these two estimates plus the annual rate of inflation since 1991. Similarly The "base price for a day swimming in Deer lake was set at $5.00 with sensitivity estimates of $2.86 for the pessimistic scenario and $6.90 for the optimistic scenario" (Kirbyson 1991, 71). The base value above of $5.00 for a day of swimming is the one used for this analysis. Using a 8% discount rate for the projected fifty year life time of the project, the dollar figures for the long term lost opportunity of fishing, and swimming in Deer lake is provided in Table # 5 below.

Table # 5 Potential Recreational Benefits for Alternatives #1, 2, 3.

LONG TERM

ALT # 1,2,3	Lost Opportunity Cost of Fishing	Lost Opportunity Cost of Swimming	Total L.O.C.
$1995 in millions	**4.0**	**3.3**	**7.3**

The LOC figures listed in table # 5 represent the benefits of a successful project as well as part of the costs of an unsuccessful one. Assuming success, previously listed capital and maintenance costs could be subtracted from these recreational benefit figures to obtain the potential net present value (NPV) of each alternative. The calculated potential NPV for each alternative is listed in the final multiple account assessment at the end of this chapter. Since there are to date no capital or maintenance cost

estimates for alternative # 3 the NPV for continuing water management strategies is left out of this assessment but may be included once figures are available. Table # 6 below provides the cost account summary for all three alternatives.

TABLE # 6: COST ACCOUNT FOR ALTERNATIVES #1, #2, and #3: OBJECTIVE IS TO MIN. COSTS.

(All Costs in Millions of Dollars, PV = Present Value, NPV = Net Present Value)

Type of Cost	Alt. #1	Alt. #2	Alt #3	PV/ ONE SHOT
Annual Maintenance	- 0.53	- 0.74	NA	PV
Remedial Maintenance	- 0.19	- 0.22	NA	PV
Capital Cost of Dredging	- 1.9	- 1.8	NA	ONE TIME
Capital Cost of Sink Ponds	- 1.7	- 2.0	NA	ONE TIME
Sediment Removal costs	- 0.41	- 0.41	NA	ONE TIME
Capital Cost of Diversion		- 1.8	NA	ONE TIME
Lost Opportunity Cost of Fishing	4.0	4.0	4.0	PV
Lost Opportunity Cost of Swimming	3.3	3.3	3.3	PV
Potential Total NPV	2.57	0.33	NA	IN 1995 $

To calculate the expected value of each restoration alternative the potential NPV figures will have to be multiplied by the probability of a successfull project. These figures are represented in the final multiple account summary in table # 14.

SEC 6.2 Minimizing Environmental impacts:

There are a number of unwanted side effects associated with dredging and constructed wetlands (EVS 1990). Many of the environmental impacts identified involve both terrestrial and aquatic ecosystems. EVS documented some project contingencies, and mitigation measures that might reduce or eliminate environmental impacts associated with dredging, and the construction of sink ponds. The EVS report also provided a subjective assessment of the size of area affected, and the expected severity of the impact. This information along with similar kinds of data contained in the Deer Lake Park Natural

Resource Analysis provides the foundation for this part of the MAA . Besides developing the environmental impact assessment model for the three alternatives, this section of the paper will also provide a brief survey of the expected environmental impacts contained in these two reports.

6.2.1 Impacts From Dredging

Dredging Deer Lake is "an option to improve the water quality and aesthetics of the lake" (Searing 1988, 7-83). Consultants suggest that approximately 90% of the shallow regions around the perimeter of the lake should be dredged. This area represents about 30% of the total lake area. Wildlife consultant, Gary Searing, has told the City that dredging can have a "profound" impact on both aquatic and terrestrial ecosystems. The re-suspension of sediments is one of the more common short term problems associated with dredging. Dredge agitation and wind action affects the amount of sediment re-suspension. The cutter dredge technology that Ceda is proposing for the Deer Lake project is noted for its problematic re-suspension of sediments. The resulting turbidity plumes re-introduce nutrients, and toxic chemicals contained in the lake sediment back into the water column. EVS has determined that the re-release of toxic chemicals could have a negative impact on both benthic organisms, and fish populations in the lake. Ceda dredging argues that disturbing sediments, and contaminating the lake with toxic residues is not a significant issue because there are no notable populations of "sport fish left in the lake to worry about" (EVS 1990, 34).

Nutrient enrichment caused by dredging can be a catalyst for alga blooms, which are both aesthetically unpleasant, and can pose a potential health risk to swimmers. The severity of alga blooms caused by the re-suspension of sediments is affected by the amount of available light, water temperature, nutrient release from sediments and the flush rate of a particular system. The Ceda proposal anticipates dredging the lake during the spring to take advantage of a potentially high storm water run-off. Consultants hope that the volume of spring storm discharge will clear the lake of turbidity plumes, thus reducing the chance of alga blooms.

Taking advantage of spring runoff to clear off any of the re-suspended sediment is a benefit for Deer Lake, but may be problematic for the downstream watershed that drains into Burnaby Lake. Spring is also the time of year when water temperatures start to rise, and daylight hours increase. Temperature and increased light, combined with the re-suspension of nutrients, would likely encourage an increase in alga growth throughout the lake. Consultants maintain that all the problems mentioned can be controlled with proven mitigation measures.

Other in-lake problems associated with dredging include lake draw-down, and the possible decimation of beneficial insects that live in the lake sediments. Lake draw-down is aesthetically unpleasant and may have a significant negative impact on flora and fauna that inhabit the shallow regions around the periphery of the lake. Dredging removes contaminated sediments. At the same time however, dredging also destroys insect populations that form an important part of an aquatic food chain. If these benthic organisms do not rebuild their populations in the short term, then any future re-stocking of the lake with trout may be unsuccessful.

The terrestrial environmental affects of de-watering the dredge spoil on site are "a major concern" (EVS 1990, 29). In the United States, EPA requires a federal permit for any dredging project that will de-water dredge spoils on wetland areas greater than four hectors. For alternative # 2, a minimum of 3.6 ha. is required to hold, and de-water the dredge spoils. Beak has proposed that the de-watering pond be located in a disturbed area that was once used for farming. This part of the park is described as a moderate impact zone that has limited portions of valued wetland. There is potential short term environmental risk to local plant species and to animals that depend on this area for shelter and food.

A large dammed area is needed to contain and de-water the dredge material. The dredge slurry can be as much as 90% water. If the pond area is under designed the de-watering of the toxic slurry may take longer than necessary. This could pose a long term potential risk to aquatic birds and other species that may come in contact with the toxic dredge material. Decomposing organic materials in the dredge slurry have unpleasant odors, and support the growth of unwanted insect populations. There is also concern over the possibility of re-introducing nutrients back into the lake through the ground water

system, and from surface run-off. Finally, there is always a chance that the dam may break and inundate valuable surrounding park land.

Short term in-lake, and down stream problems noted above can be mitigated or avoided (EVS 1990). Consultants suggest that, choosing the right dredging technology, and implementing specific mitigation measures, can all help to reduce the scope of these environmental impacts. Predictions are, that the "impacts of a well-designed dredging program on benthic organisms and sport fish are likely to be short-lived and tolerable relative to the longer-term benefits" (EVS 1990, 28). Major short term environment concerns include, impacts from de-watering dredge material on site, and construction impacts on noise and air quality. "Construction of settling ponds will remove habitat for some birds and small mammals. ... The anaerobic lake sediments, decomposing plants and animals ...in de-watering ponds may cause a considerable odor problem in the park" (EVS 1990, 47). For the purposes of this assessment only short term terrestrial impacts from storing the dredge spoils in the South west corner of the park are considered.

In the long term there is concern over the aquatic impacts of maintaining the dredged area. Annually, aquatic plants are harvested to maintain the aesthetic advantages gained from dredging. "In addition, remedial maintenance will be required, since the benefits of dredging are predicted to last only from five to twenty years" (Kirbyson 1991, 55). Remedial maintenance is required every tenth year. This involves the removal of sediments that have accumulated during the ten year period. To reduce nutrients and toxic materials in lake sediments, EVS has recommended that 30% of the periphery of the lake be dredged down to a maximum depth of three meters. This area is to be maintained on a regular basis with annual and remedial maintenance. In the long term this means that 30% of the lake will be reasonably maintained as an area with limited amounts of plant and insect life. Consultants suggest, that leaving 70% of the lake undisturbed will support healthy natural populations of flora and fauna in the entire lake. "Dredging and related activities will have a profound affect on the productivity and habitat availability of the lake for wildlife. ... Deepening the lake by 1 meter ...will render much of the previous shallow water zone of the lake unattractive and unavailable to many species of waterfowl and frogs. The effect will be approximately proportional to the extent of the shoreline that is dredged" (Searing 1988, 7-84). The long

term aquatic environmental impacts modeled in this analysis refer to the portions of the lake that the City plans to dredge and maintain in the long term.

6.2.2 Impacts of Construction of Wetlands

Building wetlands in the western regions of the park, is a major feature common to both alternatives # 1, and # 2. The Deer Lake Park Natural Resource Analysis and Recreational Land Use Plan (Referred to in the future as the Deer Lake Land Use Plan) describe this area as a high impact zone. The Deer Lake Land Use Plan singles this area out, as one that has many unique plants and animal species, that have ecological as well as visual importance.

Although very close to a natural system, constructed wetlands are not a benign technology. Environmental issues include, increased levels of nuisance insects, the loss of flood control capacity, the loss of transitional plant and wildlife habitat. Wetlands also provide attractive habitat for nesting and feeding birds. Birds are identified as a significant contributor to high coliform counts in Deer Lake.

The decrease in flow capacity may result in the flooding of upstream habitat, including forested, and grassland areas. An increase in mosquito populations is one of the more common complaints of residents who live close to constructed wetlands. Increased water temperature is associated with the decrease of oxygen in the lake, and an increase in concentrations of unwanted blue green algae. "To demonstrate that these concerns are not warranted involves a system design that provides for abatement of mosquito problems, a net removal of material from the flood basin, adequate flow capacity to prevent upstream flooding and no net loss of transitional environment" (EVS 1990, 33). Consultants maintain that, most of the problems mentioned above can be controlled. However, the loss of valued terrestrial habitat still remains as an unavoidable consequence of building a sink pond in the western portion of the park. It is anticipated by consultants that "pond development will severely alter existing land use and vegetation cover types" (Searing 1988, 7-82).

To date there is still considerable debate over which site should be the location for the proposed network of sink ponds. The most current proposal is to construct a series of ponds "along creek three" which is an area that is particularly vulnerable to development(Johnston 1991, 4.0). Consultants propose the implementation of an annual, and remedial maintenance program to maintain a productive, efficient and healthy constructed wetland. "The aquatic macrophytes must be harvested regularly ... to eliminate the phosphorus and nitrogen accumulated in the plant tissues. ... A remedial maintenance program will also be required on the ponds to remove contaminated sediments" (Kirbyson 1991, 58). Therefore, the wetland system will remain as a controlled ecosystem for the long term. This will have an environmental impact on indigenous wildlife, and plant species currently found in the area scheduled for construction. "The development of this pond must be considered both, as a potential source of disturbance, and as a loss of habitat" (Searing 1988, 7-83). Environmental concerns modeled by this assessment include the long run terrestrial impacts to vegetation and wildlife in the proposed construction area.

6.2.3 Impacts of Diversion

There are no specific environmental impacts identified in any of the existing documentation regarding the proposed storm water diversion project. However, the Beak report has mapped out a preliminary location for the diversion of creeks 11,12, and 13 (See appendix # 3). By overlaying this graphic information on top of the vegetation and wildlife development impact maps in the Deer Lake Land Use Plan, it was possible to determine the expected magnitude of the environmental impact for the sink pond diversion part of the project. The proposed diversion right-of-way traverses a heavily forested area, described as a major to moderate wildlife zone, with moderate to high development impact potential. This forested area already has a number of existing rights-of-ways, roads, and paths. For this analysis, the location of the proposed sewer right-of-way is considered as a disturbed ecosystem. As such, the constructed portion of the proposed diversion project is considered to have moderate impact on vegetation and moderate impact on wildlife.

The other phase of this project involves the direct diversion of creeks 16 and 17 into Deer Lake's single outlet stream. There is no data regarding the downstream impacts of diverting these two streams

into the receiving waters of Burnaby Lake. Burnaby lake suffers from the same maladies as Deer Lake, and is also a candidate for City restoration and management initiatives. The drainage from Deer Lake is one of many sources of storm discharge into the much larger Burnaby lake. Therefore, for this part of the analysis the additional storm water inputs from creeks 16 and 17 are assumed to have minimal downstream environmental impact. However, if it is determined that these potential downstream environmental impacts are important they can be included later once the necessary data is collected. For this first part of the project, the only impacts from diversion that are considered, are the long term terrestrial impacts of maintaining a cleared right of way in a previously forested area.

Many of these environmental impacts are explained in greater detail in the 1990 EVS report. In addition to a detailed discussion about the likelihood of the various impacts, and the prescribed mitigation measures, the EVS report also provides a graphic summary of the environmental impacts. The 1990 report contains considerable documentation about the type of area affected, and the severity of impact. A graphic summary, provided in the form of a Leopold Matrix, expresses the size and scope of impact as a fraction. To illustrate, one cell in the matrix describing the impact of dredging on wildlife might have a fraction of high/med. Translated, this means a high environmental impact on a medium sized area. The EVS document, in part, derived its environmental impact summary from the 1988 Deer Lake Land Use Plan. This plan details the environmental sensitivity of all areas in the park. These two sources of information represent the accumulation of a number of subjective expert judgments about the scope and magnitude of environmental impacts. Both sources, with some modification, provide the basis for the numerical evaluation of these impacts provided in this assessment

6.2.4 Environmental Impacts of Alternative # 3: Water Management Strategies

Water management strategies such as street sweeping and bird control will not by themselves return Deer Lake to some former and more desirable trophic state. Experts agree that restoration as well as source controls will be required to resume water sport recreation in the lake. In his 1991 master's thesis, John Kirbyson identified the expected outcome of doing nothing to restore and maintain water the water quality of Deer Lake. The impacts included the loss of swimming and fishing opportunities, the decline in boating experience, restrictions in park development options, and the "continual degradation in lake aesthetics" (Kirbyson 1991, 48). Most of these impacts are recreational or park development impacts, rather than environmental impacts, and are implicitly or explicitly modeled in the "minimizing costs" part of this analysis. The continued decline in lake aesthetics is a consequence of untreated storm water reaching the lake. If potentially damaging activities within the watershed go unchecked, the environmental degradation of the lake would be expected to continue into the long term. "If no measures are taken and the lake is allowed to continue its present rate of deterioration, its value as a park resource will greatly diminish, and any effort to restore the lake, subsequently will result in much higher costs. ... Deer lake may rapidly change from the community gem to the community eyesore" (Beak 1981, 1-2). In the literature it is roughly estimated that management strategies or source controls such as the ones already implemented by the City will at best improve certain water quality problems by ten percent (Foran 1991). Due to a lack of information the environmental impact of the pursuing water management options only is not definitively modeled in the first part of the decision making process. It is acknowledged that there are significant benefits to these types of programs, and as such should be included as part of the final analysis. This requires expert assessment of the magnitude, likelihood, and duration of the expected environmental impacts. For this part of the analysis, only restoration alternatives # 2 and # 3 that are intended to restore the lake to a mesotrophic state and maintain water quality entering Deer Lake will be modeled in this first stage of the analysis.

6.2.5 Environmental Impacts of Alternative # 1: Limited Sink Pond and Dredging:

Two basic attributes are considered for measuring environmental impact. The first attribute, magnitude of impact, is based on the subjective assessment contained in the 1990 EVS report, and in the 1988 Deer Lake Park Plan. The second attribute considers the size of area directly affected by the proposed restoration or management alternative. Both the EVS report and the Deer Lake Park Plan express environmental impact as low, medium or high impact. The size of impact is represented as a percentage of the total area of the ecosystem that is affected. There are two ecosystems that are considered, the first is the terrestrial part of the park, and the second is Deer Lake itself. The park has a total area of 195 ha and Deer lake has an area of 35 ha.

Alternative # 1 proposes, dredging the lake and de-watering the dredge spoils on 2.4 ha of park land. Consultants concluded that de-watering the dredge spoils in the western region of the park, will have a short term, low impact on vegetation and wild life (EVS 1990). When considering air quality and noise levels, the impact area considered is the entire park, and EVS describes this as a short term high impact zone. "The anaerobic lake sediments, decomposing plants and animals in de-watering ponds may cause considerable odor problems in the park" (EVS 1990, 47). For example, the short term impact on vegetation is represented as the ratio of dredge spoil area of 2.4 ha to total park area of 195 ha, and the value impact is described as low.

Table # 7 summarizes the short term terrestrial impacts for alternative # 1.

Table # 7: Short Term Terrestrial Impacts.

Impact on	Mag. of impact	Area impacted	Total Area	% 0f Total Area
Vegetation	Low	2.4 ha	195 ha	1.2%
Wildlife	Low	2.4 ha	195 ha	1.2%
Noise & Air	High	195 ha	195 ha	100%

Long term terrestrial impacts are a consequence of building a 4.5 hectare constructed wetland in the western region of the park. According consultants, this area will be maintained as a wetland, and is expected to have high long term impacts on both wildlife and vegetation Table # 8 below represents the calculated impacts.

Table # 8: Long Term Terrestrial Impacts.

Impact on	Mag. Of Impact	Area Impacted	Total Area	% Of Total Area
Vegetation	High	4.5 ha	195 ha	2.3%
Wildlife	High	4.5 ha	195 ha	2.3%

Dredging will have a long term impact on 30% of the lake or 10.5 hectares. These are long term affects because the City has proposed to annually maintain this area, and re-dredge it every tenth year. Experts consider Deer Lake a high development impact zone. Table # 9 represent the calculated impacts.

Table # 9: Long Term Aquatic Impacts.

Impact on	Mag. of Impact	Area impacted	Total Area	% Of Total Area
Vegetation	High	10.5 ha	35 ha	30%
Wildlife	High	10.5 ha	35 ha	30%

6.2.6: Environmental Impacts of Alternative # 2: Sink ponds, dredging and diversion:

The scale of the dredging project proposed for alternative # 2 is the same as in alternative # 1. Therefore, the magnitude and percentage area figures for short term terrestrial and long term aquatic impacts are the same as in table # 7 and # 9 above.

Alternative # 2 proposes a larger sink pond to handle the volume of storm water discharge from the diversion of creeks 11,12, and 13. The sink pond for this project will cover an area of 6.75 ha. The diversion project will require a right of way 2.96 hectors. Both of these areas will be maintained in the long term, and as such will have long term impact on vegetation and wildlife. According to EVS the sink

pond location is in a high impact zone for both vegetation and wildlife. Referring to the Deer Lake Park Plan, the diversion right of way traverses a vegetation zone that is described as having a high development impact. This diversion is also expected to have a moderate to high impact on wildlife. Table # 10 models the long term terrestrial impacts of diversion and construction of a larger sink pond.

Table # 10: Long Term Terrestrial impacts.

Impact on	Mag. Of Impact	Area Impacted	Total Area	% Of Total Area
Vegetation	**Moderate to High**	**9.71**	**195**	**5%**
Wildlife	**Moderate to High**	**9.71**	**195**	**5%**

Table # 11 below contains all of the individual values for alternatives # 1 and # 2.

Table # 11: SUMMARY ACCOUNT FOR ENVIRONMENTAL IMPACTS: OBJECTIVE IS TO MIN. ENVIRONMENTAL IMPACT.

	Alternative # 1		**Alternative #2**	
Description	Magnitude	% of Total Area Impacted	Magnitude	% of Total Area Impacted
Short Term Terrestrial Impact				
On Vegetation	**Low**	**1.2%**	**Low**	**1.2%**
On Wildlife	**Low**	**1.2%**	**Low**	**1.2%**
On Air and Noise	**High**	**100%**	**High**	**100%**
Long Term Terrestrial				
On Vegetation	**High**	**2.3%**	**Moderate to High**	**5%**
On Wildlife	**High**	**2.3%**	**Moderate to High**	**5%**
Long Term Aquatic				
On Vegetation	**High**	**30%**	**High**	**30%**
On Wildlife	**High**	**30%**	**High**	**30%**

SEC 6.3: MAXIMIZING AESTHETIC BENEFITS TO THE LAKE:

Aesthetic characteristics often influence public perception of a healthy lake. Water clarity, odor, color, and turbidity all affect the sensory appeal of spending time near, or on a lake. Different water quality parameters in the watershed may influence the aesthetic features of a lake. "The two principle factors causing the deterioration of Deer Lake are high phosphorous concentrations and high silt load" (Beak 1982, 2). The relationships between the aesthetic features of a lake, phosphorous loading, and siltation are complex and indirect. Over fertilizing a lake with phosphorus encourages summer blooms of algae, which in turn has an impact on turbidity. High concentrations of nutrients may also cause the formation of green oily patches of scum on the water surface. Alga blooms and a high sediment load from urban storm water both contribute to odor problems. Sediment mixing and planktonic growth encouraged by increased fertilization, and heavy silt loading contributes to high turbidity, and a green/ brown water color. This is an in-lake, and watershed problem.

The most desirable attributes to measure the impacts of alternatives are natural attributes, such as the cost in dollars used to measure the economic impacts. Natural attributes make a clear and definitive statement of the direct impact of each alternative considered in this decision. It would also be desirable to know what measurable attributes directly affect the aesthetic features of Deer Lake. Due to the complex interaction of different biological and chemical factors there appears to be no natural attribute, like dollars, which can be used to evaluate the improvement to each of the aesthetic features noted above. However, from the reports done to date, it appears that change in phosphorus concentrations, and in the amount of total suspended solids may serve as an indirect measure of the aesthetic improvement to the lake. The percentage changes in these chemical, and physical water quality parameters may serve as proxy attributes, to measure improvements to the aesthetic qualities of Deer Lake. "The relationship between the proxy attributes and the environmental degradation is very complex. It is nevertheless precisely this relationship that is necessary to evaluate the relative desirability of alternatives intended to reduce the pollutant concentrations" (Keeney 1992, 112). Therefore the two attributes used for measuring improvements to lake aesthetics are the percentage change in phosphorous and percentage change in total suspended solids (TSS).

Alternative # 3 is not expected to improve any of the aesthetic features of the lake and is therefore omitted. Alternatives # 1 and # 2, which involve dredging the lake, diversion, and the construction of sink ponds are part of this analysis. In the short term, dredging out the phosphorous contaminated sediments and removing the plants that recycle nutrients back into the lake, is expected to have an immediate impact on reducing phosphorus levels.

The annual and remedial maintenance programs, are expected to maintain the short term gains in nutrient and sediment control from dredging, into the long term. Constructed wetlands should reduce both the sediment loads, and phosphorous contained in the storm water runoff. EVS maintains that sink ponds will take some time to reach maximum efficiency. This means that the short term impacts will be different from the long term.

6.3.1 Aesthetic Benefits of Alternative # 1

The expected short term percentage change in phosphorous from dredging is derived from the 1990 EVS report. Fourteen percent of the total phosphorous loading in Deer lake comes from aquatic plants. Three percent of the total phosphorous (P) budget for Deer Lake is attributed to the re-absorption of chemical fertilizer contained in lake sediments. Ceda dredging is proposing to remove 90% of the lake plants and 30% of all lake sediments. Therefore the total expected short term reduction in phosphorous from dredging is, (90% x 14%) + (30% x 3%) = 13.5 %.

The 1990 EVS report predicts that short term P removal efficiencies for sink ponds will initially start out at 50% of the maximum expected efficiency level. Ultimately these efficiencies should reach a sustainable level of approximately 75% of the maximum predicted performance. In the short term then it could be expected that sink ponds may have an average performance of 62% efficiency. Alternative # 1 proposes, building a limited sink pond to control storm water discharge from creek three. Creek three contributes 25% of the total Deer Lake phosphorus budget. Data from Knight, Ruble, Kadlec, and Reed's sink pond performance data base, (citing over 60 examples, see appendix # 1) indicate that on

average constructed wetlands can be expected to remove a maximum of 54% of the phosphorous entering the system (Knight 1993, 48). Therefore in the short term Alternative # 1 should remove 54% x 62% x 25% = 8%. In the short term then dredging and a sink pond for creek three should remove 13.5% + 8% = 21.5% of all total phosphorous budget for Deer lake

To calculate the short term percentage change in TSS, it is assumed that sink ponds will need the same time to reach maximum efficiency for the removal of sediments as they do for phosphorous removal. Furthermore, it is assumed that the same individual inputs for phosphorous from the different creeks represented on page 22 of the EVS report will apply to TSS inputs. Moreover it is assumed that there are in-lake contributions as well as external watershed contributions made to TSS in Deer Lake. "During the fall, winter and spring, major sources of turbidity are suspended particulates from watershed runoff and stirred up sediments" (Beak 1982, 4-12). Therefore in the short term, dredging is expected to remove (30% x 3%) + (90% x 14%) = 13.5% of TSS.

Recent information indicates that sink ponds on average remove 68% of the TSS. (Knight 1993, 48) Creek # 3 contributes 25% of the total TSS inputs, and sink ponds are expected to have a short term efficiency of 62%. Therefore the expected short term percentage change in the removal rate of TSS from a sink pond on creek # 3 should be 68% x 25% x 62 % = 10.5%. Combining the two estimates, the total expected short term change in TSS for alternative # 1 would be the sum of 13.5% + 10.5% = 24% in TSS.

The long term efficiency rate for the removal of phosphorous and TSS should increase to 75% from 62% (EVS 1990). It is expected that this performance efficiency will be maintained in the long term because of the planned remedial and annual maintenance programs. It is also expected, by maintaining the dredged areas annually, and re-dredging every 10th year, that the gains in P and TSS removal from dredging can be continued into the long term. The percentage change in P from dredging should in the long term remain at 13.5% and similarly the percentage change in TSS from dredging should also be sustained at 13.5%. The long term increased efficiency of sink pond performance should improve the

percentage change in P removal by 10.1%, and similarly TSS removal should increase by 12.8%. In the long term then, for alternative # 1, the total percentage change in P would be 13.5% + 10.1 % = 23.6%. For TSS, the total percentage change would be 13.5% + 12.8% = 26.3 %.

6.3.2 Aesthetic Benefits From Alternative # 2

The short term and long term benefits from dredging, measured in the percentage change in P and TSS concentrations are the same as they are for alternative # 1 (13.5 % for both). The constructed wetland proposed for alternative # 2 will handle P and TSS inputs from creeks 3, 11,12, 13 that represent 48% of the total inputs (EVS 1990). An additional 16% of P and TSS will be removed by diverting creeks 16 and 17 into the outlet stream, assuming a 62% efficiency rate as in alternative # 1. In the short term, the expected phosphorus removal from the proposed sink pond and diversion projects will be the short term efficiency rate of sink ponds times the average P removal rate, times the P contributions from creeks 3,11, 12, and 13, plus the P removed from direct diversion of creeks 16 and 17 and plus the expected P reduction from dredging or (62% x 54% x 48%) + 16% + 13.5% = 45.6%. Similarly the expected percentage change in TSS would be the short term efficiency rate of sink ponds times average TSS removal rate for sink ponds, times the TSS contributions from creeks 3,11, 12, and 13, plus the TSS removed from direct diversion of creeks 16 and 17 and plus the expected TSS reduction from dredging or (62% x 68% x 48%) + 16% + 13.5% = 49.7%.

In the long term, the efficiency of the constructed wetland is expected to reach, and be sustained at a minimum of 75% of the best expected performance. Considering Knight's database, the best expected phosphorous removal rate for a constructed wetland is 54% and 68%. for TSS. Thus, in the long term, with 13.5 % from dredging, and 16% from diversion, the expected percentage change for P would be the long term efficiency rate of sink ponds times the average P removal rate, times the P contributions from creeks 3,11, 12, and 13, plus the P removed from direct diversion of creeks 16 and 17 and plus the expected P reduction from dredging or (75% x 54% x 48%) + 16% + 13.5% = 48.9%. Similarly the long term expected change in TSS would be the short term efficiency rate of sink ponds times average TSS

removal rate for sink ponds, times the TSS contributions from creeks 3,11, 12, and 13, plus the TSS removed from direct diversion of creeks 16 and 17 and plus the expected TSS reduction from dredging or (75% x 68% x 48%) +16% + 13.5% = 54%.

Table # 12 below summarizes all the expected percentage changes in P and TSS from alternatives # 1 and # 2.

TABLE # 12 : ACCOUNT FOR AESTHETIC BENEFITS TO DEER LAKE:

Percentage Change in;	**Alternative # 1 Limited Sink Pond and Dredging**	**Alternative # 2 Total Control Sink Pond, Dredging & Diversion**
Short Term		
Phosphorus	**21.5%**	**45.6%**
Total Suspended Solids	**24.0%**	**49.7%**
Long Term		
Phosphorus	**23.6%**	**48.9%**
Total Suspended Solids	**26.3%**	**54.0%**

6.4 MAXIMIZE RECREATIONAL BENEFITS: FISHING AND SWIMMING

The City wants to reestablish water contact sports and fishing activities in Deer Lake. Returning Deer Lake to a mesotrophic status would promote these two activities. A lake's productivity defines its trophic status. "Phosphorus is the most significant nutrient affecting recreational opportunities. ... Recommended phosphorus concentrations for cold water fish range from 9.9 to 18.5 mg./cubic meter" (Kirbyson 1991, 43). Trout survival is also affected by "high metal concentrations particularly lead and copper" (Kirbyson 1991, 45). Much of the heavy metal is concentrated in sediments, which reach the lake through the storm water system. For the purposes of this analysis, concentrations of TSS solids are used as a second marker for water quality in Deer Lake. The British Columbia Environment Ministry standard for maximum allowable concentrations of suspended solids in Deer Lake are 10 mg/L. In 1992 the ministry found that Deer Lake had on average 34 mg/L of TSS. For re-establishing fishing activities, the probability of reaching both standards for TSS and P is the attribute used to measure the effectiveness of alternatives # 1 and # 2.

Due to high coliform counts, Deer Lake is currently closed for swimming. The probability of meeting the health board standard for fecal coliform concentrations is the proxy attribute used to assess the likelihood of re-establishing lost swimming opportunities. "The federal Health and Welfare (1983) water quality standard for Class "C" water use, (which includes swimming) recommends that fecal coliforms densities should not exceed a running log mean of 200/100 ml nor exceed 400/100 ml in more than 10 percent of the samples over a 30 day period" (Kirbyson 1991, 44). The BC Environment Ministry found that in the months of July and August 1992, coliform levels in Deer lake were as high as 768 organisms per 100 milliliters of water. Summer time coliform levels in 1991 were recorded at 512 organisms per 100 ml. However, in 1992 the lake also registered a geometric mean reading of 147 organisms per 100 ml.. This is less than 200/ml., and therefore would have met Health Board standards. Mr. Kirbyson reported levels as high as 2000 organisms per 100 ml. in 1981 (Kirbyson 1991, 44). Large populations of birds on and around the lake, pet waste in the storm water, and leaking sanitary sewers have been identified as likely contributors to these variable coliform counts.

To date, there remains much uncertainty over which factor is the major contributor to coliform levels in the Lake. Estimates of the coliform contribution by birds were addressed in the 1982 Beak report. This report suggests that within a 24 hour period in the summer each of the estimated 300 birds on the lake could deposit as many as 11 million coliform organisms. Considering an estimated lake volume of 1.3 million cubic meters, the coliform contribution by birds could be as high as 252 organisms per 100 ml of lake water. This level would exceed acceptable standards. The City in 1988 instituted a bird management program to deal with the in-lake contribution of coliform. Currently there are no estimates of how well the management program is doing in controlling the bird populations on Deer Lake. However, the lake still remains closed for swimming due to high coliform counts.

The two lake treatment alternatives considered here do not directly address the in-lake contribution of fecal coliform densities. Rather, these treatment alternatives do deal with the external contributions of coliforms that reach the lake through the storm water system. Considering the rough estimate of the contribution made by birds it appears that both internal and external sources of coliforms will have to be controlled to réestablish swimming opportunities. For the purposes of this analysis, it is assumed that the bird management program will in the long term be able to handle the in-lake coliform contributions made by birds. This leaves only the external coliform sources as a problem. As a result, the objective of meeting the Health Board standard for coliform densities refers only to the external contribution from the watershed. The probability of meeting the minimum allowable fecal coliform density is the third proxy attribute used in this section to assess the performance of alternatives # 1 and # 2. There is no supporting data to confirm the impact of the water management alternative on improving levels of phosphorus, total suspended solids, and fecal coliform. For this reason Alternative # 3 is not considered here.

6.4.1 Alternative # 1: Probability of Establishing a Healthy Cold Water Trout Fishery and Swimming Opportunities in Deer Lake

Dredging Deer Lake is expected to remove 90% of the macrophytes that contribute 14% of the lake's total P load. Thirty percent of the sediment that contributes 3% to the internal phosphorus budget will also be removed during the dredging operation. Constructing a sink pond on creek three should handle 25% of the total input of phosphorus from all sources (EVS 1990). It is estimated that on average Deer Lake has 72 mg/m^3 of phosphorus (EVS 1990, 10-18). To reach the maximum suggested level or 18.5 mg/m^3 for mesotrophic lakes, dredging and a sink pond on creek 3 would have to remove 53.5 mg/m^3 of phosphorus. At 100% efficiency a sink pond on creek 3 would remove 25% of the total budget or 18 mg/m^3 of phosphorus, while dredging is expected to handle (0.90 x .14) + (0.3 x .03) x 72 = 9.7 mg/m^3. In total then, alternative # 2 will remove an estimated maximum of 27.7 mg/m^3 of P, which is just over half of what is needed to meet the desired standard of 18.5 mg/m^3. However, based on existing data, sink ponds rarely if ever operate in the short or long term at 100 % efficiency. This would indicate that the above estimate of P is also an over estimate. Therefore, for alternative # 1, the probability of meeting Health Board standard for phosphorus concentrations in the long term and short term is considered to be 0%.

For this section, only external sources of TSS are considered. In the previous section TSS are used as a proxy for sediment removal in wetland systems. The percentage change in TSS from wetlands was combined with the percentage change in sediments removed by dredging the lake. Dredging the lake, natural wind agitation and the activities of aquatic fauna can stir up bottom sediments. This kind of agitation may contribute to a re-suspension of solids, and toxic materials into the lake (EVS 1990). There is no data set to confirm the amount or probability, of contamination from the re-suspension of sediments. It is therefore assumed, that there are no significant in-lake contributions to TSS. Impacts of any possible re-suspension of sediments during the dredging operations can be mitigated by using alum to precipitate out any toxic chemicals (EVS 1990). Consultants have also proposed that bottom barriers or sediment covers can be used to discourage the natural re-suspension of internal lake sediments.

Furthermore, it is assumed that the contribution of TSS made by the various streams identified in the 1990 EVS report are in the same proportions as the P inputs. Assuming no internal inputs, and pro-rating the external inputs of P represented in the 1990 EVS report, creek 3 is expected to contribute 36.7% of the TSS inputs into Deer Lake (EVS 1990, 17). In a 1992 BC Government water quality study, it was found that Deer Lake had 34 mg/L of TSS (British Columbia Ministry of Environment 1993, 180). Assuming 100 % effectiveness (expected efficiency based on Knights data base is on average 68.8%) in the long term and short term, and at a rate of 37%, it could be expected that a sink pond on Creek 3 could reduce TSS by a maximum of 0.37 x 34 = 12.58 mg/L. To achieve the minimum standard for mesotrophic lakes, the reduction in TSS would have to be 24 mg/L (34mg/L - 10 mg/L). This falls far short of the desired standard, even at 100% effectiveness. Therefore the probability of achieving the desired standard for TSS in the long term and short term for alternative # 1 is considered to be 0%.

For both TSS and P markers, the limited sink pond and dredging proposal for alternative # 1 has no chance of meeting the standards for mesotrophic lakes. Therefore, alternative # 1 will not provide the conditions necessary for the re-establishment of a healthy cold water trout fishery in Deer Lake.

Considering the 1982 Beak report, average fecal coliform densities near the outlet of Creek 3 were 9000 org /100 ml (Beaks 1982, 3-A). This information was derived from readings taken from March to November of 1981 on all the major creeks that enter Deer Lake. Considering a number of studies contained in Moshiri's book, on average, it can be expected that constructed wetland should remove 98% of the fecal coliform inputs. At 98% efficiency 8,820 of the coliform organism could be removed from creek three, leaving 180 to enter the lake. This would meet Health Board requirements for Creek 3, however, in 1981 Creeks 11,12, 13, 16, and 17 would have still been contributing, on average a total of 23,200 coliform organisms into the lake. Therefore, the probability of meeting Health Board standards of 200 organisms per 100 ml in the long term and short term, for all streams, would be 0%. This is because a sink pond on creek three only treats one of many streams that contribute to the problem. This means that alternative # 1 will not meet the standard necessary to re-open Deer Lake for swimming.

6.4.2 Alternative # 2: Probability of Establishing a Healthy Cold Water Trout Fishery and Swimming Opportunities in Deer Lake

Dredging the lake and diverting streams 16 and 17 into the outlet channel should remove a total of 29.5% or 21.2 mg/m3 of the estimated total 72 mg/m3 P budget for Deer Lake. To meet the maximum allowable concentration of 18.5 mg/m3, suggested for mesotrophic lakes, it will be necessary to remove an additional 32.3 mg/m3. Creeks 11,12,13, and 3, contribute 48% of the total P budget or 34.6 mg/m3 (EVS 1990, 17). To remove 32.3 mg/m3, a sink pond handling 48% of the total phosphorus budget, would have to operate at 93% efficiency. A short term is considered as three years or less. Taken from Knights database for the performance of sink ponds, there are 3 out of 27 examples that have over 93% efficiency in the short term (Knight 1993, 47). This would translate into a 11% chance of meeting the short term objective. In the long term 2 out of 13 examples equal or exceed the 93% efficiency, which translates into a 23% chance of meeting the phosphorus reduction objective.

Diverting Creeks 16 and 17 into the outlet channel should reduce the level of incoming TSS by 23.6% or 8 mg/ml., based on the pro-rated value stated in the EVS report (EVS 1990,17). Subtracting 23.6% from the existing TSS concentrations of 34 mg/ml, leaves a further reduction 16 mg/ml to meet the desired standard of 10 mg/ml. Diverting creeks 11,12, and 13 into a larger wetland constructed on creek 3, at 100% efficiency, would be expected to treat the remaining 70.4% or 23.9 mg/ml. of the TSS budget for the lake. A sink pond handling this much storm water would have to operate at 66.9% efficiency to remove the additional 16 mg/ml TSS, that is required to meet the desired standard. In the short term, referring to Knight's database, 18 out of 31, or 58 % of the sink ponds exceed 67% efficiency (Knight 1993, 47). In the long term 9 out of 13 or 69% meet or exceed the required rate of efficiency. Therefore, based on the available data, in the short term there is a 58% probability, and in the long term a 69% probability of meeting the standard for 10 mg/ml of TSS for mesotrophic lakes.

To meet the water quality objectives for re-establishing a healthy cold water trout fishery, both TSS and P objectives have to be met. Therefore, the probability of creating a healthy trout ecosystem would be the probability of meeting P standards times the probability of meeting TSS standards. In the short term then there is a (11% x 58% = 6%) six percent chance of meeting the fishing objective. Similarly, in the long term there is a (23% x 69% = 16%) sixteen percent chance.

Considering studies in Moshiri's book that deal with coliform removal rates, sink ponds appear to be extremely efficient (Moshiri 1993). Compiling the results of five different articles, made it was possible to develop a limited data base with a sample size of 12 (Bastian and Hammer 1993, 63) (Kadlec and Watson 1993, 230) (Vymazal 1993, 256) (Manfinato, Filho and Salati 1993, 340) (Hammer, Pullin, McCaskey, Eason and Payne 1993, 345). The performance of sink ponds in removing coliforms ranged from 90.4% efficiency to 99.97% with a median of about 99.5%. Some of these results were from experimental sink ponds, and others from established systems. Results were taken from monitoring treated storm water sewage, and sanitary sewage. It is acknowledged that this is a limited data set, and as such should only be used as an approximation of the expected probabilities. However, for this thesis, a constructed data set provides a basic understanding of what level of performance can be expected from a constructed wetland.

Considering this information it is anticipated, that sink ponds on average will remove 98% of all fecal coliforms. The studies used to create the data set do not make a distinction between short term and long term expected performance. For this section, it is assumed that the short term and long term performance expectations are the same as those for phosphorus removal outlined in the 1990 EVS report. Therefore, in the short term it is expected that sink ponds will operate on average at 62% of their maximum expected performance rate, or in this case, 62% x 98% = 61% efficiency. The progressive change in sinkpond removal rates for coliforms is based on expert opinion, and not necessarily supported by the limited data set used for this assessment. Therefore, it is recommended that more information regarding the short term performance of sinkpond performance should be gathered before a final decision is made.

Creeks 16 and 17, on average contribute 11,544 organisms/100 ml and 4,686 organisms/100 ml of fecal coliforms into Deer Lake (Beak 1982). It is assumed that diverting Creeks 16 and 17 would remove 100% of their coliform contribution. Considering the average readings between the months of March and November of 1981, the remaining major creeks contributed a total of 16,006 organisms/100 ml into the lake. In the short term, and operating at a 60% efficiency, a larger sink pond should remove 9,604 organisms/100 ml from Creeks 11,12,13. The remaining 6,402 organisms left to enter the lake would still exceed Health Board standard of 200 organisms/100 ml. Therefore, in the short term, there is 0% probability of meeting the coliform standard for all treated inlet streams.

In the long term if sink ponds reach their expected average potential of 98% efficiency, a total of 15,686 organisms/100 ml would be removed from creeks 11, 12, 13, and 3. The remaining 320 coliform organisms would still exceed Health Board standards. It would take a sink pond efficiency of 98.8% to reach the desired level of 200 organisms/100 ml. Considering the studies in Moshiri's book, 9 out of 12 sink ponds monitored had efficiencies equal to or greater than 98.8%. This would indicate that there is a 75% probability of attaining the Health Board standard for fecal coliforms in the long term.

For alternatives # 1 and # 2 the probability of re-establishing fishing and swimming objectives is summarized in table # 13.

TABLE 13: ACCOUNT FOR RECREATIONAL BENEFITS TO DEER LAKE:

Recreational Probabilities	Alternative # 1	Alternative # 2
Short Term Prob. For Resumption of Cold water Trout Fishing	0%	6%
Long Term Prob. For Resumption of Cold water Trout Fishing	0%	16%
Short Term Prob. For Resumption of Swimming	0%	0%
Long Term Prob. For Resumption of Swimming	0%	75%

6.5) MULTIPLE ACCOUNT SUMMARY:

Table # 14 below provides a numerical and descriptive summary of the selected alternatives.

TABLE # 14 MULTIPLE ACCOUNT SUMMARY

ACCOUNT	ALTERNATIVE #1	ALTERNATIVE # 2	ALTERNATIVE # 3
COST ACCOUNT (1995 MILLION $) PV	-4.72	-6.96	NA
POTENTIAL BENEFITS PV	7.3	7.3	7.3
POTENTIAL NPV	2.58	0.34	NA
Short term Expected Value = Prob of Fishing and Swimming x Potential NPV	0	0	NA
Long term Expected Value = Prob of Swimming and Fishing x Potential NPV	.16X.75X.34X 0=0	.16X.75X0.34=.04 OR $40,000	NA
ENVIRONMENTAL IMPACTS	MAGNITUDE OF IMPACT/%AREA	MAGNITUDE OF IMPACT/%AREA	MAGNITUDE OF IMPACT/%AREA
1) SHORT TERM TERRESTRIAL Vegetation	Low / 1.2%	Low / 1.2%	NA
2) SHORT TERM TERRESTRIAL Wildlife	Low / 1.2%	Low / 1.2%	NA
3) SHORT TERM TERRESTRIAL Air and Noise	High / 100%	high/ 100%	NA
4) LONG TERM TERRESTRIAL Vegetation	High / 2.3%	Moderate to High / 5%	NA
5) LONG TERM TERRESTRIAL Wildlife	High / 2.3%	Moderate to High / 5%	NA
6) LONG TERM AQUATIC Vegetation	High / 30%	High / 30%	NA
7) LONG TERM AQUATIC Wildlife	High / 30%	High / 30%	NA
AESTHETIC BENEFITS			
SHORT TERM % CHANGE IN P	21.5%	45.6%	NA
SHORT TERM % CHANGE IN TSS	24.0%	49.7%	NA
LONG TERM % CHANGE IN P	23.6%	48.9%	NA
LONG TERM % CHANGE IN TSS	26.3%	54.0%	NA
PROBABILITY OF RE-ESTABLISHING RECREATIONAL OPPORTUNITIES			
SHORT TERM PROB. OF FISHING	0%	6%	NA
LONG TERM PROB. OF FISHING	0%	16%	NA
SHORT TERM PROB. OF SWIMMING	0%	0%	NA
LONG TERM PROB. OF SWIMMING	0%	75%	NA

This multiple account evaluation indicates the costs, expected dollar benefits, environmental, aesthetic, and risk implications of two of the three alternatives considered for this analysis. The summary matrix presents the advantages and disadvantages of the different alternatives and the tradeoffs between them. The water management alternative is included because it represents the status quo. Due to the lack of data, there is no assessment of the risks, NPV, environmental and aesthetic implications of alternative # 3. Alternative # 1 involves the construction of a limited sink pond and dredging Deer Lake. Disregarding source control initiatives, alternative # 1 is the least costly option. Alternative # 1 also has no chance of restoring lost recreational benefits. Including dredging, alternative # 2 proposes the diversion of two creeks and the construction of a large sink pond to handle the total storm water discharge of the remaining Deer Lake inlet streams. This option costs 2.2 million dollars more than alternative # 1 and has a long term expected value of 40,000 dollars. The expected value is calculated by multiplying the probability of achieving long term or short term swimming and fishing times the potential NPV. The forty thousand dollar benefit is based on future recreational opportunities and should be discounted to the time at which these activities may be expected to resume. However, for alternative # 2 the time line for the expected resumption of fishing and swimming is unclear and the discount factor is therefore left out. The magnitude of the environmental impacts of alternatives # 1 and # 2 are similar. However, compared to alternative # 1, alternative # 2 will have a long term environmental impact on 2.7% more of the total park area. Aesthetically, in both the short term and long term, alternative # 2 will have twice the aesthetic impact as alternative # 1. Alternative # 2 provides a long term chance for restoring lost swimming opportunities and a marginal long term chance for providing healthy cold water trout habitat.

As a decision making framework, this multiple account evaluation can help the committee make an informed decision regarding the future of Deer Lake. The accounts in table # 14 represent the value based objectives that were derived from committee interviews and correspondence. The information presented in the previous chapters and summarized in table # 14 "will not generally determine which alternative is unequivocally preferred. It is designed to inform, not to supplant decision-making" (Crown Corporations Secretariat 1993, 23). There are tradeoffs that will have to be made in selecting between

alternatives. It is up to the committee to "utilize this information systematically and effectively within their own decision making framework" (Crown Corporations Secretariat 1993, 23).

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

7.1 CASE STUDY SUMMARY

Table # 14 is a representation of the impacts of all three alternatives. Data contained in this table is based on existing reports previously commissioned by the City of Burnaby. Some of the data is supplemented with some statistical information from the literature. The first three steps in the application of VFT have been completed. This has included structuring the decision, defining alternatives, and measuring the impacts of selected alternatives.

Formal structuring for this decision began with statements of what the committee thought was important. The value tree depicted in figures 4 through 9 represents all of the issues that are important for the Deer Lake Restoration and Management Committee. These objective statements were derived from interviews with the committee members. The decision was broken down into its constituent parts and reassembled into a set of objectives, represented in the form of a tree structure. The decision tree presented in chapter four provides an analytical tool for the assessment of selected alternatives. The interview process stimulated considerable thought about alternative ways to achieve the stated objectives. Many of the alternatives suggested, were in turn, rejected by the committee as a group. However, one acceptable new alternative was created and used in this first stage of the process. Alternative # 2 (diversion, larger sink pond and dredging) is a new alternative that was in part resurrected from the 1982 Beak report. The objective's hierarchy provides the basis for the quantitative modeling in chapter six.

Assessing the impacts of the alternatives using MAA, was the third stage of this decison making process. Measuring impacts required the use of different types of attributes. An obvious attribute (cost in dollars) was used to assess the objective of minimizing costs. The magnitude of impact and the size of the area affected, was the constructed attribute used to measure the alternatives across objective # 3. The percentage change in certain water quality measures was another example of a constructed attribute

that was used to assess the impact on aesthetic qualities of the lake. Certain water quality standards have to be met before water contact sports can be resumed. As a proxy attribute, the probability of achieving these specific standards seemed to be the most reasonable way to assess the performance of alternatives #1 and # 2 in achieving the recreational objectives. To operationalize these measures, it was necessary to evaluate and condense a great deal of scientific data and subjective impact assessments contained in the numerous reports commissioned by the City of Burnaby. Table # 14 represents a summarized assessment of the possible consequences of the selected alternatives. The multiple account summary matrix should provide the committee with a decision making tool to effectively move on with their decision regarding the future of Deer Lake. Based on the available data alternative # 2 seems to be the most desirable course of action.

The impact assessment in chapter six provides a preliminary assessment of the consequences of three alternatives considered to date. This partial analysis also provides some general insights into the benefit of using Value-Focused Thinking and MAA for urban lake planning. The final decision making process is expected to include the participation of relevant public, and private sector stakeholders. This MAA is offered as an example of how the committee could organize the decision for the final Deer Lake Restoration and Management project.

7.2 INSIGHTS AND RECOMMENDATION FROM THE CASE STUDY

The current initiative to proceed with the restoration of Deer Lake is stalled. Certain Committee members appear to have lost interest in the process because of the time that has already been spent, and due to the inability to come to any clear resolution on what to recommend to Council. During the interview process all the Committee members agreed that this initiative lost momentum when the Committee lost its political champion, Joan Sawicki. **Therefore, the first recommendation is that the Committee should seek out a new political champion to oversee and facilitate the restart of the Deer Lake Restoration and Management initiative.**

All Committee members mentioned the need for more public involvement at some further point in the decision making process. There are many advantages to involving stakeholders in the initial stages of a planning process. Defining stakeholder objectives at an early stage can lead to the creation of new and better alternatives. Early stakeholder involvement can minimize the chance of adversarial iterations and facilitates effective communication. This kind of interactive decision making can provide opportunities for assessing tradeoffs early on in the process, all of which can lead to an early consensus on a preferred strategy. **Therefore, it is recommended that the City restart this process with full stakeholder involvement.**

During the impact assessment stage of this case study, it became apparent that there were limited amounts of information regarding the type and extent of external, and internal sources of coliform. The recreational swimming objectives are the political flagship for this decision. **As such it is recommended that the City undertake a comprehensive assessment of the origins of fecal coliform concentrations to the lake.**

All the water quality impact assessments done in the case study were based only on estimates of sink pond and dredging performance. Since 1988 the City has had a number of source control programs in place, which could ultimately make a positive contribution to water quality in the lake. At the time of this study, due to a lack of supporting data, it is impossible to estimate the contribution to water quality improvements that water management programs could make. Before any final estimates of the total potential removal rates for P, TSS, and coliform, are calculated, the impact of source controls will have to be ascertained. **Therefore it is recommended that the City should assess the impact of source control programs currently underway, and investigate the potential water quality gains from extending these initiatives. This information can then be used as part of the final MAA.**

The environmental impacts of pursuing current water management strategies are not modeled in this analysis. Experts suggest that Deer lake will continue at an accelerating rate, to suffer serious environmental consequences if nothing is done to reduce the level of nutrients and toxic substances that enter the lake. "If no measures are taken and the lake is allowed to continue its present rate of

deterioration, its value as a park resource will greatly diminish, and any effort to restore the lake, subsequently will result in much higher costs. ... Deer lake may rapidly change from the community gem to the community eyesore" (Beak 1981, 1-2). **It recommended that the City commission an expert assessment of the environmental impacts of using only water management strategies to improve the water quality in Deer Lake.**

This first run assessment is based on average estimates of certain costs, environmental and water quality parameters. **For a final assessment it is recommended that a range of values be included to determine the sensitivity of each account.**

7.3 APPRAISAL OF VALUE FOCUSED THINKING AND MULTIPLE ACCOUNTS ANALYSIS AS IT PERTAINS TO URBAN LAKE PLANNING

An urban lake planning process should contain the four steps common to most planning processes, goal setting, developing alternatives, decision, implementation ... and conflict resolution (Reeve 1988, 108). For the purposes of this paper, establishing goals is considered synonymous with setting objectives. Except for the implementation part of the process, the three steps in this analysis serve as an effective generic tool to accomplish the urban lake planning tasks mentioned above. A well-structured objectives hierarchy can guide the search for creative solutions to difficult problems. By putting the emphasis on structuring the problem before analysis begins, better alternatives can be selected. VFT provides a tool for structured negotiation by accommodating all aspects of a problem that have value to the interested parties. Representing complexities in a simple and meaningful way promotes understanding at all levels of expertise. This in turn expedites reaching a consensus, by providing laypersons and experts with a level playing field to assess all relevant information, including the impacts of the proposed alternatives. The combined application of VFT and MAA separates facts from values, represents uncertainty in a straightforward realistic manner, and measures the impacts of the proposed alternatives with the desired objectives. All these factors contribute to honest communication between stakeholders, and sincere dialogue helps to foster negotiation and anticipate conflict, thus expediting consensus on a preferred planning strategy.

A strength of VFT is its ability to incorporate "all the aspects of a problem that have value to people" (Gregory, Lichtenstein, Slovic 1992, 22). This type of structured decision making process can explicitly represent the value statements of different stakeholders and provide a platform for constructive communication about the different alternatives and the tradeoffs that should be considered. "Understanding preferences is crucial to informed decision making" (Keeney R. 1992, 56). The Committee represents the interests of the City departments who have a stake in this decision and as such will likely play an important role throughout the final decision making process. "The objectives for a decision situation should come from individuals interested in and knowledgeable about that situation" (Keeney R. 1992, 56). The final decision for the restoration proposal is the responsibility of the City Council. The committee mandate is to advise council on the best way to continue. Any final proposal may also involve a public process. As the decision process evolves over time, new stakeholders may be identified. Keeney argues that in situations where objectives are not set by decision makers "a logical identification and structuring of objectives can provide significant help for all those who end up involved in the decision process"(Keeney 1992, 56). It is important for individuals responsible for the final decision to understand how project objectives are set, who set them, and what kinds of perspectives were included.

Members of the Committee have a variety of professional backgrounds. Within the context of these backgrounds, it was possible to identify certain professional biases. Objective statements in table # 2 reflect these biases. To facilitate meaningful communication between bureaucratic, political and public stakeholder groups, it is important that the professional biases of the different committee members be represented in a straight forward and honest way.

The committies engineering representitive would be expected to put forward the interests of the City's Engineering Department. All Committee members concerning question # 1 table # 1, expressed a desire to see the Lake returned to some past pristine state, and maintained as a totally natural environment for future generations. This committee member shared this vision, but maintained the importance of retaining the lake as part of Burnaby's urban storm water system. As an engineer this person acknowledged the tradeoffs necessary to achieve all of these objectives, particularly in a

watershed, that is experiencing significant environmental impacts from increasing commercial and residential densities. It was maintained, that water treatment options would have limited scope for returning Deer Lake to some pre-urban condition. As a design engineer, he expressed a preference towards end of pipe treatments versus watershed controls.

The City's environmental planner believes that any decision on the future of the lake should be guided by principles of ecological stewardship. There should be no further loss of natural aquatic and terrestrial habitat, within the park. Every effort should be made to control the application of fertilizers and pesticides within the watershed. She maintained that a dollar value should be assessed to the environmental impact of development, and the use of any potentially toxic materials in the watershed. These costs should be directly reflected in the City's development cost charges, and in the consumer prices of products that contain potentially toxic chemicals. She also felt that there should be less emphasis put on restoring swimming and fishing opportunities, and more attention paid to protecting important natural ecosystems within the lake and park.

A member of the Cities Long Range Planning Department was concerned with finding a solution that was both suitable to the politicians and the public. As a long range planner, he seemed to lean towards a proposal that fit within the environmental goals set in "The State of The Environment Report" (SOER)". He also favored incorporating public values into the decision making framework.

A representative of Burnaby's Environmental Health Department revealed a preference for a technical solution that would provide safe swimming opportunities. In contrast to other Committee members this person seemed to have less regard for maintaining the lake as a natural ecosystem. He suggested that water birds were the main contributors to the high coliform counts, and as such should be removed from the lake and surrounding park land. It was also suggested that the lake function more as a natural outdoor swimming pool similar to some of the concrete marine tide pools found in Vancouver parks.

A parks superintendent, presented a comprehensive vision of the lake restoration proposal. He favored a solution that provided for enhancing natural areas of the lake while at the same time restoring water contact sports activities. However, the superintendent also recognized, that it may not be possible to achieve, nor maintain the water quality standard that would support these activities. It was stated that, the short term lake rehabilitation and management costs were much less important than the loss of recreational opportunities, and the environmental risks associated with the restoration.

The interests of each member of the committee where explicitly addressed during the consolidation of the objectives listed in table two. The decision tree represented in figures # 4 through # 9 is a compact logical representation of the consolidated objectives derived from table # 2. The sometimes, competing interests of the committee are accommodated in this analysis. This demonstrates that VFT and MAA can represent a cross section of perspectives in a concise and understandable way. VFT and MAA facilitates negotiations in a number of ways: "by clarifying objectives that indicate what is important, ... and by providing a logical framework that incorporates diverse sources of information" (McDaniels 1992, 47). Apparently each member of the Committee has a different set of values, which could be a reflection of their professional backgrounds, personal attitudes, or departmental responsibilities. Each member of the committee will have to "consider the relative weight to put on different accounts" (Crown Corporations Secretariat 1993, 23).

The elicitation process, and formal structuring of the objectives helped to identify new and possibly better alternatives. Questions asked during the interview process seemed to stimulate some creative thinking on alternate means to achieve the stated recreational objectives. One committee member felt that a small portion of the lake could be physically isolated and the water disinfected with an ultraviolet sterilization. This would provide safe swimming opportunities in a small portion of the lake. This is a recognized treatment option for lakes that suffer from high levels of coliform bacteria. The same committee members suggested altering the physical landscape to discourage bird visitations and help further reduce coliforms concentrations. Both of these options where rejected by other members of the committee as being too narrow a focus and lacking any regard for environmental impacts. However,

these examples demonstrate, that this decision making process is useful as a communication tool, and can stimulate thinking about new and perhaps better alternatives.

Complexity can confound efforts to think creatively, because not all planning problems can be simplified to the point where the merits of each option are intuitively obvious (Andrews 1992). Simplicity on the other hand, helps lay-persons understand the decision making process, it makes value judgments easier by distinguishing between facts and values, and helps the decision analyst communicate to the stakeholders how the process works(Howard 1979). Complexity is a built-in feature of urban lake planning. The need to address multiple objectives, deal with intangible values, attempt to satisfy different stakeholders, assess complex technical reports, identify good alternatives, anticipate risk, and plan for the long term, are some of the complex issues that urban lake planners face. The combined approach of VFT and MAA represented in this case study provides an example of how structured decision making can accommodate these kinds of complexities.

Within this decision making framework, values are used to set the fundamental objectives. The objectives hierarchy provides the foundations for the value model. Facts derived from existing information are used to measure the achievement of an objective. Separating facts from values in the initial stages of the process helps to focus the data collection process. In the assessment stage of the analysis this distinction between fact and values helps the decision makers overcome conflict, by determining if disagreements are about facts rather than values.

A tree structure provides a simple and concise rendition of a complex series of stakeholder (committee) objectives, and the attributes used to measure the achievement of these objectives. The decision tree represents qualitative aspects of the decision. General concerns such as costs, and environmental impacts, are represented at the trunk. Specific attributes used to assess the impacts are found at the twigs of the tree. This rather intuitively simple structure, can help stakeholders identify missing objectives, clarify the qualitative implications of the decision, and generally improve the "understanding of the values that matter" (Keeney 1992, 86). Simplicity helps an analyst communicate

issues, and helps laypersons understand the process, both of which contribute to a more open and honest representation of the issues that are important.

Chapter six of the case study describes, and measures the impacts of each alternative for the desired objectives. Previously commissioned reports provide much of the scientific and technical information used for this part of the analysis. These reports were written by experts in the fields of engineering, wildlife biology, and lake ecology. Finding facts hidden in a maze of technical and scientific jargon makes it difficult for lay-persons to assess the validity of restoration proposals. Representing technical and scientific data in a simple and meaningful way was one of the major hurdles of this case study. The decision tree in figures # 4 through # 9 graphically represented the connection between the different performance accounts in table # 14, with the value base objectives of the committee in a straightforward way.

Uncertainty is another form of complexity that urban lake planners have to face. In chapter six of this case study, the uncertainty regarding the achievement of specific water contact recreational benefits were addressed. Uncertainty regarding the impacts of the proposed alternatives was represented as the probability of achieving specific water quality standards that would allow for the resumption of swimming and fishing opportunities in Deer Lake. Ultimately a simple numerical probability based on actual performance data was calculated for each of the alternatives and presented in table # 14. This provides the stakeholders with a clear and realistic assessment of the likelihood of achieving the stated goals in both the short term and long term.

As a planning tool, the combined approach of VFT and MAA analysis offers stakeholders a decision making strategy that can decompose "a possibly uncertain, complex, and dynamic decision problem into the choices, information and preferences of the decision maker" (Howard 1979, 6). This thesis offers the City a methodology that can represent the diverse and often competing interests of different stakeholder groups. This kind of framework provides a means of analyzing the alternatives for stated objectives. Complex and uncertain consequences are represented in a clear and straightforward way. Structured analysis and responsibly simplifying complex technical reports can facilitate a better urban lake planning

process. "This approach will reduce the black box nature of the analysis work, and build the group's confidence in the results. It will also tap the creativity of the participants, and allow them to invent better options than those currently on the table" (Andrews 1992, 196). **Considering all the benefits of this approach, it is recommended that City of Burnaby employ the combined approach of VFT and MAA as a comprehensive decision making framework for the rejuvenation of Deer Lake**.

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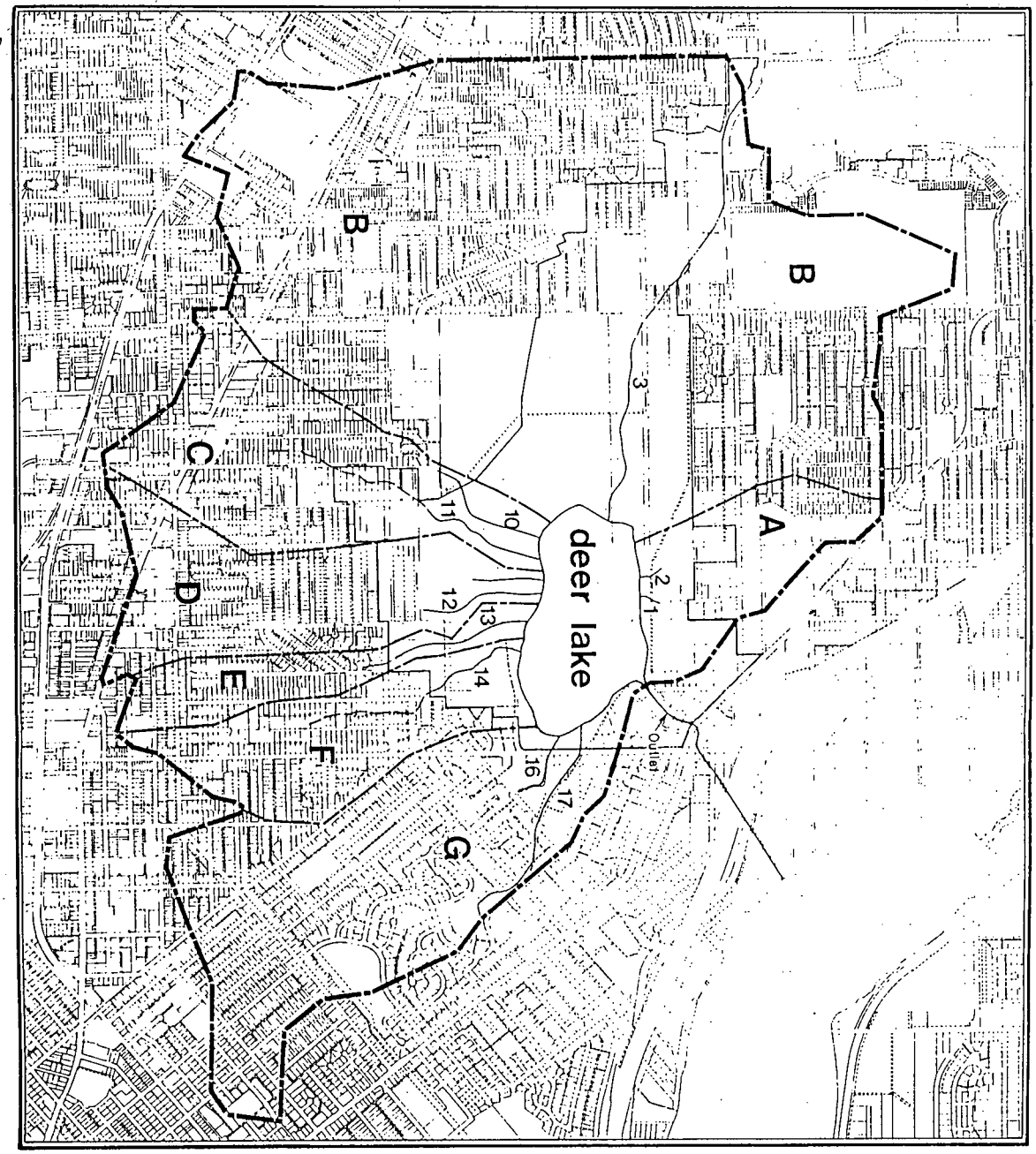
APPENDIX # 1 **SINK POND PERFORMANCE DATA BASE.**

TSS = Total Suspended Solids. P = Phosphorus

No. of years in operation	% change TSS	% change P	No of years in operation	% change TSS	% change P
2	12	56	0.5	97	97
2.6	72	21	4	62	36
2		43	4	60	26
0.8		90	4	60	52
3		23	4	92	80
2.8		94	4	90	95
11.2	77	56	1	60	38
1	75	16	1		28
4	46.5	64	2	96	40
1	70	79	0.7	96	
0.5	63	30	0.8	66	
3.7		84	0.2		
3.3	75	95	11	73	
1.2	45	8	0.7	86	
1.2	36	8	0.8	66	
1.2	53	33	1		
1.8		7	1	69	
1		30	1	79	
11		91	1	71	
1	22	91	15	94	
0.5		90	1	46	
0.8	91	47	1	71	
3	92	93	1	35	
1.7	82	32	1	79	
1.7	73	12	1	66	
1.7	66	38	2	96	
6		85	1.5	67	
0.8		78	1.1	78	
2		4	3.1	82	
0.5		97	2.8	70	
			1.7	82	

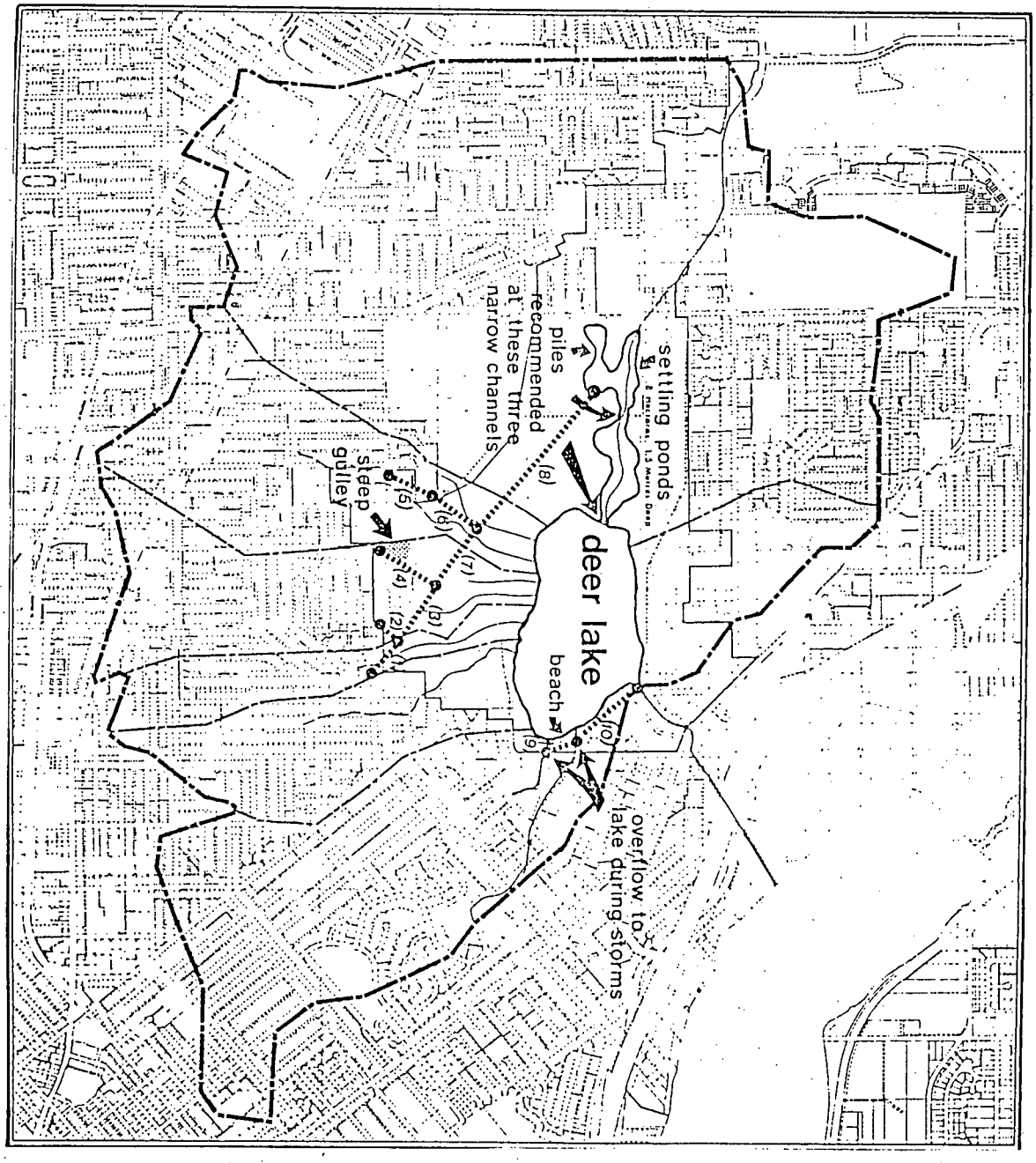
Source (Knight 1993, 35-58)

APPENDIX # 2
DEER LAKE CREEKS, AND WATERSHEDS



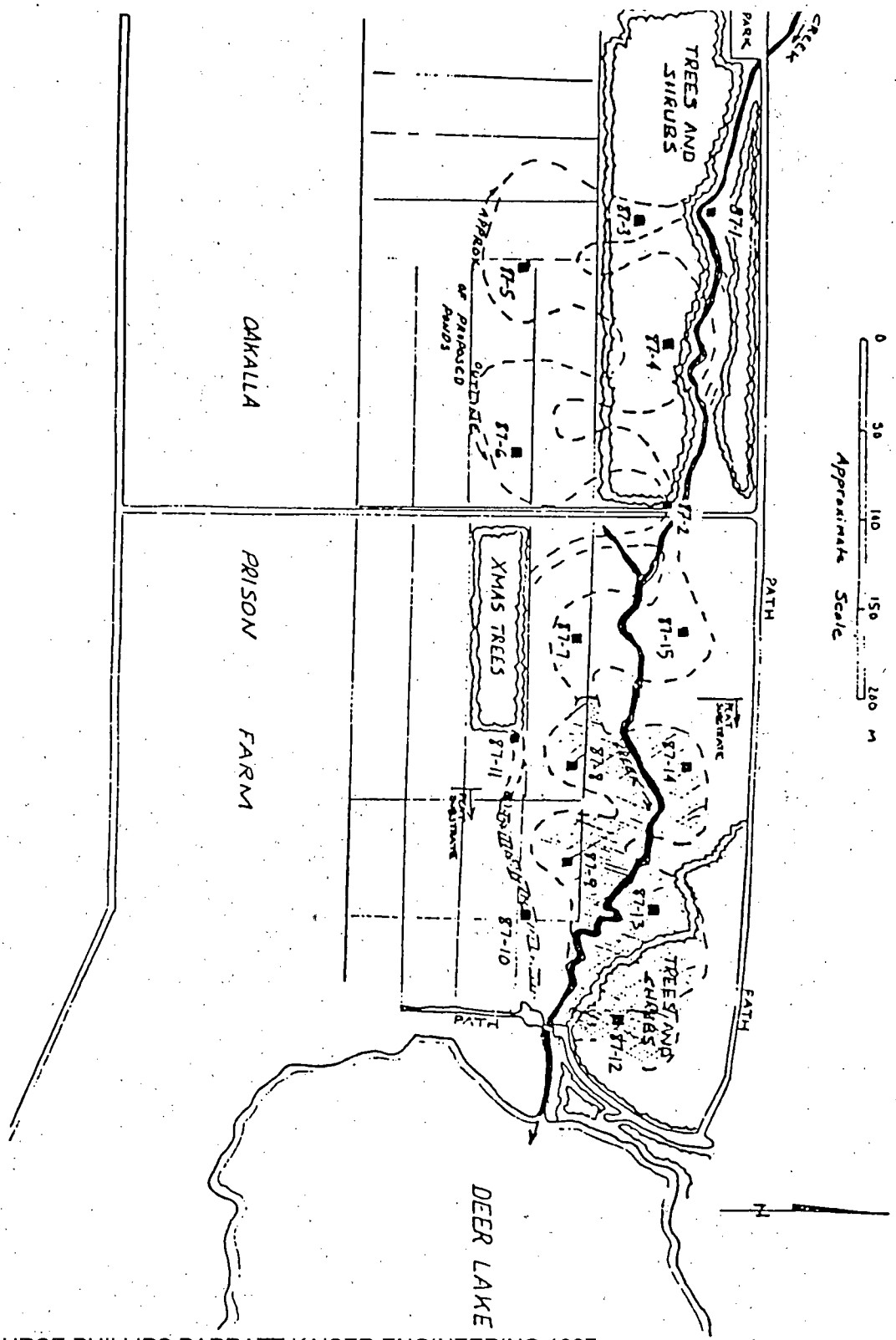
SOURCE BEAKS 1982

APPENDIX # 3
STORMWATER DIVERSION SYSTEM



SOURCE BEAKS 1982

APPENDIX # 4
LOCATION OF NUTRIENT-SINK PONDS



SOURCE PHILLIPS BARRATT KAISER ENGINEERING 1987