An Ecological Approach to Landscape Design:
The Muddy Pond Wetland - A Nova Scotian Case Study

BY

Clinton W. Pinks

A Practicum
Submitted to the Faculty of Graduate Studies in Partial Fulfillment of the
Requirements for the degree of

Master of Landscape Architecture

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The Muddy Pond Wetland-A Nova Scotian Case Study

submitted by Clinton W. Pinks

in partial fulfillment of the requirements for the degree of

Master of Landscape Architecture

The Practicum Examining Committee certifies that the practicum (and the oral examination, if required) is:

APPROVED X

NOT APPROVED ______

Advisor
Professor Charles H. Thomsen

Dr. M-E Tyler

External Examiner
Dr. Baydack

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AN ECOLOGICAL APPROACH TO LANDSCAPE DESIGN:

THE MUDDY POND WETLAND-A NOVA SCOTIAN CASE STUDY

BY

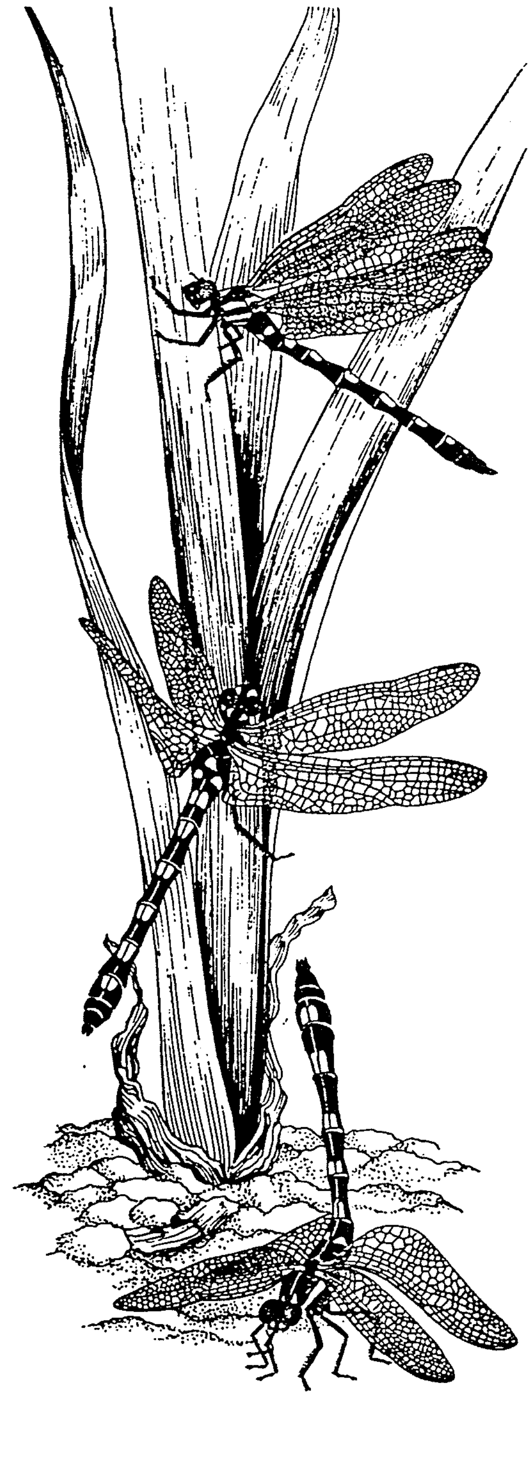
CLINTON W. PINKS

A Thesis/Practicum submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements for the degree of

MASTER OF LANDSCAPE ARCHITECTURE

"Understood by but a few, landscaping is still in its youth. It speaks of truth, and as the true significance of our life becomes better understood, it will grow and flourish. The landscaper belongs to the future. It is he who will weave the works of man and of the primitive into one harmonious whole, counteracting the scars made on mother earth through ignorance. He will oppose the enslaved thoughts of our machine age by singing with the freedom of our musicians and our poets of hills and valleys, of far-reaching plains, of intimate brooks and of sea-going streams."

(Jens Jensen, Siftings, 1939)



Abstract

In the profession of landscape architecture, responsible design should reflect the ecological processes of the landscape. The 'ecological approach' can be seen as a reaction to both the present socioeconomic atmosphere and conventional design practices. The goal of this project was the protection of a small wetland system, in southern Nova Scotia. The complexity of Muddy Pond was chosen for an ecological analysis, in demonstrating the importance of first principles of ecology in landscape design. This practicum addresses how design will influence the ecological processes of the landscape and how those processes may, in turn, influence and enrich the design. A proposed access road and parking lot, adjacent to Muddy Pond, ere designed based on the protection of the ecological processes of the wetland. In order for landscape design to be considered responsible design, the human intervention placed within the landscape must acknowledge the ecological processes occurring within that landscape. Responsible design should be comprised of environmental as well as ecological design.

Acknowledgements

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Mary-Ellen Tyler, B.Sc., M.E. Des., Ph.D., Department of City Planning,
Richard K. Baydack, Ph.D., Natural Resources Institute, and
Professor Charlie Thomsen, Department Head, Department of Landscape Architecture and Committee Chair.

And

Mr.Robert J. McDonald and Mr. Frank Garner
of the Charles L. McDonald Sports Park Association

And

Family and Friends

For providing their guidance and support.

"Life is not so short but that there is always time enough for courtesy."
(Ralph Waldo Emerson)

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List of Figures and Tables

Species List

While a detailed inventory of the flora and fauna of Muddy Pond and the Sport's Park was not conducted, the following is a list of those species (with page reference) mentioned within this practicum.

Flora:

Birch	*Betula spp.* L.	38,39, 201.
Black Spruce	*Picea mariana* (Mill.) B.S.P.	29,38,41,44,49,201.
Bladderwort	*Utricularia spp.*	38,39.
Blue Flag Iris	*Iris versicolor*	40.
Bog Laural	*Rhododendron canadense*	38,40.
Bulrush	*Scirpus spp.*	38,39,71,72.
Cattail	*Typha spp.*	29,39,46,63,71,82138.
Clover	*Trifolium spp.*	72.
Cranberry Family	*Vacinium spp.*	33,38,40.
Eastern White Pine	*Pinus strobus* L.	38,40,201.
Eastern Hemlock	*Tsuga canadensis* (L.) Carr.	38,201.
Glasswort or Samphire	*Salicornia europaea* L.	72.
Hardhack	*Spiraea latifolia*	38,39.
Larch (Tamarack)	*Larix laricina* (Du Roi) K. Koch	29,38,39,40,41,44,49.
Orchid	*Arethusa sp.*	34.
Pickeral Weed	*Pontederia cordata*	38,39.
Pink Lady's Slipper	*Cypripedium sp.*	38,40.
Pitcher Plant	*Sarracenia purpurea*	38,40.
Purple Loosestrife	*Lythrum salicaria*	39.
Red Oak	*Quercus rubra* L.	38.
Red Maple	*Acer rubrum* L.	38,39,44,49,201.
Rhododendron	*Rhododendron spp.*	39.
Round-leaved Sundew	*Drosera rotundifolia*	40.
Sedge	*Carex spp.*	38,40,71.
Spatterdock (Yellow Water Lily)	*Nuphar variegatum*	38,39,138.
Speckled Alder	*Alnus rugosa* (Du Roi) Spreng.	38,39.
Sphagnum moss	*Sphagnum spp.*	29,38,40,49.
Sweet Gale	*Myrica gale*	38,39.
Trembling Aspen	*Populus tremuloides* Michx.	41,201.
Water Milfoil	*Myriophyllum spicatum*	38,63,138.
White Water Lily	*Nymhaea alba*	29,38,39,138.
Wild Rice	*Zizania aquatica* L.	33.
Willow	*Salix spp.* L.	38,39.

Fauna:

Glossary of Selected Terms

For the purposes of this practicum the following definitions are provided:

Biotic diversity or bio-diversity:
"the variety of different species, the genetic variability of each species, and the variety of different ecosystems they form" (Province of Nova Scotia Wildlife Advisory Council, 1993).

Change:
"the alternation in the structure and function of the ecological mosaic over time" (Forman and Godron, 1986). Also called Succession and refers to the process of change over time (Weller, 1994).

Conservation:
An area or species management strategy that involves protection, preservation and/ or appropriate utilization (Province of Nova Scotia Wildlife Advisory Council, 1993).

Ecology:
The scientific study of the interrelationships that exist between organisms, including humans, and their environment. Sometimes called environmental biology (Province of Nova Scotia Wildlife Advisory Council, 1993).

Ecosystem:
An integrated and stable association of living and nonliving resources functioning within a defined physical location. More narrowly defined as the flow of energy within a community of plants and animals (Province of Nova Scotia Wildlife Advisory Council, 1993).

Function:
"the interactions among the spatial elements, that is, the flows of energy, materials and species among the component ecosystems" (Forman and Godron, 1986).

Landscape ecology:
"a study of the structure, function and change in a heterogeneous land area composed of interacting ecosystems" (Forman and Godron, 1986).

Landscape:
"a heterogeneous land area composed of a cluster of interacting ecosystems that is repeated in similar form throughout" (Forman and Godron, 1986).

Landscape Architecture:

"the profession which applies knowledge of the earth's natural systems and human cultures to the planning, design and management of sustainable urban and rural developments. Its goals are to promote attitudes of respect, care and responsibility in conserving the landscapes of our heritage and understanding the physical and cultural environments in which new places are created" (Manitoba Association of Landscape Architects, 1994).

Structure:

"the spatial relationships among the distinctive ecosystems or elements present - more specifically, the distribution of energy, materials and species in relation to the sizes, shapes, numbers, kinds and configurations of the ecosystems" (Forman and Godron, 1986).

Watershed:

A natural drainage area defined by topography and often referred to as a drainage basin (Province of Nova Scotia Wildlife Advisory Council, 1993).

Wetlands:

"land that has the water table at, near, or above the land's surface or which is saturated for a long enough period to promote wetland or aquatic processes as indicated by hydric soils, hydrophytic vegetation, and various kinds of biological activity that are adapted to the wet environment" (National Wetlands Working Group, 1988).

Wildlife:

All wild mammals, birds, reptiles, fishes, invertebrates, plants, fungi, algae, bacteria and other wildlife organisms and their habitats (Province of Nova Scotia Wildlife Advisory Council, 1993).

1

Introduction

The Global Paradox and Ecological Design - the role of the landscape architect.

In this world, where the 'state of the environment' seems commonplace among the political agendas of world leaders, it is ironic that there appears to be a lack of applicability of the ever increasing accumulation of knowledge about the environment. This paradox, between the increasing knowledge base and the unwillingness to apply it to development, could be the result of two global trends (Hansen and di Castri, 1992). One trend, the global depletion and deterioration of the environmental resources, spurs a deepening understanding of the natural environment. The other trend, the disarray and growing deterioration of the world's economy and social infrastructure, fuels a passion to be more efficient.

While these two trends are often isolated and addressed separately, it is not difficult to understand that these two trends are linked. With chaotic development producing deleterious effects on the environment, the deterioration of the environment and its natural processes represent a major constraint toward a holistic concept of sustainable development. Hansen and di Castri (1992) point out that part of the solution to achieving sustainability lies in the realization that ecology and economy must become more interactive and integrated. It is in part the responsibility of the landscape architect, through their profession, to ensure the sustainability of the environment, both for present and future generations.

Through the discipline of landscape ecology, it is becoming more and more the profession of landscape architecture to not only understand, but also to interpret, manage and share the responsibility for the increasingly complex issues between the natural and cultural environments as they share the same common resource, namely the "land."

Project Rationale and Scope of Work

Philosophy for the Project

It is the underlying philosophy of this project that, for landscape design to be considered responsible design, the human intervention placed within the landscape acknowledges the ecological processes occurring within that landscape. This can be translated into having an understanding of how the design will influence the ecological processes of the landscape and how those processes may, in turn, influence and enrich the design. It is with intent that this project be viewed, not with a conservation mentality, but rather as a demonstration of first principles of ecology. This project demonstrates how landscape design can be influenced by and respond to particular ecological processes of the site and of the greater region. For this purpose the ecological processes of a wetland system have been chosen.

Choice of Wetlands

Historically wetland utilization and perception have been misinterpreted, misappropriated and misused (Manuel, 1992), similar to human-environment relationships today. As a single system, wetlands reflect at a manageable scale the diversity and complexity of structure that is characteristic of the environment (Manuel ,1992). The choice of wetlands as a focus in this project is in part due to our lack of understanding of the importance and dependency we have upon the resource, and in part due to the rich diversity of plant and animal life that wetlands have to offer the greater landscape.

At the present time, the definition of a watercourse in Nova Scotia does not include wetlands. The original versions of the Environment Act discusses wetlands as being part of the definition of a watercourse. Cantwell (1995) stated that subsequent confusion as to the delineation and definition of a wetland caused the category to be removed from the legislation. Currently, a wetlands working group is trying to come up with policy vis a vis wetlands, but the definition of a watercourse in Nova Scotia does not include a wetland. Cantwell (1995) suggests that this is somewhat ambiguous and confusing, but generally typical of the difficulty governments are having in defining what is and what is not a watercourse and when a wetland is worth saving.

Study Area

The study area for this project lies in the Village of Waverley, Nova Scotia (population 1600), where a small freshwater wetland is threatened by the encroachment of an adjacent community sports park (Figure (1.)). The Charles L. McDonald Sports Park (hereinafter referred to as the Park), is a 57± hectare (141± acres) wooded site (Department of Lands and Forests, 1988) situated on the western shores of one of a series of chain lakes and rivers which transect the province - the Shubenacadie-Stewiacke River system. (See Appendix (1.) *Technical Report on the Environmental Inventory,* and Appendix (4.) *The Shubenacadie Headwaters* for further description). In the southern portion of the Park is 'Muddy Pond', a 10 hectare (25 acres) wetland, which constitutes the collection zone for a second order drainage basin (Marsh, 1991). The basin drains an area of approximately 249 ± hectares (615± acres), which extends beyond the Park boundaries. The drainage basin is situated at the headwaters of the Province's largest watershed, the Shubenacadie-Stewiacke River Basin, which has both cultural and historical significance. At a regional scale, it is generally accepted that any detrimental impact to the environment in the Muddy Pond basin system may have negative repercussions downstream. Until the 1930s Muddy Pond was a dumping ground for the tailings from gold mining operations in the Waverley area (See Appendix (6.) *Waverley*, for further description of gold mining operations).

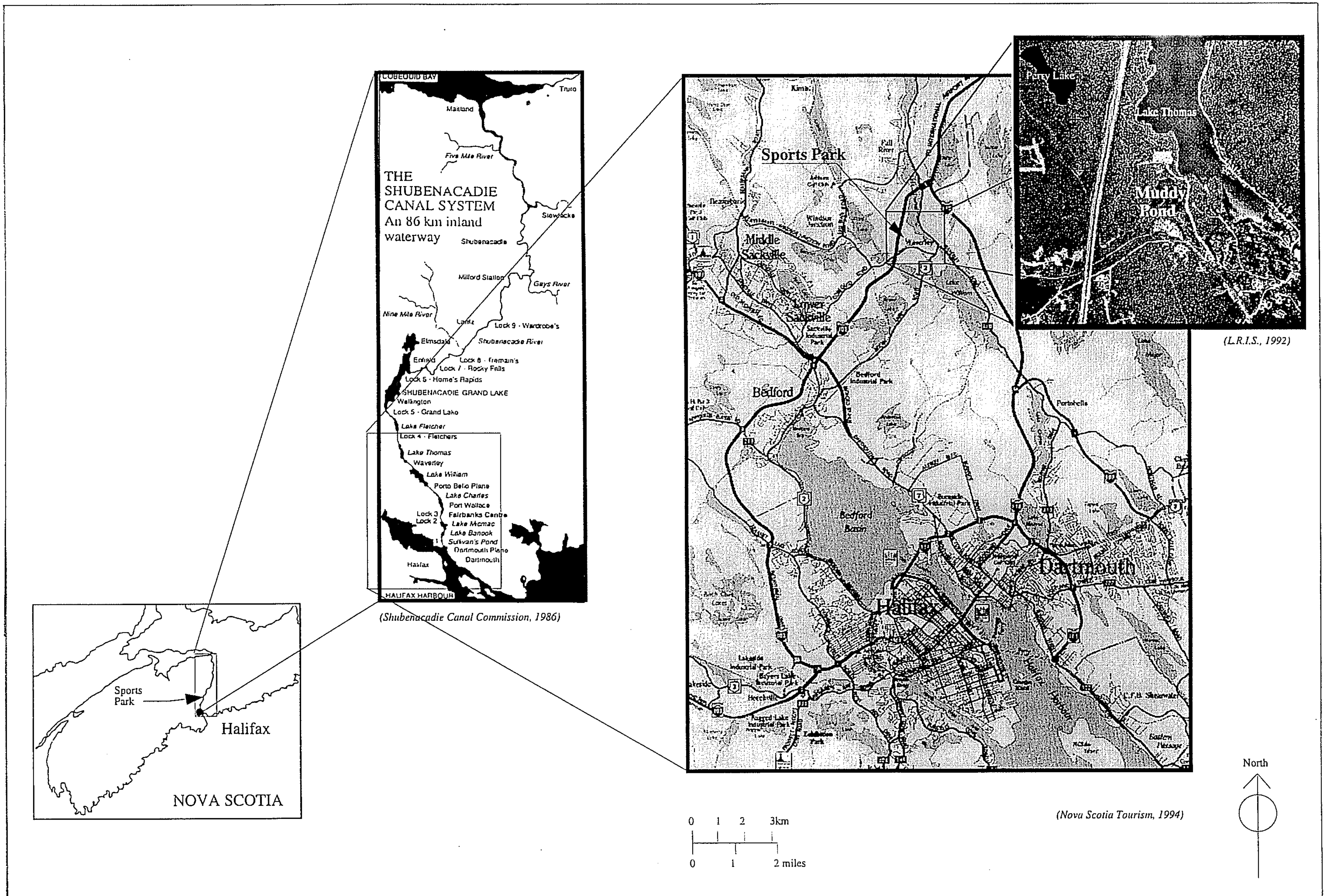


Fig. (1.) SITE LOCATION MAP FOR THE CHARLES L. McDONALD SPORTS PARK

With the present lack of protective legislation for wetlands in Nova Scotia, and the awareness of their ecological roles, both at the site scale and the greater regional scale, it is important to understand how the wetland system functions before responsible design can occur. Today Muddy Pond is under pressure from development, both directly from sport facility planning within the Park, and indirectly from other land use activities outside the Park, including residential and industrial development. The primary focus of this project is to identify those land use activities associated with the development and management of the Park most detrimental to the ecological processes of the wetland, and propose design techniques for their mitigation.

Project Goal and Objectives

The **goal** of this project is the protection of the Muddy Pond wetland system. To achieve this the following **objectives** are provided:

1) To make aware the functions and values of the Muddy Pond ecosystem.

2) To identify the wetland processes in Muddy Pond.

3) To identify land use activities associated with the Sports Park and their impact on the wetland.

4) To identify and illustrate how landscape architectural techniques can be implemented to mitigate impact from selected activities.

Methodology

The issues of responsible landscape design and wetland contamination from land use development were first presented as an area for a practicum topic (Figure (2.) Methodology flow chart). Of interest, were the ecological processes of a wetland that may be affected by development. The question arose as to what role the landscape architect could play in the protection of wetland processes in the development and management of a site -in this case a recreational sports park in rural Nova Scotia. An environmental inventory was compiled during the summer of 1994, identifying the drainage pattern for Muddy Pond, the trophic status of the wetland and the history and extent of development already present within the Sports Park. (See the Appendices for further background information) An analysis of Muddy Pond system, illustrating the structure of the wetland and the flow of energy through the system, was prepared to identify the major ecological processes occurring in the Pond. From the environmental inventory, a list of the Park's features was produced describing the ecological impact that each might have on the wetland. The features with the greatest impacts to Muddy Pond were identified and illustrated, showing how they impact on the wetland system. A list of design considerations for stormwater discharge into Muddy Pond was compiled based on the literature. This, in association with the environmental inventory, the ecological processes of the wetland and the major features contributing to the pollution of Muddy Pond, were used to produce a series of detailed illustrations showing how to mitigate the impact from those features. Finally a list of future Park management recommendations for the protection of Muddy Pond were produced.

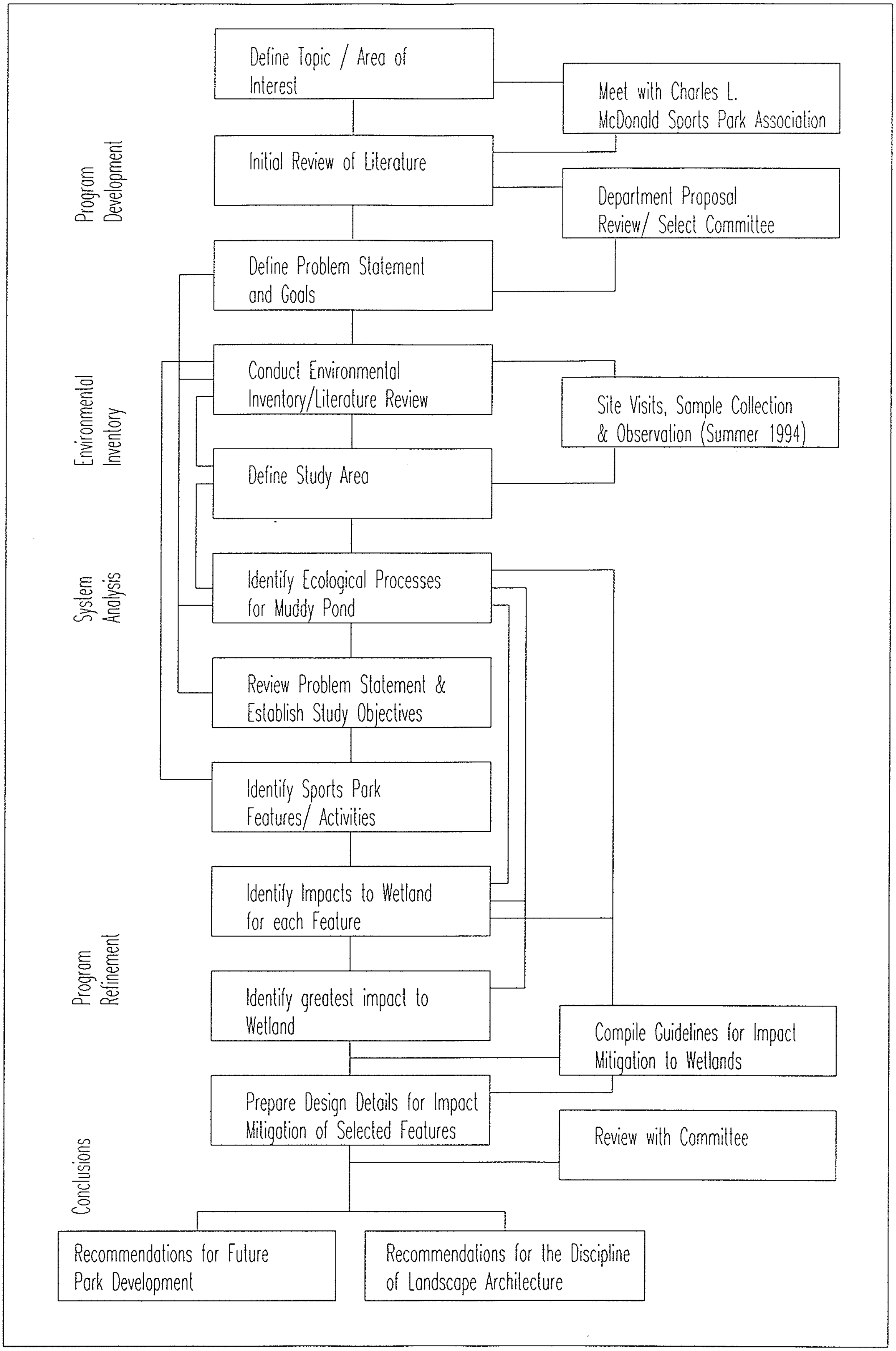


Fig. (2.) Methodology Flow Chart.

2

The Discipline of Landscape Ecology

The Genesis of an Idea

In its infancy the relatively young school of landscape ecology has many advocates who have differing views as to the role this discipline should play in design. The predominantly European field of landscape ecology is only about 60 years old, with the term "landscape ecology" first defined in 1939 by Carl Troll, a geographer concerned with the natural environment and human landscapes (Naveh and Lieberman, 1994). It is only recently that the study of ecology at the landscape scale has been applied to practical problems and incepted as a discipline (Selman and Doar, 1992). Before then, however, there were those in the field of landscape architecture that recognized the importance of ecological processes. Of those, it is Jens Jensen who is seen as the inspiration for a whole new generation of designers (Grese, 1992).

Grese (1992) suggests that Jensen's natural design of parks and gardens were an attempt to awaken people to the beauties around them and to reconnect people to the biological heritage of their region. Grese (1992) even goes so far as to state that Jensen alone, in this century, has successfully demonstrated how a deeply felt land ethic could be translated into physical form and ritual. Jensen (1939) believed that knowledge and understanding of the out-of-doors reveals to one's mind motives and forms and that while it is easy to imitate these forms, they are, themselves, an inspiration to greater sleeping forces that will eventually bear "wholesome fruit" (Jensen, 1939).

Grese (1992) states that the naturalistic designs of Jensen and others (O.C. Simonds, Frank A Waugh), at the turn of the century, were being supported by the growing field of ecology, whose ideas of plant communities and dynamics had become important to these landscape architects. Jensen, through his designs sought to further people's understanding and appreciation of nature. These landscape architects, Grese (1992) points out, were no longer content with just harmonies of form, line and colour, but with harmonies learned from nature's arrangements of species within defined boundaries.

Different Perceptions of the Discipline

More recently other proponents of landscape ecology, including Aldo Leopold *(Land Ethic*, 1948), Ian McHarg (*Design with Nature*, 1969), Michael Hough (*City Form and Natural Process*, 1984), Forman and Godron (*Landscape Ecology*, 1986) and Naveh and

Lieberman (*Landscape Ecology: theory and practice*, 1994) have echoed Jensen's view in understanding the importance of the landscape in which they work. Because landscape ecology has a transdisciplinary nature -crossing many disciplines, its proponents often bring differing views as to the relevance of the new discipline.

Landscape ecology is concerned with the spatial relationships and functional interactions between ecotopes (patches of heterogeneous land area) and how these affect the structure and function of the greater ecological mosaic over time (Forman and Godron, 1986; Selman and Doar, 1992). Landscape ecology is typically associated with human ecology (Parker, 1987; Selman and Doar, 1992) with "biophysical health -plant productivity, biodiversity, survival of species, minimal erosion, "tight" nutrient cycles and clean water" (Selman and Doar, 1992). While Basso (1994) describes landscape ecology in reference to space and time, Moss (1988) states that landscape ecology is interested in the form, function and genesis of the landscape, commonly viewed by landscape ecologists in one of three different, but not unrelated points: (1) visual aspect or landscape as scenery, or land form (2) chorologic aspect or horizontal heterogeneity such as patches and corridors and (3) topologic aspect or vertical heterogeneity, implying the landscape as an ecosystem which includes the first two. (See Figure (3.)).

Zonneveld, a geographer and not an ecologist (1972, in Naveh and Lieberman, 1994), interpreted landscape ecology quite differently from Moss (1988) or Basso (1994). He described landscape ecology as the crucial subdivision of 'land(scape) science.' Zonneveld (1972, in Naveh and Lieberman, 1994) stated that the landscape is a holistic entity made up of different elements, all influencing each other (See Figure (4.)). Zonneveld felt that the land, not the living organisms, constitutes the central point of landscape ecology (Naveh and Lieberman, 1994). It is reasonable that any perception of the discipline of landscape ecology brings into its definition a certain bias. In the profession of landscape architecture it may be reasonable to perceive landscape ecology as a tool to be utilized in responsible landscape design -a design ethic.

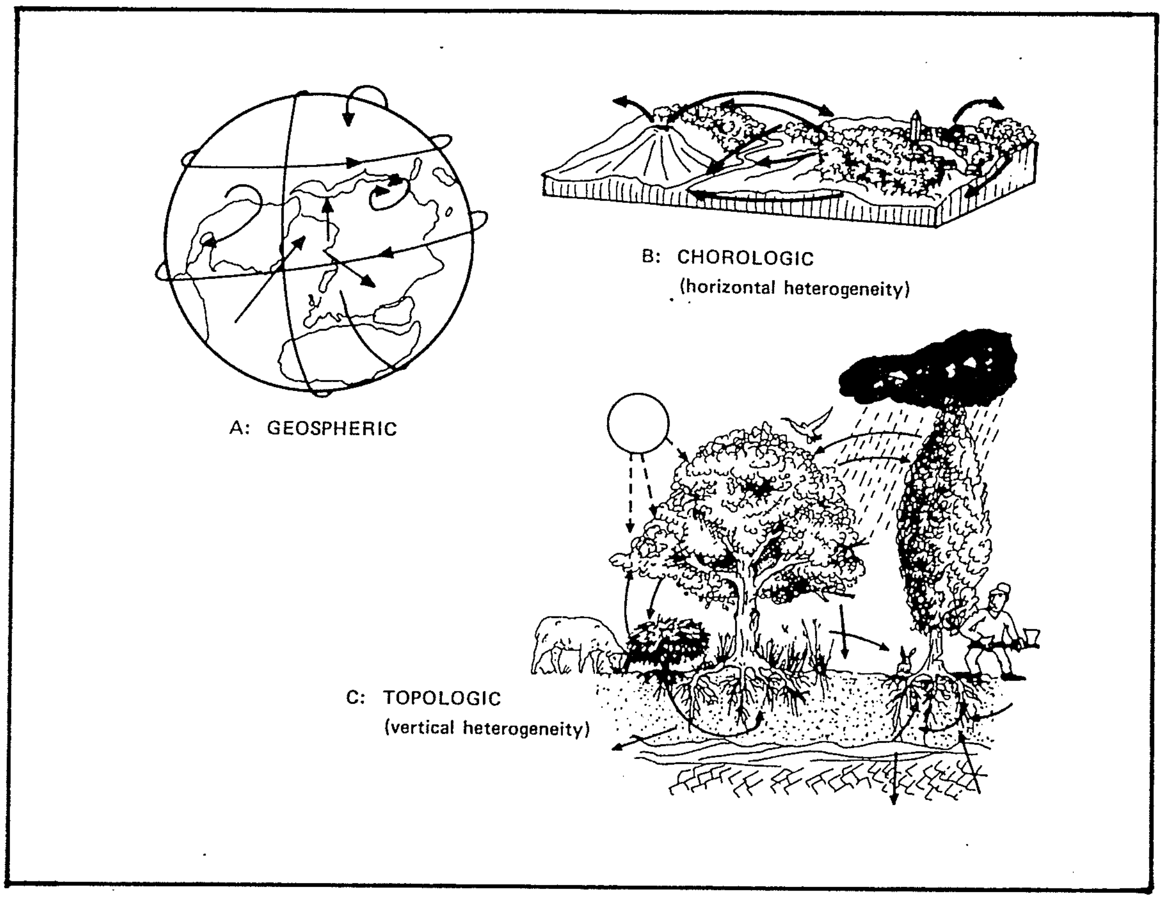


Fig. (3.) Landscape ecology dimensions (Moss, 1987).

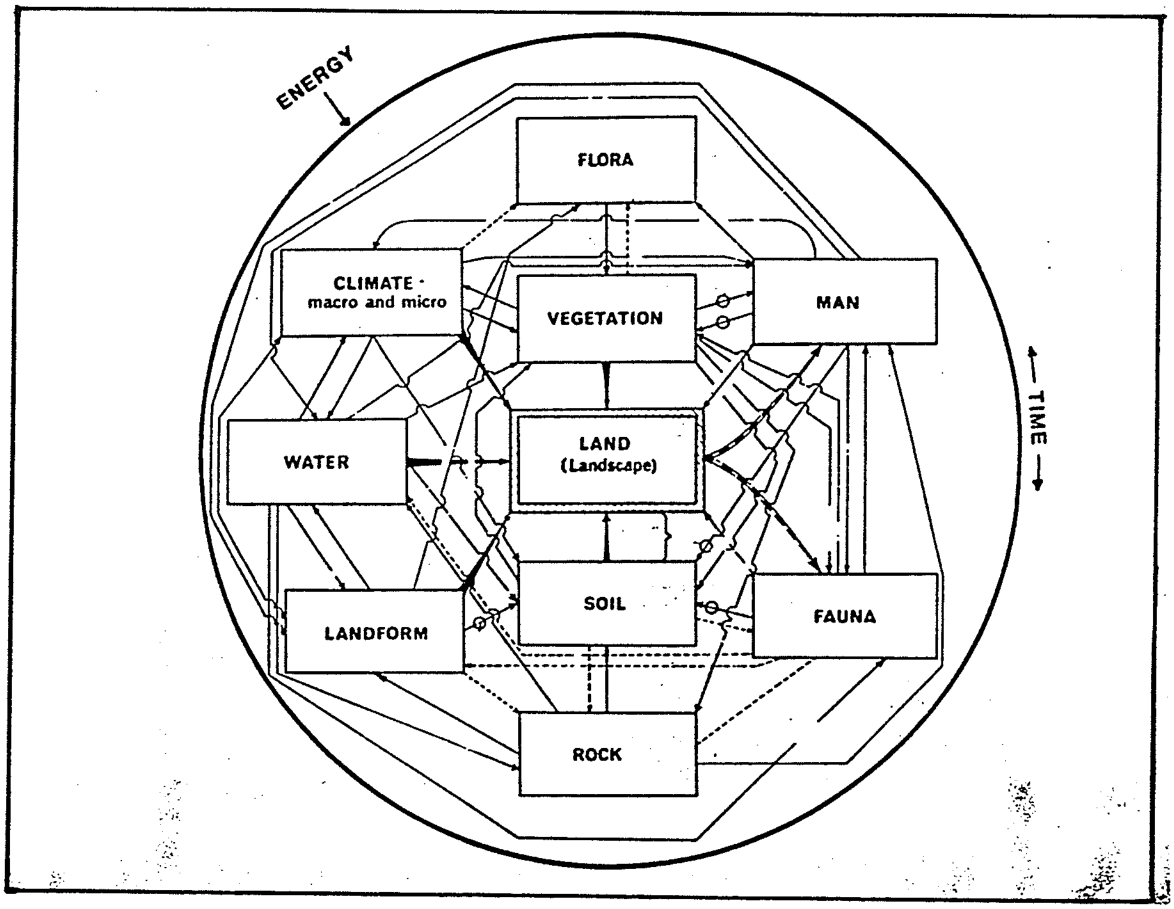


Fig. (4.) Land-forming factors and attributes and their interrelation (Zonneveld, 1972, in Naveh and Lieberman, 1994).

Understanding Scale and the Ecotone

Selman and Doar (1992) suggest that because landscape ecology addresses scale, changes in the structure and function at the small scale will ultimately have impact on the larger landscape and vice versa. Selman and Doar's remarks on scale (1992) reiterate the notion "think globally, act locally" offering designers one way in which to address large complex issues, such as watershed management and water resource contamination, at more manageable scales which still have relevancy in the greater ecosystem. In reference to Muddy Pond, and the ecological roles it plays in the greater landscape, contamination of the water regime at the pond level may influence water quality on the other side of the province.

In its most simple form the scale of the landscape ecosystem can be viewed as four interacting components, climate, soil, plants and animals interacting among themselves. At a more detailed level the ecosystem would describe the actual complex movement of materials through it (Bradshaw and Handley, 1982). Ecosystems are dynamic at any given point in time. They are also in a dynamic state with time (Bradshaw and Handley, 1982). Because ecosystems can acquire and accumulate materials utilized by individual organisms within the ecosystem, the system itself can become larger and more complex and more productive -what Bradshaw and Handley (1982) describe as the process of natural succession. The organisms, themselves are also not static, but continually evolving into specialized populations (or ecotypes) which optimize the environmental conditions within the ecosystem. Because the environmental conditions constantly change throughout the ecosystem, due to shifting environmental gradients, the ecotypes at the center of an ecosystem may be quite different than those found around the edge of the system -referred to as the ecotone. Hansen and di Castri (1992) state that, in many instances, the limits of a species range occurs within an ecotone and that therefore these zones may be sensitive to environmental changes. This is an important aspect in understanding the ecological processes of the system, particularly in wetland systems where there are many ecological processes at work.

Bradshaw and Handley (1982) state that the ecological processes occurring within these ecotypes can be adapted to 'ordinary' conditions such as drought, cold, grazing or wind, as well as specialized conditions such as nutrient loading, metal pollution or herbicide application. It is this remarkable adaptability which allows the organisms to fit their environment and better survive. Parker (1987) describes this "fit" as the organism's niche within the environment and is dependent upon both, a flow of energy and the recycling of materials.

In reference to scale, wetland systems can be considered ecotones (Tyler, 1995) and at the same time have their own ecotones. An ecotone is a "zone of transition between adjacent, interconnected, ecological systems, having a set of characteristics uniquely defined by space and time scales, and by the strength of the interactions between adjacent ecological systems" (Hansen and di Castri, 1992). Figure (5.) illustrates the interaction of the various environmental parameters of a single wetland system through time.

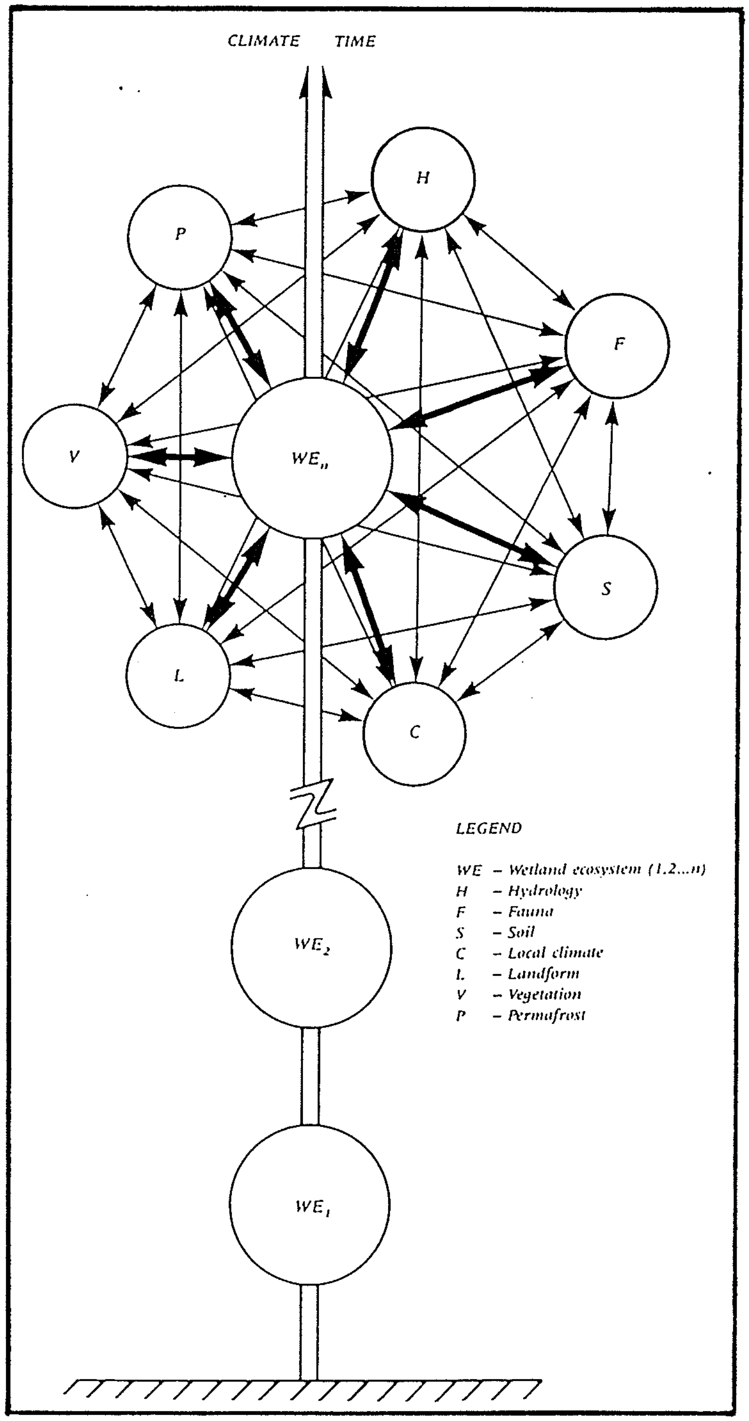


Fig. (5.) Diagram of interactions between environmental parameters and wetland ecosystems through time and changing climate (NWWG, 1988).

As transitional zones between the land and the water, wetlands are sensitive, complex, open systems, historically viewed as detrimental to economic development (North American Wetlands Council of Canada (NAWCC), 1992; Manuel, 1994) and still misunderstood for the important ecological role they play within the landscape (Manuel, 1994).

The important aspect of the wetland systems, as ecotones , is how they influence the ecological processes within the landscape. At one level of scale wetlands provide unique habitats optimal to some species and hospitable to others, serving as either barriers or corridors between gene pools (Hansen and di Castri,1992). Regionally, wetlands act as stabilizers within the larger landscape controlling natural drainage and floodwater distribution between the land and the water. At another level wetlands may act as buffers between adjacent communities, serving as semipermeable barriers across which energy, nutrients and propagules may pass.

Ecological Process and Landscape Design

McHarg's approach (1969) to resource management comprised of the resource (the land or site) being analysed by identifying and delineating the homogeneous components (features and uses). Once the whole was broken down into its many parts and analysed, they were then resynthesised using "map-overlays" and the site's opportunities and constraints were extracted, from which the final design was based upon (McHarg, 1969).

Although McHarg's simplified, reductionist approach to environmental planning was the "state-of-the-art" in 1969 with the publication of the text Design with Nature, it is no longer enough when addressing issues of environmental design and landscape conservation, especially when the important role which complex ecological systems play are just beginning to be understood.

Traditionally landscape design has been perceived in the static sense. Often, the idea of maintaining the landscape was to retain the design as the status quo. Of course, nature is much more dynamic than a static solution, responding, instead to the natural processes occurring on the landscape. Hough's design philosophy (1984) is based upon process. Hough (1984) suggests that design and maintenance should be utilized collaboratively in a process "guiding the development of the man-made landscape over time." The ecological process is never really finished, but instead dynamic and changing as the landscape changes. Responsible design should incorporate ecological processes, such as growth and decay and succession, into their environments. Ecological design should maintain the biological activities and energy cycles of the landscape. Innovative ecological design would meet the challenge of improving upon these activities where warranted. The design process, therefore should not be linear but circular and include the management of the landscape as an integral part of the design. The management of the landscape, as opposed to traditional landscape maintenance, allows for a more dynamic landscape, one which can evolve over time, responding to the ecological processes of the landscape and adapting to the ever-changing environment.

Bradshaw and Handley (1982) differentiate between natural and ecological approaches to design, stating that the use of indigenous species planted in natural associations as measures for specific landscape solutions is not an ecological approach to design. Instead it is a naturalistic approach and a small part of an ecological approach. A full ecological approach goes beyond plant associations and involves many different principles of ecology all of which would be the outcome of understanding ecosystems and natural processes. An ecological approach to design would acknowledge the natural processes occurring on the site. Koh (1982) distinguishes between Modern environmental design and Post-Modern environmentalistic design. Environmental design refers to the environment that is designed whereas environmentalistic or ecological design refers to the process or approach taken. Koh (1982) states that as an approach, ecological design is a "transformation" of McHarg's ecological approach to planning "finding its value not only in its social relevance but also in the philosophical soundness of a holistic, evolutionary view of the world."

Manning (1982) states that whether the approach is "naturalistic" or "ecological" is for philosophers to debate, as long as the process replaces restricted, artificial and expensive conventional landscapes. The use of an ecological approach to design over a traditional solution should be relatively more self-sustaining and less labour intensive in the long run. The design itself, too, should be self sustaining, economical, unique and aesthetically pleasing and ultimately in response to the landscape.

Conclusion

In 1939 Jensen was describing the landscaper of the future as one "who will weave the works of man and of the primitive into one harmonious whole, counteracting the scars made on mother earth through ignorance." Landscape ecology evolved out of a passion to become reconnected with the land. Today landscape ecology has evolved into a transdisciplinary ethic responding to environmental issues and sharing a common goal - that of taking responsibility for our actions. As a discipline landscape ecology can be applied at any level of scale, from global warming to municipal wastewater treatment to residential landscapes for wildlife habitat. As an approach to landscape study and management, the conventional, discipline-oriented, and mostly reductionist scientific paradigms can be replaced by more integrative, holistic, and transdisciplinary approaches and methods, based on a systems view (Naveh and Lieberman, 1994).

Jensen believed that there was no other art that was so full of life than that of landscaping. "The art of making landscapes [as] just a branch of architecture", Jensen felt could not be further from the truth. Jensen saw the landscaper as an artist, his forms as growth stimulated from the land itself (Jensen, 1939). However our actions are recognized as major influences on the structure and function of the land. With a combination of scale and the recognition of human involvement, landscape ecology is an attractive framework in which both planners and landscape architects can address the real land management issues of our time. While there is a growing appreciation of the relevance of landscape ecology to such pressing and complex ecological and sociological problems as land degradation, habitat fragmentation and loss of biodiversity, attractiveness and recreation amenities and its importance to conservation and restoration ecology, the role of the landscape architect as 'steward of the landscape' becomes a greater responsibility.

3

The Muddy Pond Wetland System

Muddy Pond in Context

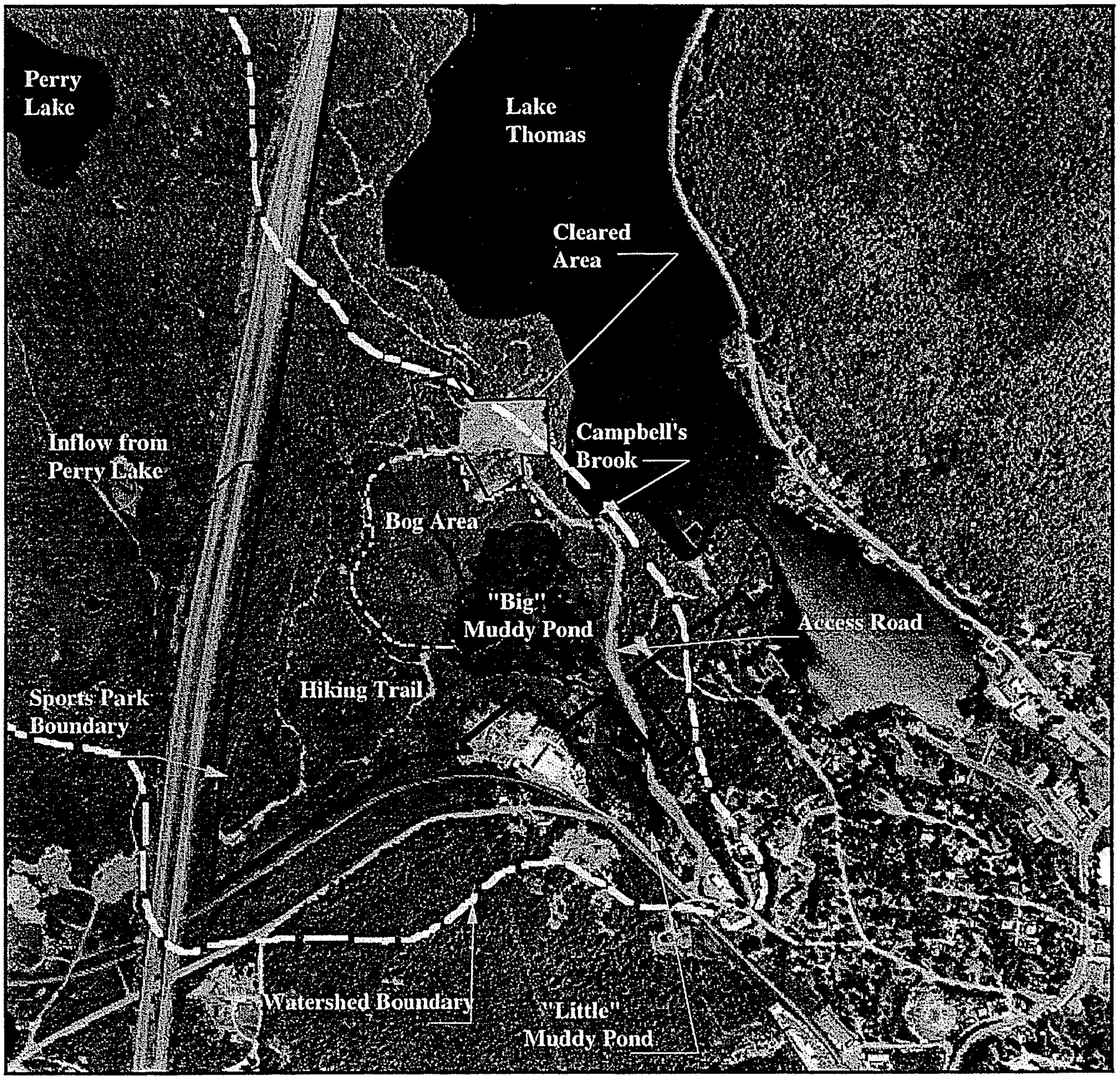
Muddy Pond is an open system, meaning that it exchanges energy and matter with its surroundings. It receives its critical energy from the sun, which is used in photosynthesis as a base of almost all life. Mineral nutrients, which flow both in and out of the Pond, are derived from the parent material and from other ecosystems. Human intervention typically increases the inputs and outputs of matter, making the system even more open (Forman and Godron, 1986). Water flow, into and out of the Pond, its rich bio-diversity and structure are all good indicators of an open system. The significance of an open system like Muddy Pond lies in its regional context and the influence it has on the greater landscape.

General Pond Description

Muddy Pond lies in the southern portion of the Charles L. McDonald Sports Park and is first evident as one enters the Park along the access road (Figure (6.) Watershed Boundary and Site Features). The access road was constructed around 1989, following the edge of Muddy Pond along the base of American Hill and terminates just north of the Pond in the cleared area, where a recreational facility is proposed.

Muddy Pond is comprised of two ponds ("Big" Muddy Pond and "Little" Muddy Pond) approximately 5 hectares (12 acres) in size and a bog-like wetland of about the same size on the north west side. The Ponds and the bog, together, make up what is known today as Muddy Pond.

Muddy Pond is fed by two small brooks which run from the other side of the Bicentennial Highway #102 into the Park. One of these brooks is intermittent, while the other carries water from a single lake called Perry Lake. Inflowing water enters through the bog-like area into Big Muddy Pond. Out flowing water from Muddy Pond exits through a small brook known as Campbell's Brook. Campbell's Brook connects Muddy Pond to Lake Thomas and is believed to be the site of Nova Scotia's first gold claim (See Appendix (7.) *Gold*).



Scale (meters):

0.0 100 200 300 400 500

Grid North

Sources: Nova Scotia Topographical Series: 11D/13-T1,
11D/13-T3, Waverley, Halifax County
Land Registration Information Series, 1975;
Air Photo flown 1992, L.R.I.S.

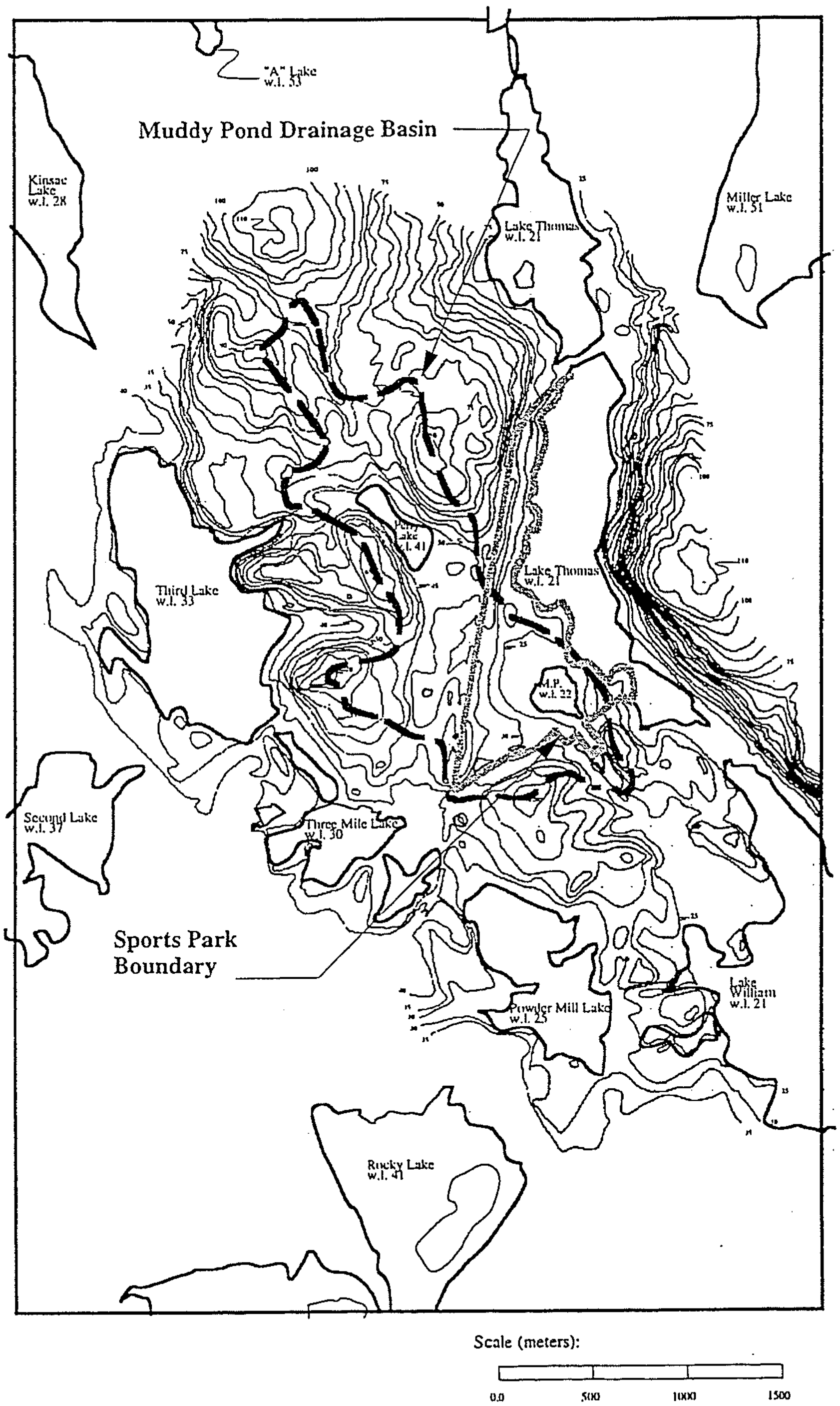
Fig. (6.) MUDDY POND WATERSHED BOUNDARY AND SITE FEATURES

The Muddy Pond Drainage Basin

Muddy Pond drains an area of approximately 249± hectares (615± acres). The Muddy Pond drainage basin sits in the headwaters of the Province's largest watershed, the Shubenacadie-Stewiacke River Basin. While the Headwaters make up only about 15 percent (approximately 375 square kilometres (145 square miles)) of the total extent of the Shubenacadie-Stewiacke River Basin, they have important, historical and cultural significance, as well as being part of an enormous river corridor system, 138 km (86 miles) in length that transects the Province from the Atlantic Ocean to the Bay of Fundy. (See Appendix (4.) for further description of the *Shubenacadie Headwaters*).

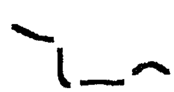
Although Muddy Pond is a second order drainage basin (Marsh, 1991), not all of the Park drains into Muddy Pond (most of the northern half of the Park drains directly into Lake Thomas). While the southern half of the Park does drain into the Pond, most of the lakes in the area drain into Lake William and do not drain into Muddy Pond (Figure (7.)).

The topography of the surrounding area is gently undulating to gently rolling with ridges and valleys (N.S. Soil Survey, 1963). In some areas within the Park slopes in excess of 30 percent slope down from the Bicentennial Highway to Lake Thomas. The soils are sandy, highly leachable and thinly distributed. This coupled with steep slopes causes concern for erosion where soils are exposed. (See Appendix (5.) for a further description of the *Landscape of the Atlantic Interior Region of Nova Scotia*, and Appendix (1.) for a description of the soils within the Park).



Area of Drainage Basin: 249 + hectares (615 + acres)

Contour Interval: 5 meters

Muddy Pond Drainage Basin: 

Sources: Nova Scotia Topographical Series: 11D/13-T1,
11D/13-T3, Waverley, Halifax County
Land Registration Information Series, 1975

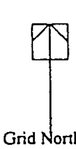


Fig. (7.) MUDDY POND DRAINAGE BASIN

Much of the MPDB is undeveloped and forested and on the western side of the Bicentennial Highway, beyond the Park's boundary. Included in this minor watershed are the mine tailings from past gold mining activities as well as the soils from the Halifax slate formations. While the quartzite tailings are associated with naturally occurring arsenic, the slates are associated with naturally occurring acidic runoff when exposed to weathering. It is on these acidic slates, in the northern most part of the MPDB, that single family residential development is beginning to occur. (See Figure (7.) in Appendix (1.)).

Regional Water Management Issues

The quality of the water in the Headwaters has been of great concern and the focus of many surveys over the years. (See Appendix (4.) *The Shubenacadie Headwaters*, for further detail). For the people of Village of Waverley (population 1600 (1986)), and other communities within the Headwaters, and along the entire Shubenacadie-Stewiacke River system, water resource management is an integral part of their lives. Water resource management is concerned, not only with how water is used, but also how the land resource is used. While Appendix (4.) describes how the resources are utilized, the main water resource management issues in the Headwaters area are; eutrophication, arsenic contamination of drinking water, arsenic and mercury contamination of beach sediments, acidic drainage from exposed slate bedrock and management of the Shubenacadie Canal. These issues are as much ecological problems as they are social or economic. Activities like erosion and sedimentation and eutrophication can adversely affect the ecology of the lakes, both in the Headwaters and further downstream. This, in turn, will affect both the social and economic qualities of the resource and ultimately the quality of lifestyle for those that depend upon the resource.

Muddy Pond is directly related to these issues by the nature of its hydrology. The Muddy Pond Drainage Basin drains into Lake Thomas, which flows into the Shubenacadie-Stewiacke River system. Therefore, poor land use management and design practices within the boundaries of the Sports Park will, not only have an impact on the ecology of the wetland and resultant quality of the water leaving Muddy Pond, but also of the entire River basin system. Because open systems are all connected and operate interactively, human intervention must proceed carefully, with an understanding of its impact on the environment, and with a willingness to show responsibility. Understanding how land use activities can affect water quality and then tailoring design and management practices to prevent contamination is perhaps the best way to show responsibility. However, this responsibility can only be achieved with a thorough understanding of the ecological processes of that system, and how that system, in turn, affects other systems.

Wetland Classification

Before the ecological processes of Muddy Pond are discussed it is first necessary to understand the general role that wetlands play in the greater landscape. Generally there are five types of wetlands in Canada: bog, fen, swamp, marsh and shallow open water (NAWCC, 1992). Under these five wetland types are many wetland forms; their list still open-ended. Presently 18 bog forms, 17 fen forms, 15 marsh forms, 7 swamp forms and

13 shallow open water forms have been identified and more are expected to be added. These wetlands occupy over 127 million hectares (314 million acres) of wetland in Canada (14% of the country), comprising 24% of the total world wetland base (NAWCC, 1992). The distribution of wetlands across Canada are presented in Table (1.). While Appendix (1.) presents a detailed classification for Muddy Pond, it is enough to say here that Muddy Pond is a freshwater wetland, 10 hectares (25 acres) in size, comprised of a shallow mesotrophic marsh rich in cattails and water lilies and a sphagnum moss-larch-black spruce fen of roughly equal size.

The Value of a Wetland

The value which society places on a wetland is derived from those goods and services that the wetland has to offer. Not all the services or benefits may be easily measurable, or of obvious, immediate value to society. Not all wetlands offer all of the same goods and services either, as both the form of wetland and the human value placed upon it differs from coast to coast. Darnell (1978) defines environmental impact in terms of the effect on human values which have been placed on wetlands, the significance of which is human judgement. In wetlands that have succession (not all do (Darnell, 1978)), the rate of succession can be gradual or sudden (Hansen and di Castri, 1992) as in the case of the natural eutrophication of a wetland versus the accelerated cultural eutrophication caused by nutrient loading from human activity. The impact that disturbances such as cultural eutrophication have on the ecological processes are just beginning to be understood (Turner, 1987).

Table (1.) Occurrence of wetlands and peatlands in the provinces and territories of Canada

Province or territory	Peatland area		Total wetland area	
	ha x 10^3	% of land area in province or territory	ha x 10^3	% of land area in province or territory
Alberta	12 673	20	13 704	21
British Columbia	1 289	1	3 120	3
Manitoba	20 664	38	22 470	41
New Brunswick	120	2	544	8
Newfoundland & Labrador	6 429	17	6 792	18
Northwest Territories	25 111	8	27 794	9
Nova Scotia	158	3	177	3
Ontario	22 555	25	29 241	33
Prince Edward Island	8	1	9	1
Quebec	11 713	9	12 151	9
Saskatchewan	9 309	16	9 687	17
Yukon Territory	1 298	3	1 510	3
Canada	111 327	12	127 199	14

(Source: National Wetlands Working Group, 1988)

Landscape heterogeneity can be increased or decreased by disturbance and while disturbances are not always considered bad, intrusion upon wetland systems are having widespread deterioration on the functions and values placed upon wetlands (Darnel, 1978). The continual alteration or conversion of wetlands in Canada has reached: 70% in central prairie sloughs, 65% in Atlantic salt marshes, 80 to 98% in urbanized regions, 70% in Pacific estuarine marshes and 70 to 80% in southern Ontario and the St Lawrence Valley (NAWCC, 1992).

Darnel (1978) identifies three main forms of intrusion: outright destruction of wetland habitat, increase in suspended solids and alteration of water quantity and stream flow patterns. Destruction of habitat is the result of such activities which would reduce water levels or alter drainage of the wetland. Increased suspended solids usually reflect increased surface runoff and activities affecting riparian areas. Alterations to water quantity stem from such activities as damming, channelization and land drainage. To the extent that wetlands are continued to be drained and filled, the systems themselves are lost. The impact of loading with suspended solids results in increased rates of succession. The impact of reducing or destroying habitat types, is the reduction of species diversity. And finally, to the extent that the physical and chemical composition of the system will become modified due to all these above mentioned alterations, the wetland itself is placed under stress (Darnel, 1978).

The North American Wetlands Conservation Council (NAWCC, 1992) define wetland functions as:

"the capabilities of wetland environments to provide goods and services including basic life support systems and that such functions may directly or indirectly provide benefits to society."

The NAWCC (1992) divides wetland functions into three groups discussed below:

1.) **Life Support Functions**:

Wetland functions such as flood regulation and soil-water-nutrient absorption address the wetland's capacity to regulate and maintain essential ecological processes and life support systems. Processes like wetland hydrology are critical in the development of wetlands. Restriction of the hydrological function can reduce or eliminate waste absorption or buffering capacity. Wetlands also influence water flow within their drainage basins, buffering against peak floods and droughts, enhancing water quality and protecting against lakeshore erosion. As filters, wetlands remove excess nutrients and toxic chemicals from the water through wetland plant uptake. The cleansing ability of wetlands has led to the growing interest in secondary treatment of sewage and stormwater.

Some wetlands, like swamps and marshes are considered highly productive or "fertile" ecosystems with complex energy transfers, while bogs and fens generally have a less complex energy web. Wetlands provide habitat for a wide variety of wildlife. Prairie potholes provide habitat for roughly 50% of North America's waterfowl, while coastal estuaries provide essential habitat for various fish and invertebrates. Freshwater wetlands provide habitat for spawning fish, amphibians and invertebrates, as well as support many mammals and predatory birds. Of the roughly 95 endangered species in Canada, 40-45 utilize wetlands. The biological functions associated with wetlands tend to attract other social and cultural values.

2.) **Social and Cultural Functions:**

The social and cultural functions of wetlands include those associated with recreational, educational and scientific values. By providing a link to the environment, culturally, wetlands provide for hunting, trapping, fishing and gathering. Socially, healthy wetlands suggest a healthy well being in us, as well as offer both scenic and aesthetic values. Wetlands are unique and hold a value all their own by just being in existence. Some people place real estate values on living next to a wetland.

3.) **Production Functions:**

Wetlands also function as producers of both consumptive (hunting, trapping, fishing) and non-consumptive (photography, bird watching) uses. Some commercial inland fisheries rely on healthy wetlands where many of these species spend some part of their life. Wetlands also provide for the harvesting of: peat, cranberries, medicinal plants, wood, fur and wild rice.

Shay (1981) also groups the importance of wetlands into three broad categories:

The Role of Wetlands in Hydrological and Biochemical Cycles

- They are the "landscapes' containers" acting as focal points for recharge and discharge of groundwater;
- They reduce the erosive effects of floods by releasing water during the dry season and retarding surface flow thus slowing down the rate of surface runoff to streams during

the wet season;

- They aid in stabilizing lakeshores and river banks, thus reducing erosion and moderating silt deposition and generally enhance the water regime;

- They act as natural filters for many chemicals such as those contained in sewage wastes, agricultural runoff and industrial pollutants, thereby improving water quality;

- They are the interface between the terrestrial and aquatic ecosystems and thus play an important role in the hydrological cycle.

Productivity and Habitat Diversity

- They provide the habitat for many species of plants and animals, thus supporting complex foodwebs. Their biotic density and diversity is frequently higher than that of adjacent uplands, making them highly productive;

- They offer a variety of resources for inhabitants of neighbouring aquatic and terrestrial ecosystems such as deer, grouse, ducks and dragonflies;

- They harbour fish, waterfowl and fur bearing animals of economic value;

- They contain rare and endangered species (such as the *Arethusa* orchid, in Manitoba) and are a storehouse of genetic diversity.

Scientific and Cultural Values

- They provide natural laboratories for research and education as well as serve for recreational purposes for such enthusiasts as canoeists, birdwatchers, fishermen, artists and photographers, naturalists, hunters and hikers;

- They are aesthetically pleasing, enhancing the quality of life for all. They offer a dynamic realm, within the landscape, adding sight, sound and smell and are ever changing.

In summary, there would be no values associated with wetlands without human intervention (Darnel, 1978). The form of human intervention has too often been in the form of wetland intrusion and subsequent deterioration of the wetlands' goods and services. In evaluating the value and capability of a wetland to provide the various goods and services the NAWCC (1992) suggest four things to consider:

1. the regional and inter-regional linkages of wetland functions;
2. the associated social/cultural and productive functions of the biological and hydrological and biochemical attributes of natural systems;
3. the values we place on these functions and relationships; and
4. the potential costs of wetland conversion

The Structure of Muddy Pond

The structure of Muddy Pond is one of complexity. Muddy Pond's history has been one of abuse, neglect and disregard. Up until as late as 1933, Muddy Pond was used as a dumping ground for the tailings from gold mining operations in and around American Hill and Muddy Pond (Hartlen, 1988). (See Appendix 6. for further description of mining operations around Muddy Pond) Consequently there is no clearly defined, textbook style, zonation pattern. Instead, the vegetation interspersion pattern of Muddy Pond reflects that of a once disturbed area and is best illustrated by Golet's Interspersion Type 2. (See Figure (8.))

Muddy Pond can be divided into three vegetative zones: Upland Forest, Fen and Mesotrophic Marsh, and are depicted in figures (9.) And (10.). Figure (11.) Illustrates the main species of flora found in each of the zones.

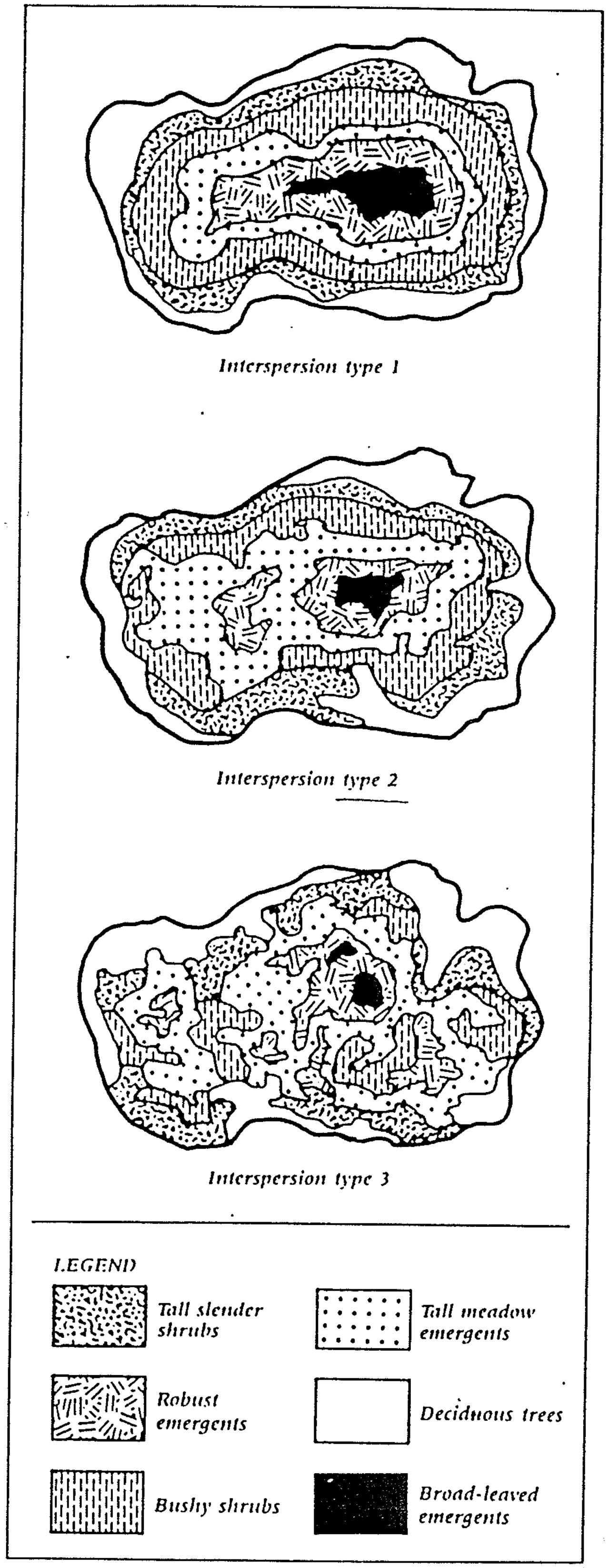
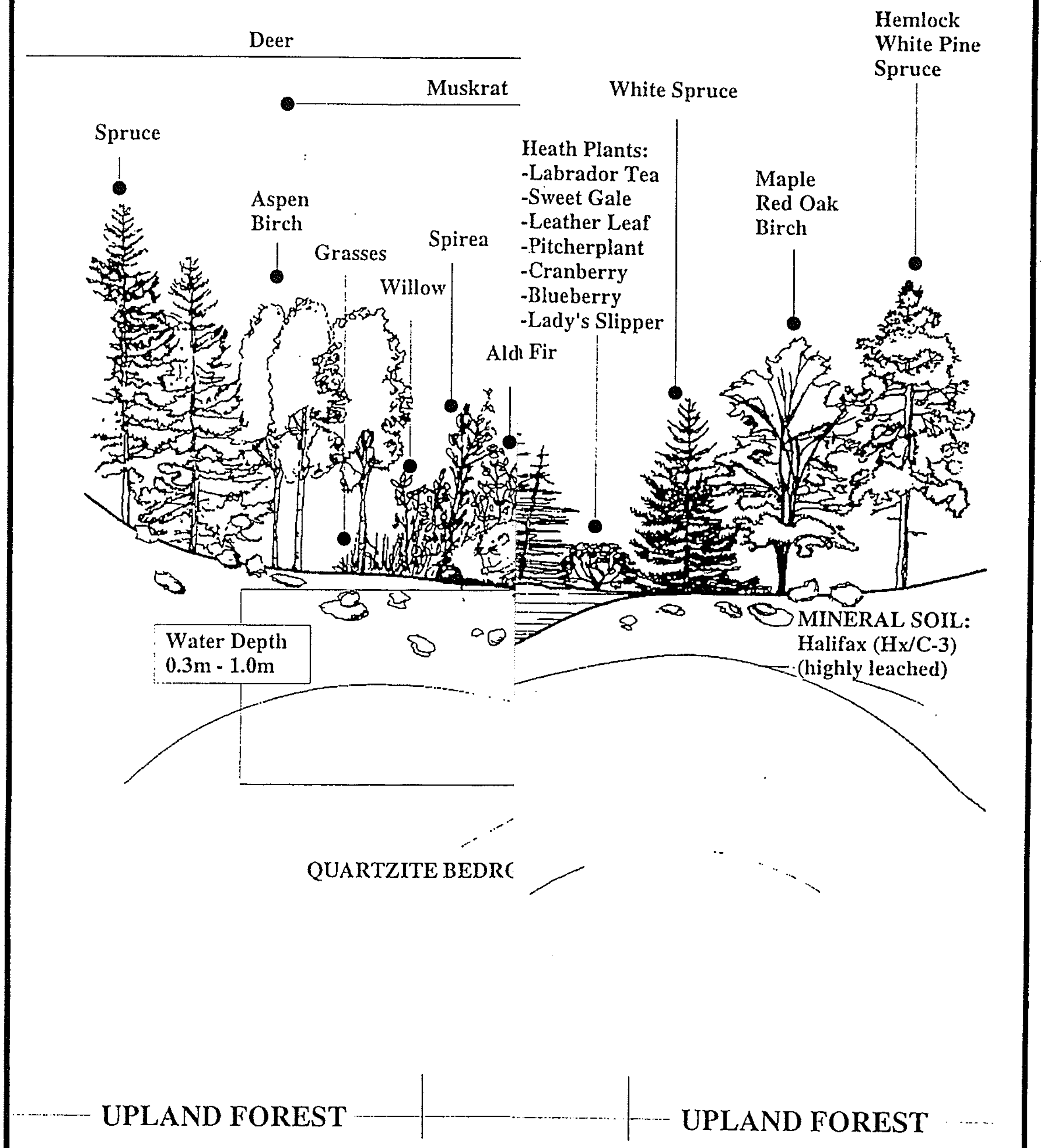


Fig. (8.) Vegetation interspersion types (Golet, 1972, in NWWG, 1988).

Fig. (9.) 'Big' Muddy Pond with marsh in foreground and fen in background.
(C.Pinks, 1994)

Fig.(10.) 'Little' Muddy Pond showing structure of emergent and floating aquatic vegetation.
(C.Pinks, 1994)



VEGETATIVE ZONES AND g. (11.) STRUCTURE

In the Upland forest, around Muddy Pond primary species like Speckled Alder, willow and Grey Birch indicate a landscape once disturbed. On the northern edge the Pond is defined by Larch, Black Spruce and Red Maple. The outermost edge of the marsh is defined by a ring (moving inward toward the centre) consisting of thick pure stands of herbaceous shrubs including Hardhack , Sweet Gale and Rhododendron. Much of the next ring is completely dominated by cattails. Cattails tends to be absent from the actual open portion of the Pond. Along the northern edge of the marsh, near the bog portion can be found Pickerel Weed . Emergents like the bulrushes, near the central portion of the Pond, illustrate the shallow depth of the water. Both the Spatterdock or Yellow Water-lily and the White Water-lily can be found in the main portion of the Pond forming large mats of floating aquatic plants. Submergents like the bladderworts can be found below the surface of the water. The deepest central part of the Pond is free of vegetation.

Purple Loosestrife, is also present in the Pond. Although only recently has the loosestrife come to the attention of avid environmentalists and bird watchers, the concern over the control of Purple Loosestrife can be dated back to the early 1960s, where, then 2,4-D was being used to try to eradicate the noxious weed (Smith, 1964). The concern is that Loosestrife, a fierce competitor, will invade and occupy wetland areas that should be occupied by waterfowl food plants. Ducks Unlimited (1993) state that waterfowl and muskrat will not eat the plant or the seeds. The monospecific stands which Loosestrife forms will displace wildlife species and those which can not move into new areas are lost.

The vegetation of the fen part of the wetland also has a degree of zonation. Closest to the Pond is the leatherleaf zone comprised of the Sphagnum mosses, sedges, the Cranberry family and other heath shrubs like Bog Laurel. Larger trees, like Larch and Black Spruce and some White Pine can be found further away from the Pond. These trees define the climax state of the bog. On the drier soils around the Pond, Blue Flag Iris, a variety of sedges, the Pitcher Plant, the Pink Lady's Slipper and the Sundew can be found.

Animal life around the wetland is also significant in that not only does it add an aesthetic quality for nature enthusiasts, but animals can influence the functioning and rate of succession of an ecosystem. Over the Pond a number of bird species, including sparrows, blackbirds, warblers, ducks, geese and hawks can be seen flying and darting over the tops of the cattails in the earlier part of the season, before the water level in the Pond drops. Ducks are more common on the open lakes in the late part of the summer than on Muddy Pond due, in part, to the drop in the water level. Also seen around the Pond are cranes, raccoons, snakes, deer, rabbits and squirrels (McDonald, 1995). The Pond contains perch, trout, bass, and eels (McDonald, 1995).

Frogs can be found along the shores of the pond, suggesting that they are inhabitants of the edge condition. The Northern Leopard and the Green Frog have been identified in Muddy Pond, while the Eastern American Toad, Northern Spring Peeper, the Bullfrog, the Mink Frog, Wood Frog and Pickerel Frog are all common to wetlands in Nova Scotia (Nova Scotia Museum of Natural History, 1994). Frogs are important indicator species as they spend part of their life cycle in water and part on land. A healthy frog population could suggest a healthy pond, as far as wildlife, or bio-diversity is concerned (Davis, 1994). Also evident within the Park, around Muddy Pond are signs of both beaver and muskrat. On drier forested lands, on the edge of the wetland are old aspen and birch stumps where beavers have been cutting trees. Although there does not appear to be any beaver dams now, there were in the past (Garner, 1994). The presence of muskrat is indicated by trails which run along the shores of the Pond under the leatherleaf and littered with freshwater clam shells. It is not clear if the clams are being harvested from the Pond itself or from Lake Thomas and then being carried to the Pond, but shells are abundant. Also easily seen around the Pond, especially near the latter half of the summer, are dragonflies, damselflies, whirligig beetles, backstriders, and diving beetles.

Muddy Pond Succession

Within the marsh zone of Muddy Pond are three main types of aquatic plants common to many Atlantic freshwater wetlands: emergents, floating and submergents (Figure (11.)). These aquatics, represent several things happening within the Pond. First there is a shift from emergents through to floating, to submergents to open water, as the water depth increases from shore inward to the centre. This pattern of vegetation suggests that the Pond is gradually filling in, otherwise referred to as succession. Most likely Muddy Pond will evolve into a Black Spruce-Larch fen-like wetland, but this process will take perhaps hundreds of years without human intervention. The richness of vegetation and abundant wildlife, otherwise referred as the bio-diversity, suggest that the Pond is also quite healthy.

The shallow water depth in Muddy Pond is most likely the result of the water body (perhaps, at one time part of Lake Thomas) gradually filling in with sediment from the outer edges towards the centre of the basin. The sediment is derived in part from that washed in from the runoff and the stream from Perry Lake and from decaying plant material. The sedimentation of the Pond may have been accelerated by past gold mining operations, where the tailings from the extraction process were deposited into the Pond (See Appendix (7.)).

Gradually, over time, floating and submergents become established. As more plant material grows and decays, the sedimentation process is increased eventually producing optimum conditions for emergents. Weller (1981, in NWWG, 1988) states that most of the wetlands in Atlantic Canada were formed by glaciation reworking the surface of the land. Formation of the marsh can also be influenced by animals such as beaver and muskrat. Development usually occurs from the outer edge inward, as is the case with Muddy Pond. Figure (12.) illustrates a simplified evolution of a freshwater basin to a marsh. Succession from open water to emergent marsh can take as little as a decade to achieve, if the conditions are right and the plant stock is already existing, otherwise marsh succession takes hundreds of years (NWWG, 1988). With nutrient input from stream water flow, marsh succession can be altered. Depending upon nutrient levels, vegetation decomposition could balance the rate of vegetation productivity, maintaining the marsh in a "steady state" indefinitely. Although there is probably some nutrient content being introduced through the stream coming from Perry Lake, it is doubtful whether this is enough, alone, to sustain the degree of diversity found within Muddy Pond.

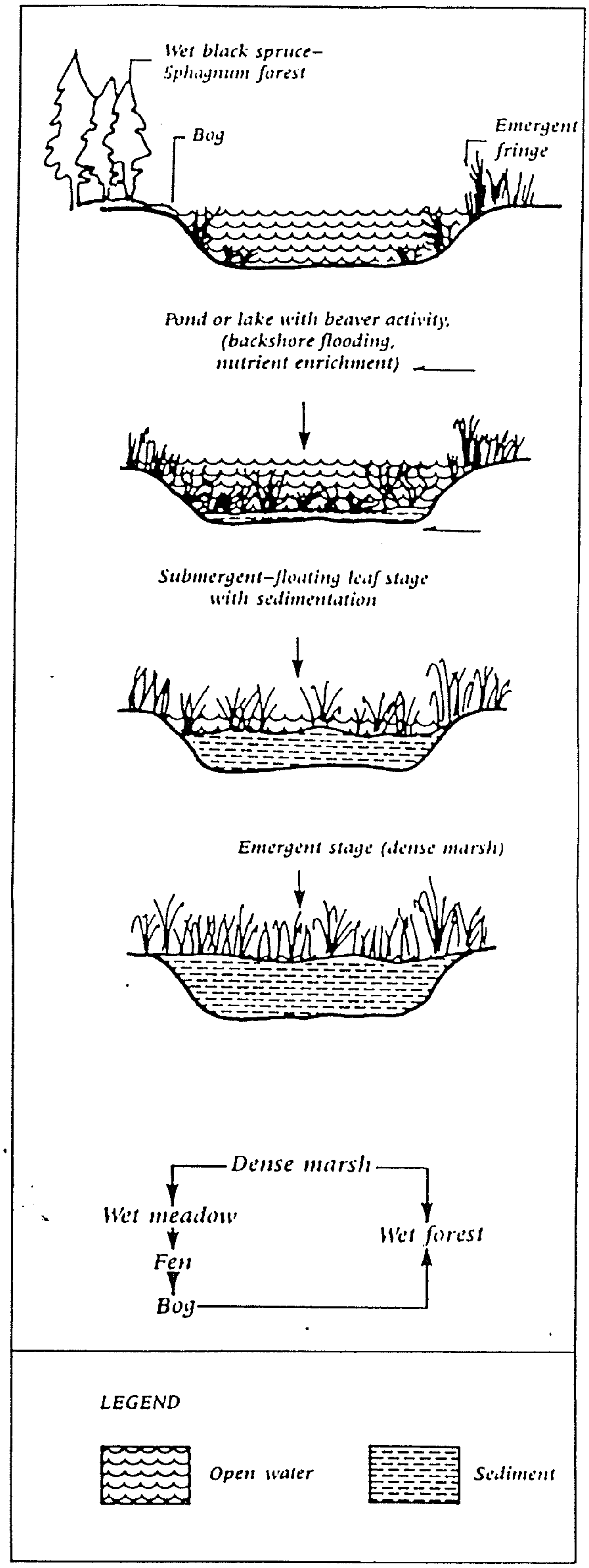


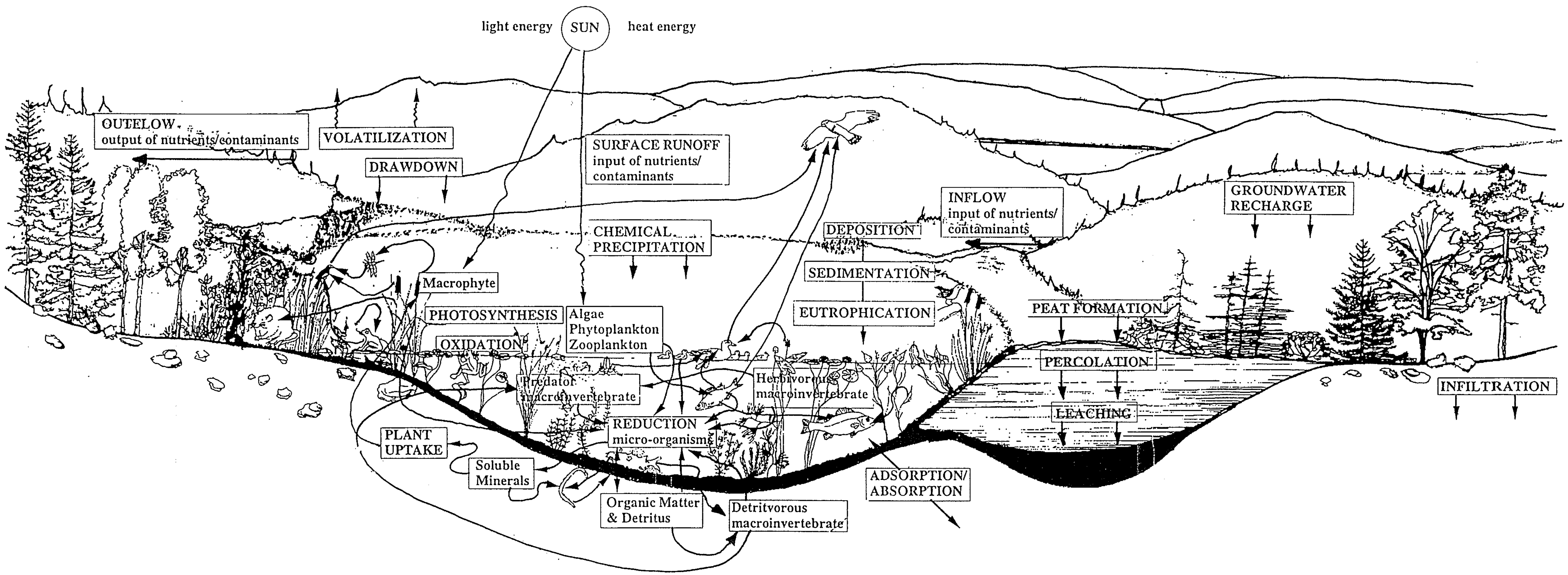
Fig. (12.) Theoretical origin and succession of a freshwater basin marsh (NWWG, 1988).

Site visits after rain have revealed sediments from both the access road into the Park and from the cleared area being eroded directly into the Pond. As previously stated sedimentation decreases light availability, affects oxygen levels and ultimately fills the Pond (Davis, 1994).

As sedimentation continues and the water level decreases, the marsh ecosystem will shift to that of a wet forest. One possible logical step might be for the establishment of tree species as Red Maple, Tamarack, and Black Spruce, which are common to wet sites and are already present in the adjacent bog.

The Ecological Processes of Muddy Pond

The ecological processes and energy transfer in Muddy Pond are illustrated in Figure (13.). The wetland processes which occur are, in essence, the mechanisms that provide the goods and services previously discussed. The processes range from surface water filtration, to reduction, to plant uptake, to water level draw-down -a process important for other aerobic processes. Throughout the wetland, the sun is the singularly most important input of energy in the form of light. Light provides for photosynthesis to occur producing both biomass and oxygen transfer. The vegetation plays a significant role in the exchange of gasses, both above and below the water's surface, as well as at the substrate surface.



ENERGY FLOW AND ECOLOGICAL PROCESSES OF MUDDY POND

Fig. (13.) FUNCTION

Human values have misinterpreted wetlands as being only useful in water quality treatment (Manuel, 1992), while in fact Muddy Pond serves many organisms, from ducks to invertebrates to phytoplankton to dense mats of cattail -all dependent upon the dynamic, yet fragile wetland processes. Although Figure (13.) illustrates how each of the wetland components within the system is dependent upon the next, most of the literature addresses only a few of the processes and how they serve in water quality treatment.

Water Treatment Processes

Hook, *et al.*(1988) suggest that nearly every water parameter, including the concentration of nutrients and micronutrients, heavy metals, pesticides and other chemical constituents, organic matter, man-made organic chemicals, dissolved oxygen and other suspended solids, bacteria and pathogens can be affected by passing through a wetland system. Hook, *et al.* (1988) suggest that wetlands appear to perform all of the biochemical transformations of wastewater constituents that take place in conventional wastewater treatment plants and in septic tanks and their drainage fields.

The properties of a wetland ecosystem which contribute to water quality improvement include high plant productivity, high decomposition rates, large adsorptive areas of sediments and low oxygen content of sediment. The tendency, Hook, *et al.*(1988) state, for wetland sediments to become anaerobic enhances retention of many compounds. Combined with the aerated conditions in the upper most sediment layer and in the water column, these conditions allow for many processes to occur at the same time, including the formation of insoluble phosphorous-metal complexes and the removal or conversion of nitrogen though nitrification and denitrification.

There are many processes which influence the removal and transformation rates of nutrients and other water quality parameters. These include sedimentation, adsorption onto soil particles, plant uptake and cycling, microbial decomposition and denitrification. Each process is generally dependent on many controlling variables including water and soil pH, temperature, soil type (mineral or organic), nutrient loading rate, vegetation type and cover. Hook, *et al.* (1988) suggest that it is the hydrologic regime and the sediment levels in the wetland which tend to be the dominant physical factors controlling the processes. Table (2.) from Hook, *et al.*, (1988) presents three categories of processes and their ability in removing contaminants from wastewater.

Most wetlands have the ability to retain or transform nitrogen and phosphorous from water at various rates. Table (2.) Suggests that suspended solids can be effectively settled or filtered out by wetland vegetation and soils. Presently there has not been much work done on heavy metal up-take by aquatic plants; (the main work in this area being done by Reddy and Smith, 1987). It is believed that the heavy metal content in waste water (or stormwater) is reduced as it passes through the wetland system and it is believed that the metals accumulate, initially, in the sediments and vegetation (Hook, *et al.*, 1988). Hydrocarbons, accumulating in the sediment and on the surfaces of the vegetation are degraded by microbial activity (Hook, *et al.*, 1988). Marsh (1991) states that by holding or detaining stormwater, water quality can be improved. Again, there appears to be little

Table (2.) Removal mechanisms in wetlands for the contaminants in wastewater

	Contaminant affected*								
Mechanism	Settleable solids	Colloidal solids	BOD	Nitrogen	Phosphorous	Heavy Metals	Refractory organics	Bacteria and virus	Description
Physical									
Sedimentation	P	S	I	I	I	I	I	I	Gravitational settling of solids (and contaminants) in pond/marsh settings
Filtration	S	S							Particulates filtered mechanically as water passes through substrate, root masses or fish
Adsorption		S							Interparticle attractive force (vander Waals force)
Chemical									
Precipitation					P	P			Formation of or co-operation with insoluble compounds
Adsorption					P	P	S		Adsorption on substrate and plant surfaces
Decomposition							P	P	Decomposition or alteration of less stable compounds by phenomena such as UV irradiation, oxidation, and reduction
Biological									
Bacterial metabolism+		P	P	P			P		Removal of colloidal solids and soluble organics by suspended, benthic, and plant-supported bacteria. Bacterial nitrification/denitrification
Plant metabolism+							S	S	Uptake and metabolism of organics by plants. Root excretions may be toxic to organisms of enteric origin
Plant absorption				S	S	S	S		Under proper conditions significant quantities of these contaminants will be taken up by plants
Natural die-off								P	Natural decay of organisms in an unfavourable environment

Notes: * P = primary effect, S = secondary effect, I = incidental effect (effect occurring incidental to removal of another contaminant)
+ The term metabolism includes both biophysical and catabolic reactions
(Source: From Tchobanoglous and Culp, 1980, in Hook, et al., 1988)

information on the length of time, or detention period, stormwater must be held to achieve the percentage removal depicted in Table (3.).

Table (3.) Representative Removal Efficiencies for Stormwater Holding Basins

Pollutant	Percentage Removal
Suspended sediment	40-75%
Total phosphorus	20-50%
Total nitrogen	15-30%
BOD	30-65%
Lead	40-90%
Zinc	20-30%

Marsh (1991) Sources based on compilation of various sources.

Conclusion

Muddy Pond is a complex, intricate, dynamic, open, living system, depicted best perhaps by its portrayal of several wetland types including that of a Sphagnum moss - Larch fen. A closer examination of the vegetation indicates the level of diversity of both flora and fauna which the Pond has to offer. The surrounding vegetation and clearly defined zonation of the Pond suggest that Muddy Pond is evolving into a forested wetland, probably of Black Spruce - Larch - Red Maple. The rate of succession and level of bio-diversity is influenced by the ecological processes occurring within the Pond. Although natural succession may take hundreds of years, the rate of succession may be increased by irresponsible land use development practices. The stress placed on one or more of the wetland processes will reflect in the rate of succession, level of bio-diversity and quality of water.

The ecological processes, that are just beginning to be understood, are the essence of any goods and services Muddy Pond has to offer. The value which society places on a wetland can only be seen once its goods and services are threatened by destruction. Then, more often than not, the value placed upon the wetland is a human judgement, and does not consider the other life forms within the system. These processes are all interconnected with one another at the site scale, as well as with the greater contextual scale. Land use management and design decisions made within the boundaries of the Sports Park will, not only have an impact on the ecology of the wetland, but also on the greater Shubenacadie-Stewiacke River Basin system.

4

Impact from Development of the Charles L. McDonald Sports Park

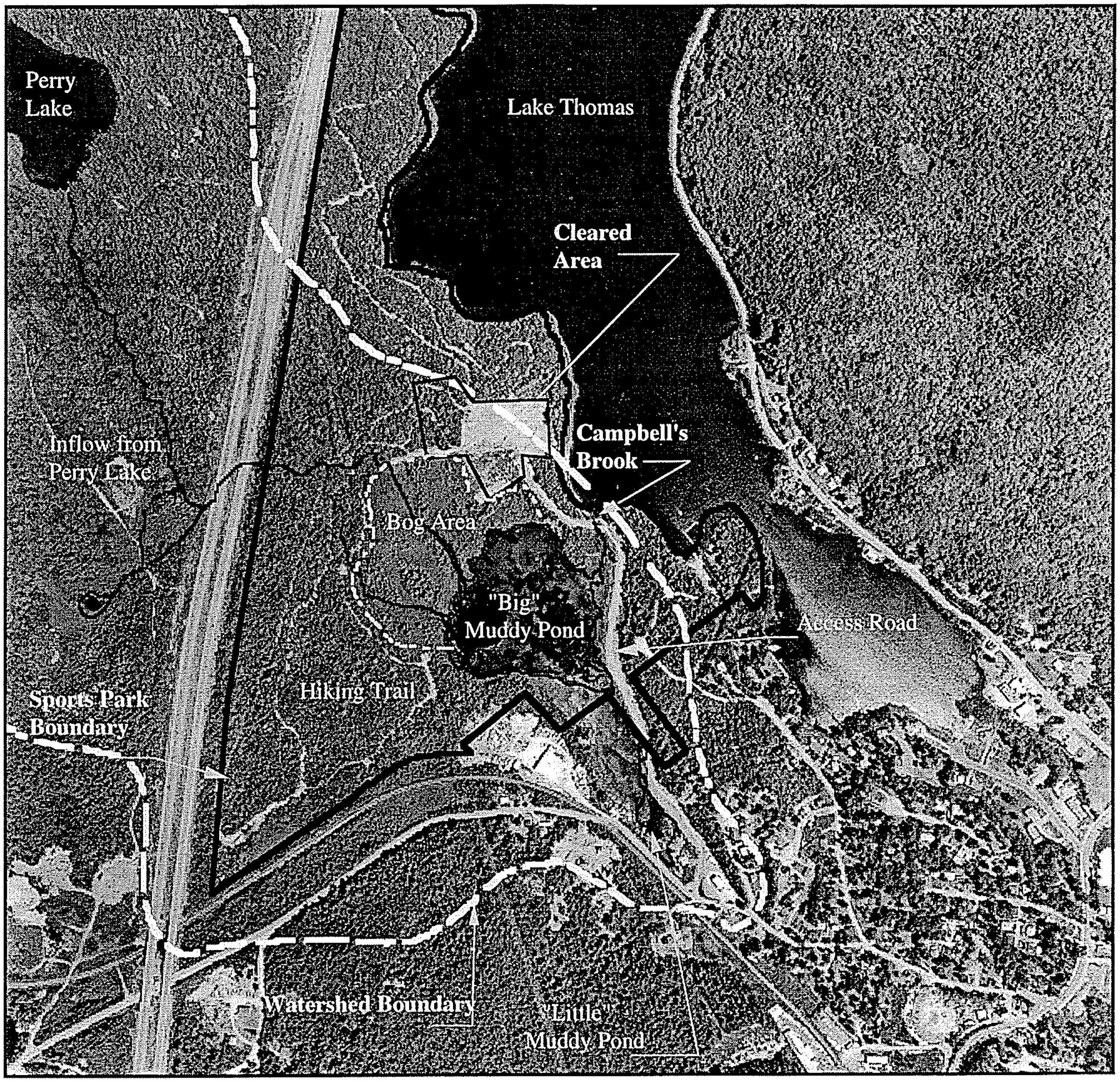
Development Program

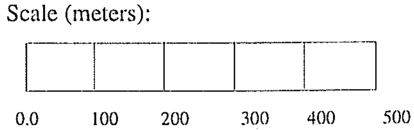
Presently the Charles L. McDonald Sports Park consists of 10 ± hectares (25± acres) of wetland centrally located within a 57 ± hectare (141± acre) mixed forest site, which has a 10 km (6 mile) trail system and relatively easy access to Lake Thomas. The trail system is part of a greater plan for the development of a community oriented sports facility, complete with soccer pitches, multipurpose buildings and water oriented activity areas along the shores of Lake Thomas. Plans for the development of the Park include a multipurpose structure, one to one and half storeys tall, and parking for in excess of 250 vehicles with easy access to the Bicentennial Highway. The Park would be open year round offering a wide range of community and provincial sporting events such as cross country skiing meets and provincial soccer matches. It is the desire of the Village of

Waverley that the Charles L. McDonald Sports Park be of the highest quality in technologically, innovative design in the area of sports and sport training, while at the same time being a community facility, accessible to all. The integration of Muddy Pond into the design of the Park would enhance the beauty of the Park as well as offer opportunity for other recreational and educational activities perhaps not yet envisioned.

Park Features and Their Potential Impact on Muddy Pond

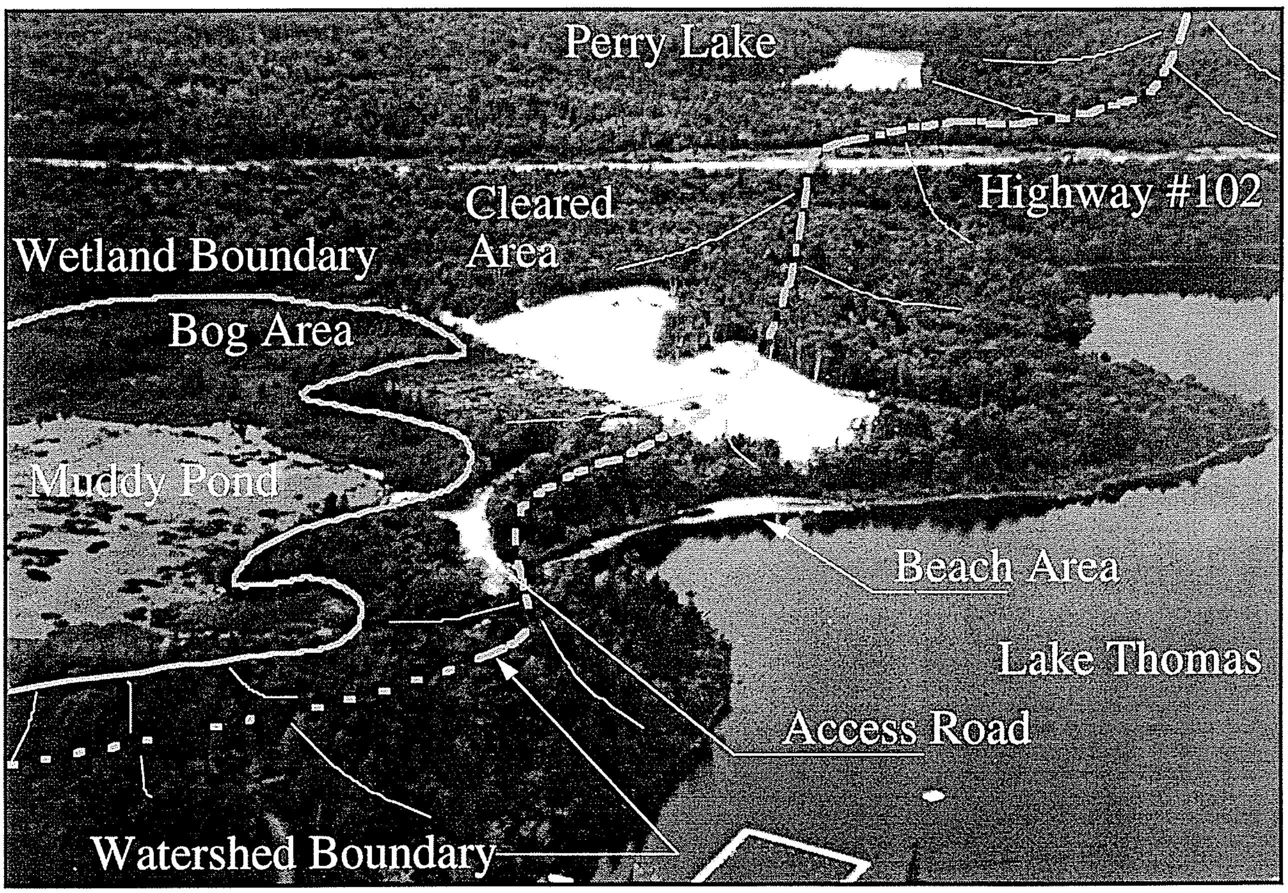
The development program for the Sports Park describes several features and amenities which could have an impact on the wetland. Figure (14.) illustrates where the various features of the Park have been proposed. These include a field house, parking lot, a trail system for hiking, a beach area, picnic areas, a multipurpose sports field and an access road to the Park. In addition to these features are the old mine tailings which reflect the history of the Park. The access road has already been installed and runs along the edge of Muddy Pond. As well, land has already been cleared for the field house, sports field and parking lot. Figure (15.) is an aerial view of the cleared area showing its close proximity to Muddy Pond. A description of each Park feature and its impact on the wetland are presented below.





Sources: Nova Scotia Topographical Series: 11D/13-T1, 11D/13-T3, Waverley, Halifax County
Land Registration Information Series, 1975;
Air Photo flown 1992, L.R.I.S.

Fig. (14.) MUDDY POND WATERSHED BOUNDARY AND SITE FEATURES



Sources: Charles L. MacDonald Sports Park;
Original Areial Photo flown 1992.

Fig. (15.) Aerial View of Park showing Watershed Boundary

Field House

The field house would be a multipurpose facility one to one and a half storeys tall, large enough to facilitate many of the amenities found in such gymnasium complexes today. The facility is to be located on the high ground in the cleared area with views to Lake Thomas and the beach area. It is quite likely that by locating the field house close to the watershed divide, the watershed for Muddy Pond will be altered, affecting the overall drainage into the wetland as well as the drainage into Lake Thomas. Other impacts to the wetland by the field house include an increase in impervious surfaces (roof) which decrease water infiltration and increase stormwater runoff. Also the materials themselves could possibly contribute to the contamination of the wetland (galvanized and zinc based roofing materials) (Prey, 1994).

Parking Lot

The development program for the Park calls for a 250 vehicle parking lot on land already cleared between the field house and the fen portion of the wetland. Parking lot configuration and size, as well as paving materials and drainage are all design components which will influence the degree of impact from stormwater runoff into the wetland. A large asphalt parking lot adjacent to the wetland would decrease water infiltration, percolation and groundwater recharge and increase surface water runoff. The constituents found in stormwater runoff from parking lots and roads are known to have detrimental effects on wetland processes and wildlife (Kobriger, *et al.*, 1983, Prey, 1994).

Trail System for Hiking

While the direct impact of the trail system on the wetland is minimal, some of the steeper slopes along the trails are susceptible to soil erosion. The erosion of the trails is due in part to repeated pedestrian traffic, which also compacts the soil, making it impervious to precipitation trying to percolate through. In one or two instances within the Park, the trail system has become a channel for surface water flow. Once eroded sediments and materials find their way into the stream coming from Perry Lake. They are then transported into the wetland. Transportation of the sediment is dependant upon stream water velocities and distance travelled (Kadlec in Reddy and Smith, (1987). Material coming into the wetland contributes to several wetland processes including deposition and sedimentation and eutrophication. The diversity and distribution of vegetation found within wetlands like Muddy Pond are an indication that external materials are entering the system. The trail system may also alter the composition of the existing wildlife habitat.

Beach Area

The designated beach area for the Park has been such for many years. Although outside the watershed of the wetland, the beach area could be impacting the nesting opportunities of waterfowl which feed in the Pond. A reevaluation of the activity and the overall development plan for the Park might find that although the beach area could be situated at various locations along the shores of Lake Thomas, there may not be as many opportunities for nesting sites of waterfowl which otherwise may not utilize the wetland.

Picnic Areas

Most of the picnic areas are situated along the shores of Lake Thomas and do not impact on the wetland. However, some of the same issues that are of concern with hiking trails also apply here.

Sports Field

Impact on the wetland from the sports field comes in the form of fertilizers used in the management of the field grass. Nutrient loading, particularly that of nitrogen and phosphorus can affect the balance of dissolved oxygen in the wetland through the process of oxidation, as well as, increasing the amount of biomass, and ultimately the amount of organic matter in the system. While nitrogen is carried readily with the flow of soil water and ground water to receiving bodies, phosphorus does not (Marsh, 1991). Hence, the lakes around Muddy Pond are characteristically phosphorus deficient, as would be expected under 'natural conditions' (Vaughan Engineering Associates, 1993). A sudden increase in phosphorus to the wetland directly, as a result of fertilizer rich stormwater runoff, will accelerate the rates of productivity in the wetland, often beyond the rates of decomposition.

Access Road

The access road into the Park runs along the edge of Little Muddy Pond and much of Big Muddy Pond. Surface runoff from the road drains directly into the Pond depositing sediment, hydrocarbons and many other substances associated with vehicular traffic. The impact to the wetland from the access road is comparable to that of the parking lot, with the exception that the runoff does not pass through the fen before entering the wetland, as it does with the parking lot.

Mine Tailings

Water quality analysis detected a single sample with an arsenic reading greater than the Canadian Drinking Water Guideline. The sample came from Little Muddy Pond, directly across from mine tailings from past gold mining operations around Muddy Pond. (See Table (4.), in Appendix (1.) for a comparison of the 1994 water quality analysis for Muddy Pond and the Canadian Drinking Water Guidelines). Of concern is the leaching and acid drainage from the mine tailings. The acid drainage is the result of the oxidation of naturally occurring arsenic in the exposed quartzite rock tailings. Further development of the access road and the overall management plan for the Park should address the mitigation of such drainage.

Greatest Impact to Muddy Pond

The greatest impacts to Muddy Pond will come from nutrient and heavy metal loading and the deposition of sediment, all of which are constituents of stormwater runoff. The impact to the wetland will be either directly, through interference with the ecological processes, or indirectly through alteration of environmental gradients (such as a change in soil moisture content). The most direct features contributing to stormwater runoff include the access road, parking lot and sports field. The design component of this practicum, however, will only address the access road and the parking lot.

Effects of Stormwater Runoff Constituents on Wetland Ecosystems

Highway and urban stormwater runoff constituents that are of major concern to wetland ecosystems include heavy metals, deicing agents, hydrocarbons, pesticides and fertilizer (Kobriger, *et al.*, 1983). Changes that stormwater constituents may cause to wetland environments can be divided into four groups: hydrological changes (in water level), water quality changes (in parameter concentrations in water and sediments), biological changes (in biota present) and changes to environmental gradients. Before these changes can be discussed it is necessary to first understand the fate of each of the constituents as it enters the wetland system. While Table (4.) presents the primary sources of many stormwater constituents, the effects that various stormwater constituents can have on wetland processes are presented below.

Pesticides

Organochlorine pesticides are readily absorbed by the high concentrations of lipids found in submergent and floating-leaved aquatic plants (Kobriger, *et al.*, 1983).

Table (4.) Common highway runoff constituents and their primary sources.

Constituent	Primary Source
Particulates	Pavement wear, vehicles, atmosphere, highway
Nitrogen, Phosphorous	Atmosphere, roadside fertilizer application
Lead	Leaded gasoline (auto exhaust), tire wear (lead oxide filler materials), lubricating oil and grease, bearing wear
Zinc	Tire wear (filler material), motor oil (stabilizing additive), grease
Iron	Autobody rust, steel highway structures (guardrails, etc.), moving engine parts
Copper	Metal plating, bearing and bushing wear, moving engine parts, brake lining wear, fungicides and insecticides applied by maintenance operations
Cadmium	Tire wear (filler materials), insecticide application
Chromium	Metal plating, moving engine parts, brake lining wear
Nickel	Diesel fuel and gasoline (exhaust) and lubricating oil, metal plating, bushing wear, brake lining wear, asphalt paving
Manganese	Moving engine parts
Bromide	Auto exhaust
Cyanide	Anticake compound (ferric ferrocyanide, Prussian Blue or sodium ferrocyanide, Yellow Prussiate of Soda) used to keep deicing salt granular
Sodium, Calcium	Deicing salts, grease
Chlorine	Deicing salts
SO4	Roadway beds, fuel, deicing salts
Petroleum	Spills, leaks or blow-by of motor lubricants, antifreeze and hydraulic fluids, asphalt surface leachate
PCB	Spraying of highway right-of-ways, background atmosphere deposition, catalyst in synthetic tires
Pathogenic bacteria (indicators)	Soil, litter, bird droppings and truck hauling livestock or stockyard waste
Rubber	Tire wear
Asbestos	Clutch and brake lining wear

(Source: Transportation Research Board, National Research Council, 1983)

Particulates

Fine particles in sediment from stormwater runoff can damage plants and invertebrates in the food web. Particulates may also affect the hatching and survival of fish and amphibian eggs. If the Particulates are nontoxic and inert their effects are less detrimental. However, organic pollutants and heavy metals often adhere to the sediment, making them more toxic. (Kobriger, *et al.*, 1983). Suspended sediment in the water column can decrease water transparency and increase turbidity (Vaughan Engineering Associates Limited, 1993), affecting photosynthetic processes of submergent plants.

Heavy Metals

Heavy metals can be temporarily immobilized in aquatic plants, as well as the litter, substrate and the water column in which they grow. Rooted macrophytes absorb heavy metals from the sediments, while other aquatic plants absorb heavy metals from the water column directly. Decomposing plant litter and substrate act as a sink for heavy metals (Kobriger, *et al.*, 1983). Lethal levels of lead and mercury in some aerobic organic decomposing bacteria may suggest that decomposition and organic processing could become retarded, pushing the wetland into an anaerobic system.

Lead will be found in the sediment where it is available to benthic organisms (organisms at the bottom of the Pond) and may reach vertebrates in small amounts. While lethal amounts of lead is commonly found in waterfowl (leadshot is retained in the gizzard), accumulations in mammals appear relatively low (Kobriger, *et al.*, 1983).

Mercury, like lead, has an indirect impact on wetlands through the food chain being transferred from prey to predator with biomagnification. Mercury present in anaerobic wetland systems could be converted to methyl mercury, which is readily accumulated in the biota. Mercury is highly toxic and accumulates in the brain, liver and kidney.

Deicing Agents

Salt, the major deicing material washed from roadways has the greatest effect on wetlands. Deicing salts are extremely mobile and most systems cannot effectively retain or "detoxify" them. However without circulation, salts can accumulate at levels toxic to many kinds of plants and animals (Kobriger, *et al.*, 1983). The major effect of sodium chloride is damage to vegetation that provides food, nesting cover and shelter. Kobriger, *et al.* (1983) suggest that an increase in sodium chloride may act to release mercury from sediments. Too often wetlands have been used as snow dumps releasing large amounts of both deicing salts and lead into the wetland, which build up from year to year.

Hydrocarbons

The migration and behaviour of petroleum products in the food chain are not well documented, but hydrocarbons in roadway runoff are expected to accumulate in the sediment or associate with plant and animal surfaces in wetlands if the circulation is slow enough. Much of the bacteria, which are responsible for most hydrocarbon decomposition are aerobic and rely on aerated conditions. The presence of higher plants enhances the retention of hydrocarbons by retarding circulation and physically filtering water as well as promoting aerobic conditions (Kobriger, *et al.*, 1983). The principle sources of hydrocarbons in highway runoff include grease, oils and unburned exhaust hydrocarbons (Kobriger, *et al.*, 1983).

Fertilizers

Nutrient uptake by plants occurs as a result of growth and the demand for nutrients. Nutrients are absorbed through the root systems from sediment in the water column, or through foliar tissue in the water column. Stimulation of plant growth by increased nutrient uptake is seasonal and therefore plants can only be a temporary sink for nutrients. Such species as cattail and milfoil grow exceptionally well in nutrient rich conditions. Increased nutrients can cause shifts in community make-up, ultimately altering the hydrology and animal usage (Kobriger, *et al.*, 1983).

Wetland Changes Due to Stormwater Runoff

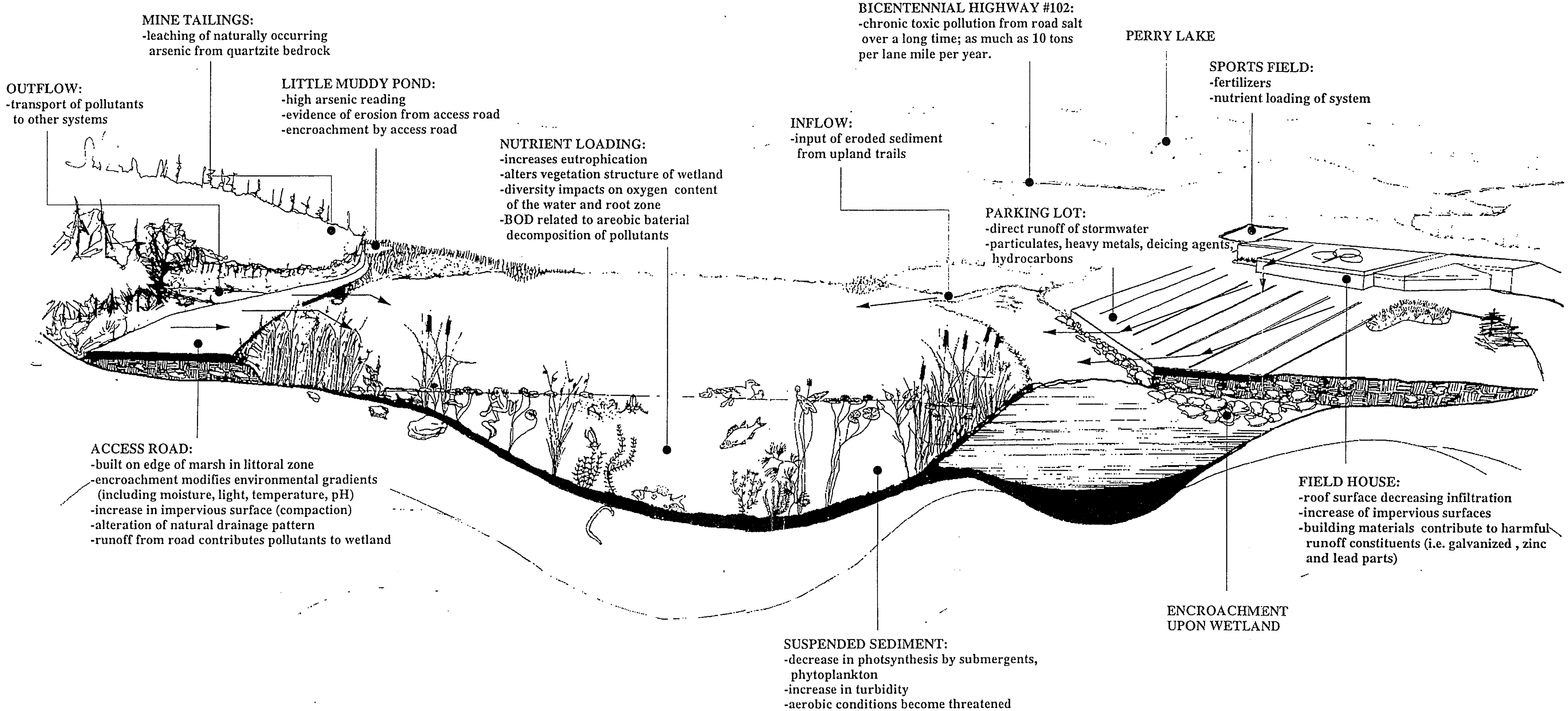
Figure (16.) illustrates and describes the immediate areas of impact from the development of the various features as well as the impact from the Bicentennial Highway. The main impact is increased stormwater runoff from impervious surfaces. Presented below are the potential changes to the hydrologic regime, water quality, wetland biota and environmental gradients caused from stormwater runoff.

Hydrological Changes

Generally, urbanization will increase the volume of stormwater runoff in a watershed due to an increase in impervious surfaces such as highways, parking lots and rooftops. Modifications to drainage patterns affecting infiltration, percolation, storage and discharge of stormwater from these surfaces can increase or decrease the total volume entering the wetland. Other impacts that development might have on the hydrological regime include alteration of size of flood peak, stream channel size and lag time (Kobriger, *et al.*, 1983).

Water Quality Changes

Nutrient impacts can be viewed from two perspectives: violation of a public health or aquatic life guideline, or from an aesthetic and/or recreational perspective. From the latter perspective nutrient loading is responsible for accelerated primary productivity, influencing the trophic status of the wetland. Although heavy metals are prevalent in highway and stormwater runoff, few studies show high levels in the water column. The high association of metals with particulates and metal enrichment of sediments implies a rapid removal by sedimentation. Toxicity of freshwater organisms to metals is associated to the hardness of the water (Kobriger, *et al.*, 1983).



IMPACT OF PROPOSED DEVELOPMENT ON ECOLOGICAL PROCESSES OF MUDDY POND

Fig. (16.) IMPACT

Biological Changes

Changes to the biota (such as accelerated plant growth or a decline in invertebrates) are influenced, and in turn influence, both the hydrology and quality of the wetland system. Most of the research in biological changes has been concerned with physical and chemical parameters. In this regard Kobriger, *et al.* (1983) described four generalized categories of pollution from urban runoff on wetland biota:

1.) **Siltation:** accumulation of particulate matter in an aquatic system
2.) **Acute Toxic Pollution:** toxic effects from high-level, short term exposure to toxic pollutants
3.) **Chronic Toxic Pollution:** long-term, low level exposure resulting in a biotic response of bioaccumulation to a toxic level.
4.) **Eutrophication:** accelerated accumulation of nutrients and organic matter.

Changes to Environmental Gradients

Environmental gradients include such things as soil moisture, pH, water depth and water temperature and usually refer to such an environmental factor over a distance. Sharp changes in environmental gradients are usually reflected in a patchiness to the ecotone (Forman and Godron, 1986). Where a major controlling environmental gradient varies evenly (linearly) with distance, as when water depth decreases evenly from the center of the Pond to its shores for example, often, a pattern of vegetation in concentric rings (zonation) is easily visible. Sharp changes, or an uneven distribution of an environmental gradient will alter the ecotone and, in this example, make the zonation difficult to detect. Changes to environmental gradients would include such things as altering the Pond's depth, which not only affects the capability of certain emergent and aquatic vegetation to physically grow, but also changes the temperature of the water.

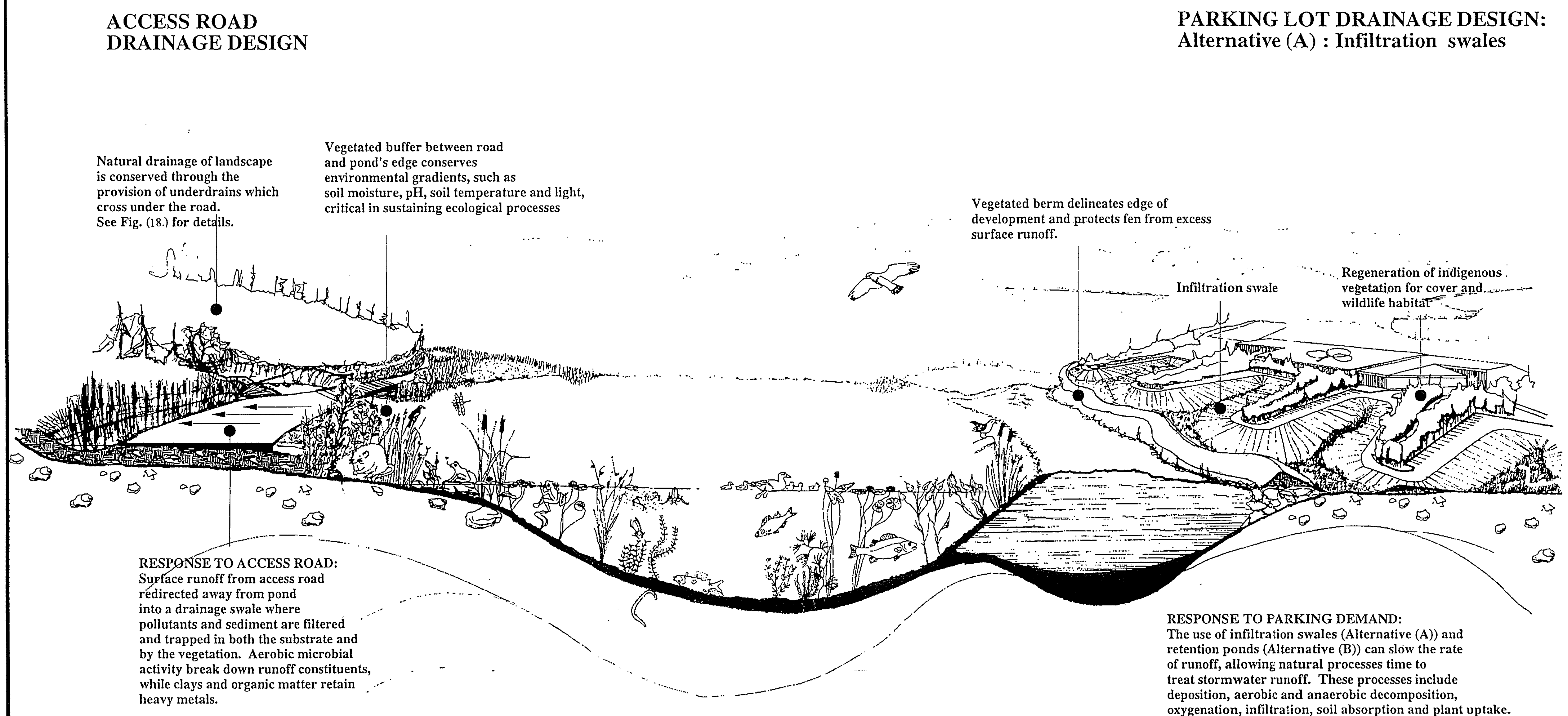
Suspended solids from erosion will also alter water and soil temperatures, as turbid waters prevent the sun's solar energy from penetrating the water and reaching the bottom of the Pond. Most ecological processes operate at particular temperatures and changes to the temperature of either the Pond's bottom sediment or the water column will have an impact on the ecological process in question.

Feasibility of Using Wetlands to Mitigate Effects of Stormwater Runoff

Figure (17.) illustrates design solutions for the mitigation of impact from stormwater runoff from the parking lot and access road. Presented below are three areas within the wetland which naturally mitigate against pollutants. Understanding these components of the wetland will assist in mitigation design techniques.

Life Form

A wetland's ability to retain water-borne pollutants is governed by the functioning of the dominant life form in the wetland- usually the most common species. The potential uptake and release of mineral nutrients and other material, the potential for retention of water and sediment caused by the density of the stems and roots, and the overall distribution of the dominant life form, are all relevant properties which must be considered in stormwater mitigation (Kobriger, *et al.*, 1983).



DESIGN SOLUTIONS FOR STORMWATER RUNOFF INTO MUDDY POND (not to scale)

Fig. (17.) STORMWATER RUNOFF MITIGATION

Substrate

The nature of the substrate is as important as the vegetation in the retention and cycling of nutrients and pollutants. Inorganic substrates consist primarily of mineral particles, gravel, sand, silt and clay and no more than 12-18 percent of organic matter. Organic soils, like peat, contain a high portion of fibrous material that is slow to decompose, while in muck soils the organic matter is more decomposed and less discernible (Kobriger, *et al.*, 1983).

Water Regime

Understanding the water regime is critical in understanding the function of the wetland. Water depth is important and varies throughout the year and from year to year. Water fluctuation is also an important component of the water regime. An important feature of saturated sediment is the extensive contact between water and roots, benthic organisms and sediment particles. A sediment's ability to retain pollutants may depend on the extent of water pollutant-particle interaction. The drawdown period in Muddy Pond serves to expose the sediment to the air periodically and allows for increased circulation in and near the sediment. While drawdown oxidizes surface sediments and improves aerobic microbial activity, Kobriger, *et al.* (1983) suggest that there is no evidence for improved chemical load of discharged waters.

Design Considerations for Stormwater Discharge to Wetlands

Site design features can influence the type and amount of pollutants reaching a wetland. Kobriger, *et al.* (1983) state that proper site design features may be the most cost-effective way to remove stormwater constituents from runoff prior to discharge into a wetland. The following design issues should be considered during development in reducing contamination from stormwater runoff.

Drainage

- Direct discharge into wetlands should be avoided. Stormwater runoff to a wetland should be directed across a grassy drainage channel that will slow water flow and promote sedimentation and retention of constituents. Reducing water velocities can be achieved through widening the drainage channels (Kobriger, *et al.*, 1983).

- Runoff should enter the wetland as sheet flow to distribute constituents across a wider area, increasing opportunity for infiltration and percolation.

- Low slopes, impoundments and dense stands of vegetation should be used to slow movement of water through the wetland for optimum runoff mitigation. Coefficients for runoff for different surfaces should also be considered in the design solution.

- Water level in retention areas should be shallow to surface saturated to permit aerobic microbial activity in the substrate. Proper alkaline conditions in water and substrate will enhance retention of metals and improve conditions for microbes (Kobriger, *et al.*, 1983).

- The use of road deicing salts should be discouraged around wetlands, while alternatives, such as sand should be considered.

- Hydrocarbon-based pesticides should not be used where they may become runoff to a wetland. Dense roadside vegetation should not be controlled with herbicides, but rather mowing, leaving the clippings to trap runoff constituents.

Substrates

- Adsorption of metals onto oxidized aerobic sediment particulate matter increases dramatically in alkaline conditions, although anaerobic sediments are also effective in retaining some metals (Kobriger, *et al.*, 1983).

- Petroleum hydrocarbon-based materials (including herbicides) are strongly adsorbed by clays and organic materials, especially humic materials. Petroleum hydrocarbons are more readily decomposed in aerobic sediments, by heterotrophic bacteria, than anaerobic sediments (Kobriger, *et al.*, 1983).

- Shallow water ponding of runoff in aerobic ditches should be encouraged to increase petroleum degradation (Kobriger, *et al.*, 1983).

- In artificial wetland construction a "muck" blanket should be spread on the soil before vegetation is planted simulating the bottom environment of a wetland and promoting better metal removal (Kobriger, *et al.*, 1983).

- Subsurface soils would ideally be alkaline and include clay minerals and organic matter to promote metal removal.

- The soils of shallow water ditches and contaminated channels may become metal saturated and require "cleaning" through sediment removal and revegetation.

Vegetation

- Wetland vegetation should be relatively dense to slow water flow and provide ample surface area for adsorption, absorption, microbial colonization and aeration. Native vegetation is most desirable.

- A diversity of vegetation is best suited to cover a wider hydroperiod (period of time sediment is saturated) (Knight and Pries, 1994) and a wider range of constituent removal. Monocultures should be avoided.

- Plant litter is an important part in the retention of stormwater constituents as well as the recycling of nutrients. Woody plants and emergent herbaceous perennials, such as sedges, cattails and rushes are slow to decompose and therefore desirable (Kobriger, *et al.*, 1983).

- Emergent perennial species are preferred because of their ability to withstand sudden contamination -their underground parts persist to later growing periods. Many of the emergents are adaptive to shallow water conditions and are highly productive.

- Succession from grasses to larger growth should be avoided in drainage swales.

- Roadside vegetation should remain on the ground after cutting to allow for nutrient recycling.

- Leguminous plants, such as clover, should be encouraged because of their ability to fix nitrogen -a limiting factor in petroleum degradation (Kobriger, *et al.*, 1983).

- Index, or key species, such as bulrushes as indicators of alkaline soils, or glassworts as indicators of salinity, should be included in a monitoring program for the status of ecological processes in the wetland system (Shay, 1992).

Wildlife

- Wetlands used specifically for stormwater constituent removal should not be used for wildlife production areas. On the other hand, wetlands containing rare, threatened or endangered species should not be used for stormwater mitigation. Change in wildlife bio-diversity should be anticipated if changes to the water regime are to occur (Kobriger, *et al.*, 1983). If wildlife is to be expected and encouraged, efforts must be made to retain pollutants in the stormwater from entering the wetland.

- Monitoring programs should be established using indicator species like the Lepoard Frog to determine the status of ecological processes within the wetland.

- Wildlife should be utilized in a design context in terms of zoning of the wetland area and recreational facilities.

5

Conclusion

Ecological Approach to Stormwater Mitigation to Wetlands through Landscape Design

> *"With the lack of ecological knowledge on the part of the planner, land-use plans are mere hypotheses. They are postulations which lack the degree of substantiation which the ecological framework provides. With the lack of knowledge of land-use planning principles, the designer finds it difficult to understand the extent to which the ecological knowledge may be employed in land-use planning."*
>
> *(Angus Hills, 1970; justifying the importance of a new ecological land-use planning course offered at the University of Toronto)*

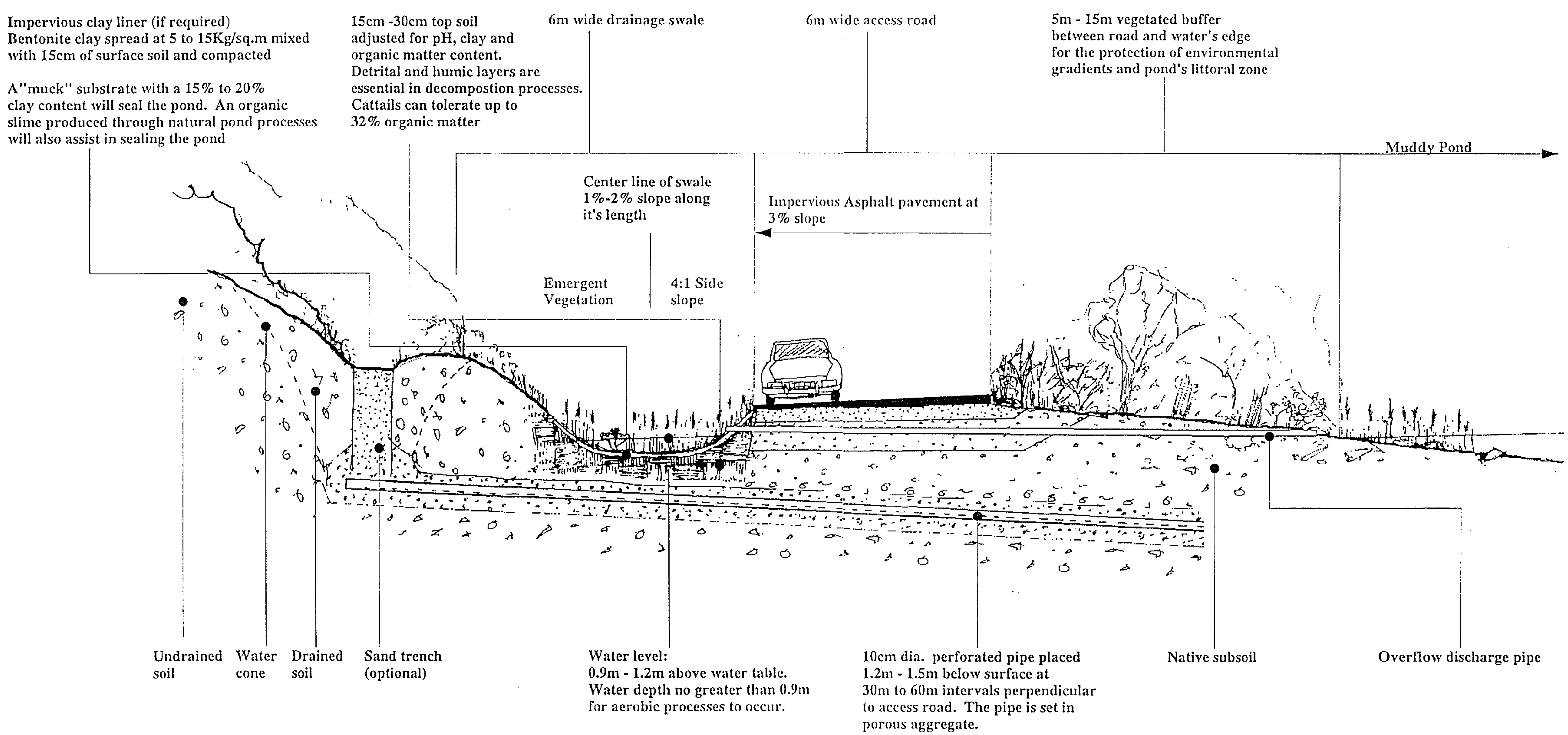
Hill, *et al.*,(1970), in describing regional ecology as a pattern of complex relationships between the organisms of a region and their environment, state that it is the ecology of the region that determines the productivity of that region. Productivity, Hill, *et al.*,(1970) define, is a measure in part, by those relationships which input time, energy, money and other products into the region against the outputs, both physical and societal from the region. If productivity is how society measures development, be it economic, social, aesthetic or other, and successful development, at any scale is reliant on a complete and full understanding of the ecology of the area, (Hill, *et al.*,1970), then it would make sense to use ecological principles as the primary design criteria for any land-use management and development project. This has been the case in this project.

Ecological Design

The following designs for the access road and parking lot of the Charles L. McDonald Sports Park are based almost entirely on the ecological processes of Muddy Pond. That is to say the design for each feature was governed by how each feature might influence, and be influenced by, the ecological processes of Muddy Pond. The designs for both features address the problem of stormwater runoff into the wetland and propose design techniques, based on ecological principles to mitigate the problem.

The Access Road

The design for the access road is depicted in Figure (18.). Presently, runoff from the access road drains into the Pond. By redirecting the runoff into retention swales, on the opposite side of the road, stormwater constituents, like hydrocarbons, salt, heavy metals and sediments are captured and retained before the runoff is allowed to enter the Pond.



SECTION THROUGH ACCESS ROAD AND DRAINAGE SWALE (not to scale)

Fig. (18.) DRAINAGE SWALE FOR ACCESS ROAD

The object of the design is two-fold. First, there is the prevention of stormwater draining directly into the Pond. Secondly, by slowing the runoff, using retention swales, the stormwater constituents have an opportunity to be retained. Capture and retention of the constituents can be in the form of settling out to the bottom on the swale, being absorbed by aquatic plant life in the swale, reduction processes by micro-organisms, and adsorption to soil particles. In all instances it is the ecological processes within the swale that aid in the removal of the constituents from the stormwater runoff. In order for these processes to operate certain conditions have to be maintained. One example of this would be having enough soil in the bottom of the swale, adjusted for the right pH, clay and organic matter content, to sustain Marco-organisms which break down constituents. Another example might be the choice of emergent vegetation over submergent, due to their aggressive behaviour and ability to withstand sudden contamination.

Two other aspects to the design of the access road are the natural surface drainage pattern off American Hill into Muddy Pond and the vegetated buffer between the access road and the Pond's edge.

One of the problems with an access road running along the edge of the Pond is its impediment, or disruption of the natural drainage. Surface water coming off American Hill drains directly into Muddy Pond. The design of the road and retention swale must address the existing hydrology of the land at the same time it controls stormwater runoff. Figure (18.) illustrates a sand trench and underdrains placed under the road every 30 - 60 metres (100-200 ft.) to redirect the natural flow of surface runoff to the Pond.

The establishment of a vegetated buffer between the access road and the Pond helps to protect environmental gradients critical to the life of the Pond. By allowing the indigenous flora, once surrounding the Pond, to become reestablished, the Pond's littoral zone and ecology are better protected. The buffer also helps in reducing any further runoff from draining directly into the Pond by capturing it in its leaf litter. Because organisms are dependent upon each other for survival (Forman and Godron, 1986), the wider the buffer the more constructive a role it will play in the maintaining the ecological processes of the Pond.

The Parking Lot

Two separate alternatives for the design of the parking lot are provided. Alternative (A), which utilizes filtration swales to detain runoff and absorb stormwater constituents is depicted in Figures (19.) and (20.). Alternative (B) utilizes a retention pond to retain the same and is illustrated in Figures (21.), (22.) and (23.). Each alternative has a plan and section. Alternative (B) was developed further, calculating the volume requirements for a ten year storm of one hour duration. These calculations are in Appendix (3.)

Alternative (A): Infiltration Swale

Stormwater runoff is directed into large infiltration swales which penetrate into the parking lot like fingers. As runoff is slowed and percolates down through the grassed surface of the swale constituents become trapped in the vegetation and soil matrix, where reduction, or breaking down processes occur.

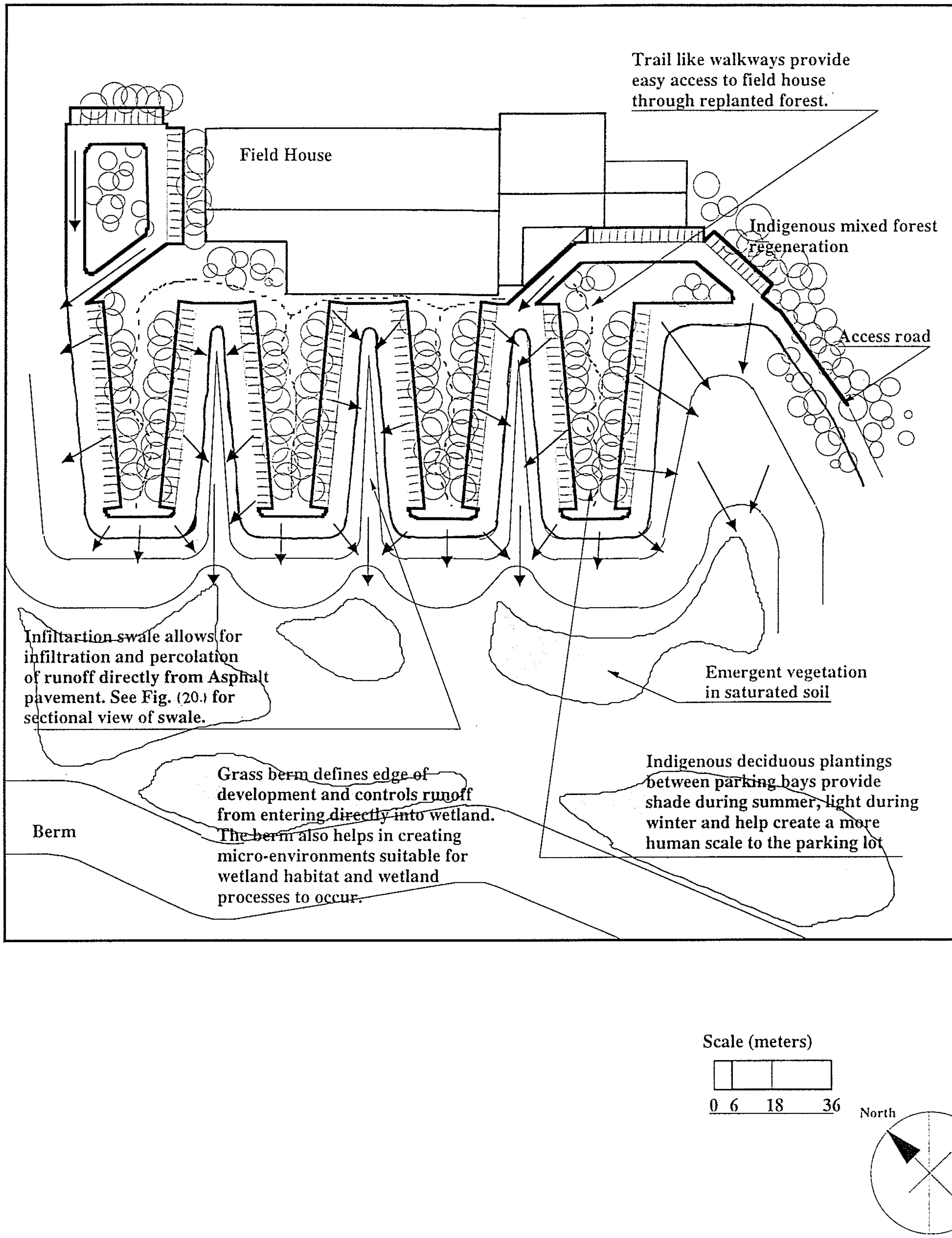
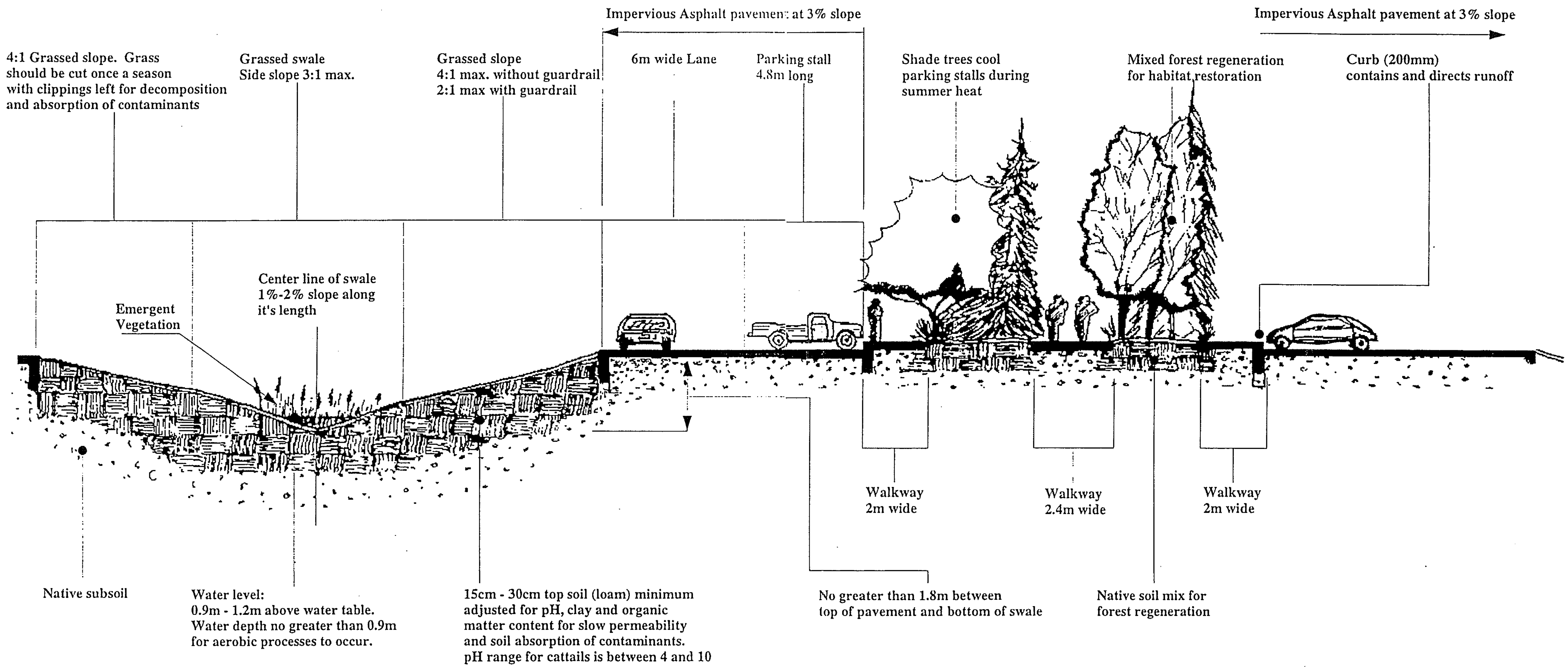


Fig.(19.) PARKING LOT DESIGN: ALTERNATIVE (A) INFILTRATION SWALE



SECTION THROUGH INFILTRATION SWALE (not to scale)

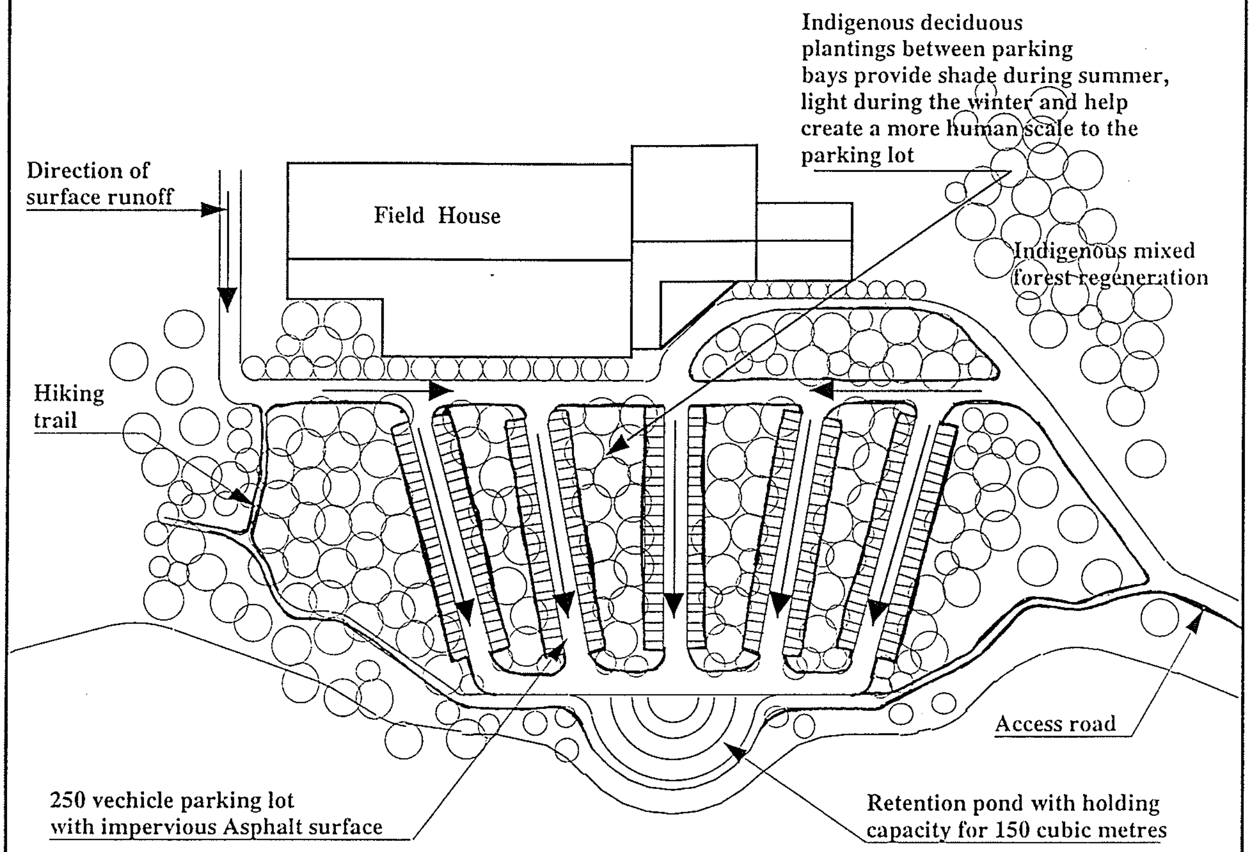
Fig. (20.) ALTERNATIVE (A) INFILTRATION SWALE

Certain constituents, especially heavy metals will become held within the soil matrix, depending upon the pH of the soil. The soil composition is critical in its retention capacity and attention must be paid to the percent of clay and organic matter in the matrix as well as the level of pH. Heavy metals are best held in alkaline soils (soils with high a pH reading) (Pries, 1996). Maintenance practices such as mowing should be reduced to one or two times per season, leaving the clippings in the swale. Chemical fertilizers and pesticides should not be used.

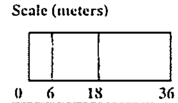
Alternative (B): Retention Pond

Alternative (B) (See Figures 21., 22., and 23.) concentrates all the runoff into a retention pond, where the constituents of the stormwater runoff can settle out to the bottom of the pond. The construction of a retention pond is perhaps more complicated than that of a infiltration bed. The pond must be sealed so water does not leak out. Whether the pond is sealed naturally or through the use of a clay liner, it is important that a permanent water level be sustained so ecological processes, such as reduction and adsorption, can occur to treat the runoff. The use of a Bentonite clay liner is restrictive in that it will crack upon draw-down processes unless properly installed (usually covered with sand or 'bottom sediment'). The pond should sustain a variety of emergent species and not be treated with chemicals.

Impervious Asphalt Area = 7968 square meters
Roof Surface = 6087 square meters
Total Impervious Area = 14055 square meters (3.5 acres)
Discharge for 10 yr. storm = 0.368 cubic meters/ sec.
Detention volume required = 140 cubic meters



See Fig. (22) for Sectional view of retention pond



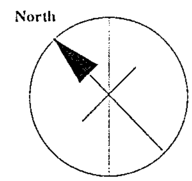
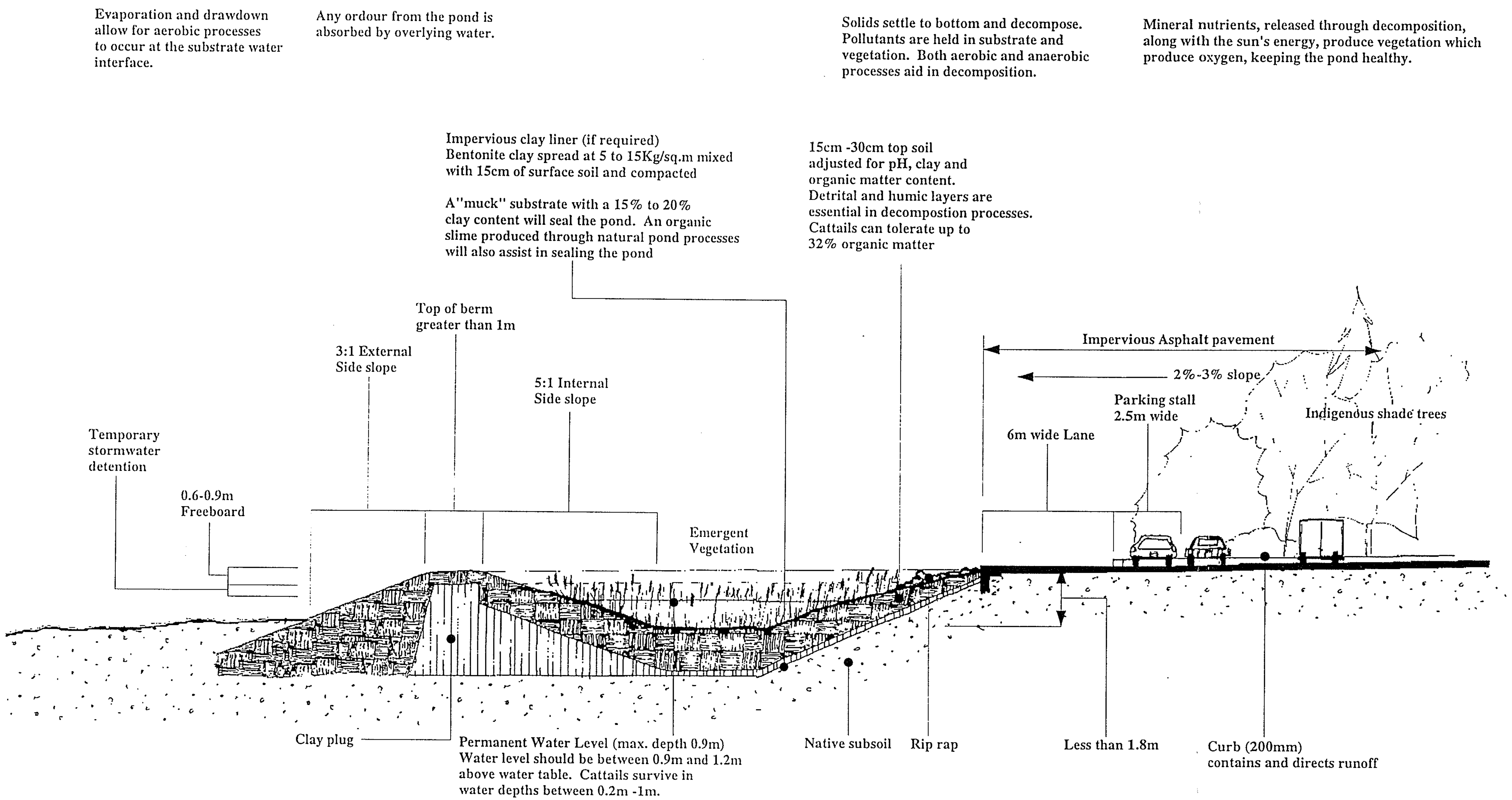
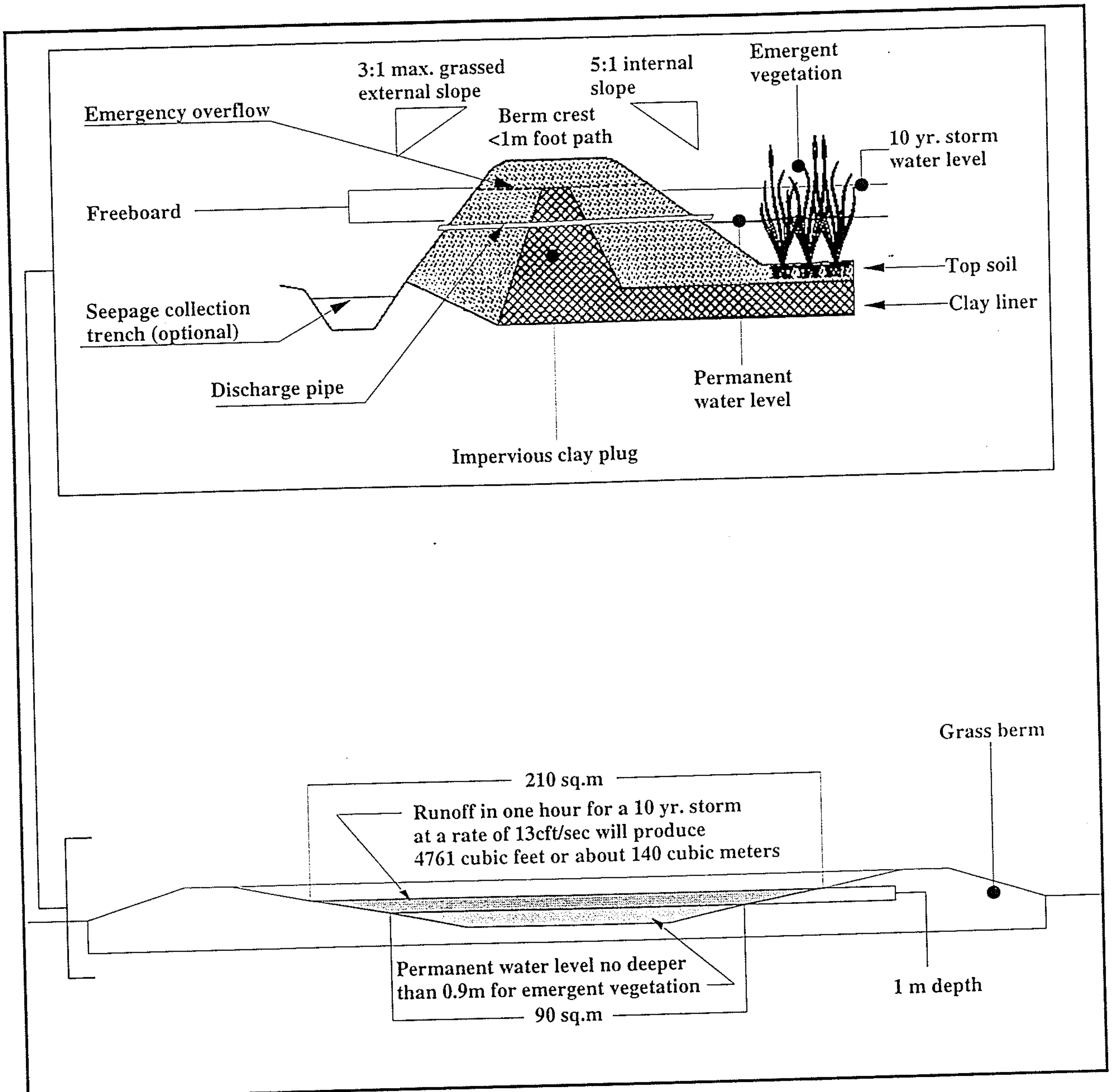


Fig.(21.) PARKING LOT DESIGN: ALTERNATIVE (B) RETENTION POND



SECTION THROUGH RETENTION POND (not to scale)

Fig. (22.) ALTERNATIVE (B) RETENTION POND



(DRAWINGS NOT TO SCALE)

Fig. (23.) RETENTION POND HOLDING CAPACITY AND BERM DETAIL

Once the volumes of runoff have been calculated, further development of the parking lot could predict loadings from certain nutrients or pollutants. This is one area for further design. Another important area for further design possibilities is in calculating the amount of pollutant a wetland the size of Muddy Pond could naturally treat. Usually this calculation is reserved for much larger wetlands being considered for secondary stormwater treatment facilities (Knight and Pries, 1994).

Comparison Between the Swale and the Retention Pond Designs

The presentation of two design alternatives creates the dilemma as to which system is better at removing contaminants from stormwater, and, at the same time, better serves the needs of the Sports Park. While the first part of this dilemma lies in the ecological processes of the respective systems, the second involves other issues beyond the ecology of the site. The two sets of issues are discussed below.

Ecological Comparison

Both systems are adept at removing contaminants from stormwater runoff from the parking lot. In both instances water infiltration can only occur where topsoil is brought in, as the underlying subsoil is too permeable for soil absorption processes to occur.

The difference between the two alternative design solutions lies in their ability to remove certain stormwater constituents from surface runoff, particularly heavy metals.

There are two areas of concern in the removal of heavy metals using either an infiltration swale or a retention pond: (1) the retention period and (2) the pH of the soils (Pries, 1996).

Retention Period

The retention period, or period of time the stormwater runoff is in the pond or swale, is important in that the longer the runoff is in the system, the more opportunity there is for ecological processes to operate in the removal of the constituents. In both designs the concern is whether the system has been adequately designed for that particular climatic region. With swales the concern is how often they are flushed, or flooded, while in retention ponds choosing which storm to design for (five, ten or twenty year storm) becomes important. If the system is inadequately designed, then constituents which have been trapped in the system will be flushed out, rendering the system ineffective in treating stormwater. Infiltration swales should be designed wide enough to carry large volumes of water and at the same time slow the velocity of the water. Retention ponds should have by-passes designed into their systems. By-passes allow for the prevention of already settled out constituents from being disturbed, (or being mixed back in with the runoff) in times where heavy rain storms produce volumes greater than the holding capacity of the pond (Pries, 1996). There is now an effort by environmental planners to lobby legislation to require developers to design for a one year storm, which would help in preventing stormwater systems failing their objectives.

Soil pH

In order for either system to capture and retain heavy metals effectively the soil must be alkaline (a high pH reading) (Pries, 1996). Exposure to acid precipitation conditions over a long time can have an effect on the pH condition of the soil. While both systems would be exposed to acid precipitation, the retention pond will be better able to retain heavy metals. A "wet" retention pond (one with water at all times) allows for certain ecological processes, such as anaerobic decomposition, to occur which naturally raises the pH value in the soil (Pries, 1996). This would not be the case with an infiltration swale and constant adjustment of the soil pH would be required in retaining metals.

Environmental Comparison

An area not addressed in this project was the suitability of developing the Charles L. McDonald Sports Park. There was no attempt made at determining whether the development of Sports Park was feasible, whether it had support from the Village of Waverley, or indeed, if the land was physically capable of supporting such a development. The position taken, for the purposes of this project, was that, if development was to occur adjacent to Muddy Pond, the protection of the ecological processes of the wetland would be the bases from which all design would stem. In other words, if development is going to occur next to the wetland, this is how it should be done so as to have the least detrimental impact to the ecological processes of the wetland, and for these reasons.

The two design solutions present other issues that go beyond just addressing the ecological processes of Muddy Pond. Such issues as pedestrian and vehicular circulation, safety, accessibility, aesthetics and economic feasibility, would all play a part in the final design. Although the main focus of this project was the protection of the wetland processes, there was some attention paid to other environmental design issues. An example of this would be the casual, easy access, in Alternative (A), from the parking lot to the field house, while in Alternative (B) there is perhaps a more conventional configuration with pedestrian circulation having to confront vehicular traffic. Likewise, in Alternative (A) the parking lot is broken up into smaller bays, providing shade and a more humanistic scale to the design, while in Alternative (B) indigenous deciduous plantings were used to provide comfort from the sun. Alternative (B) also presents the idea that if the treatment process is made visible (the large retention pond at the end of the parking lot), then an awareness for the importance of the wetland may be better achieved.

Responsible Design

> *"The waterflowers themselves are far from being the whole scene; really, they are just the accompaniment. The essence of the motif is the mirror of water, whose appearance alters at every moment, thanks to the patches of sky..."*
>
> *(Monet, around 1916, in House ,1991)*

Because the design solutions address environmental and ecological issues, it should be clear that responsible design can not be based entirely upon just ecological processes. For design to be considered responsible, it must address issues like safety, and whether or not it does what it was designed to do. Having a design based only on ecological principles does not necessarily take into consideration other societal and economic issues. Responsible design is not ecological design but rather environmental design, which is rooted in an understanding and respect for ecological processes, at the site level and the greater regional context. The following are recommendations for the future development of the Sports Park and the profession of landscape architecture.

Future Park Development Recommendations

Muddy Pond

- The protection of the Muddy Pond be a priority of the Park for the conservation of the ecological processes of the wetland.
- Muddy Pond be seen as a valuable asset of the Park, and that the Park adopt the initiative in wetland awareness.
- In protecting Muddy Pond, all future land use plans, which may affect the wetland, be scrutinized by the Park as to their effect on the ecological processes of the wetland.
- All unvegetated lands within the Park be seeded immediately, or some other action taken, to prevent further sediment loading of the wetland.
- a monitoring/demonstration program be established to monitor outflow from Muddy Pond.

Sports Park

- All future land use development plans and proposed land use activities be reevaluated as to their effect on the ecological processes, not only associated with Muddy Pond, but also with those of the lake shore, the beach area and the forest systems.
- A development plan for the Park be prepared, which implements an ecological approach, and at it's center, exemplifies the interrelationships between systems, both within and beyond the Park's boundaries.

Village of Waverley

- That the Village Planning Strategy adopt policy recognizing the ecological importance of Muddy Pond and in so doing establish guidelines as to its protection.

- Lands west of the Bicentennial Highway, which fall within the Muddy Pond watershed be controlled to prevent sediment loading and increased surface water runoff into Muddy Pond.

- That the Department of Transportation is encouraged to evaluate alternative practices for salting the Bicentennial Highway and other roads within the Muddy Pond drainage basin.

Recommendations for the Discipline of Landscape Architecture

- That the discipline play a larger role in understanding and teaching how our decisions about the built environment influence the very environment in which we build.

- That the discipline go further to be better able to interpret what other ecologically oriented disciplines are saying.

- That the discipline be more responsible in designing within the landscape, not for our own well being, but for the well being of the land.

Areas for Further Research

There is much work to be done in promoting, not only the importance of wetlands in the landscape, but also, from a landscape architectural point of view, the greater issue of responsible design. Within this project there have been several areas where further research could assist in better understanding how wetland systems operate and how they could be utilized by the profession of landscape architecture and the discipline of landscape ecology in promoting responsible landscape design. They are briefly described below.

Metal Up-take in Aquatic Plants

Presently there has not been much work done on heavy metal up-take by aquatic plants; (the main work in this area being done by Reddy and Smith, 1987). It is believed that the heavy metal content in waste water (or stormwater) is reduced as it passes through the wetland system and it is believed that the metals accumulate, initially, in the sediments and vegetation (Hook, *et al.*, 1988).

Retention Period and Velocity of Flow in Wetlands for Pollutant Removal

There seems to be little information on the length of time, or detention period, stormwater must be held to achieve the percentage removal presented in Table (3.) (Page 49) of this report. Knight and Pries (1994) also state that there is little work done on the velocity of flow of water through natural or artificial wetlands.

Index Species and Monitoring Programs

Observations, like an algae bloom in a wetland, which may suggest a sudden increase in the level of nitrogen, are one way in which wetlands can be inexpensively monitored . Although this practicum did not explore monitoring programs in any detail, any responsible design, which suggests as its bases the ecological processes of the system involved, would include a monitoring program for the system. Monitoring need not refer to costly bio-assays and sampling procedures, but rather regular observation and recording of landscape change (or behaviour) over time.

Size of Wetlands for Pollutant Removal

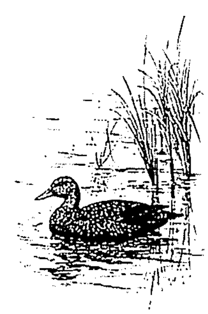
Although this practicum did not discuss the size of a wetland required to treat a known volume of pollutant, this would be one important area for further research. Knight and Pries (1994) provide known volumes for stormwater runoff constituents and the calculations needed to determine wetland size for their treatment.

Epilogue

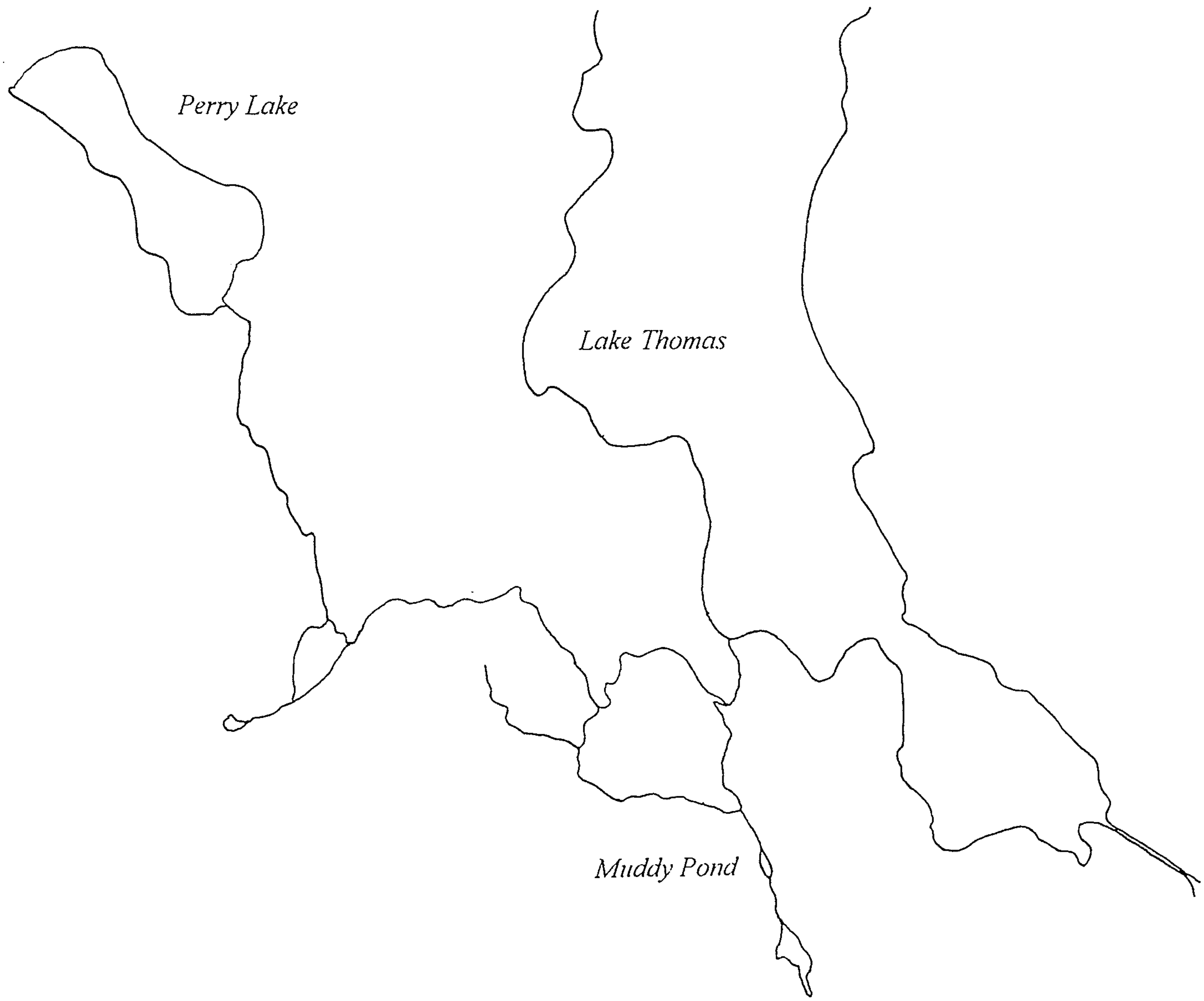
"What if all ponds were shallow? Would it not react on the minds of men? I am thankful that this pond was made deep and pure for a symbol. While men believe in the infinite some ponds will be thought to be bottomless."

(Henry David Thoreau, Walden, 1854).

E.O. Wilson, an ecologist and entomologist, said on a recent television broadcast that we haven't even begun to understand the processes which are occurring around us, and that the science of ecology is still in it's infancy (PBS, 1995). There is much in this world we still know little about. Our profession advocates sustainability, conservation and understanding for the physical and cultural environments in which we inhabit. If we continue to apply knowledge of the earth's natural systems and human cultures to the planning, design and management of our sustainable developments, then it is not enough. If we, as designers, are stricken with the task of understanding our living world and reconnecting ourselves to the landscape, then we can go beyond our developments and reach out to the land itself - then we take on the role of custodians of the land. This is responsible design and so, as E.O. Wilson said on that same show (PBS, 1995), *"Lets Get Started!"*.



The Muddy Pond Wetland



Appendix One: A Technical Report on the Environmental Inventory of the Muddy Pond Wetland System.

Table of Contents

1

Introduction

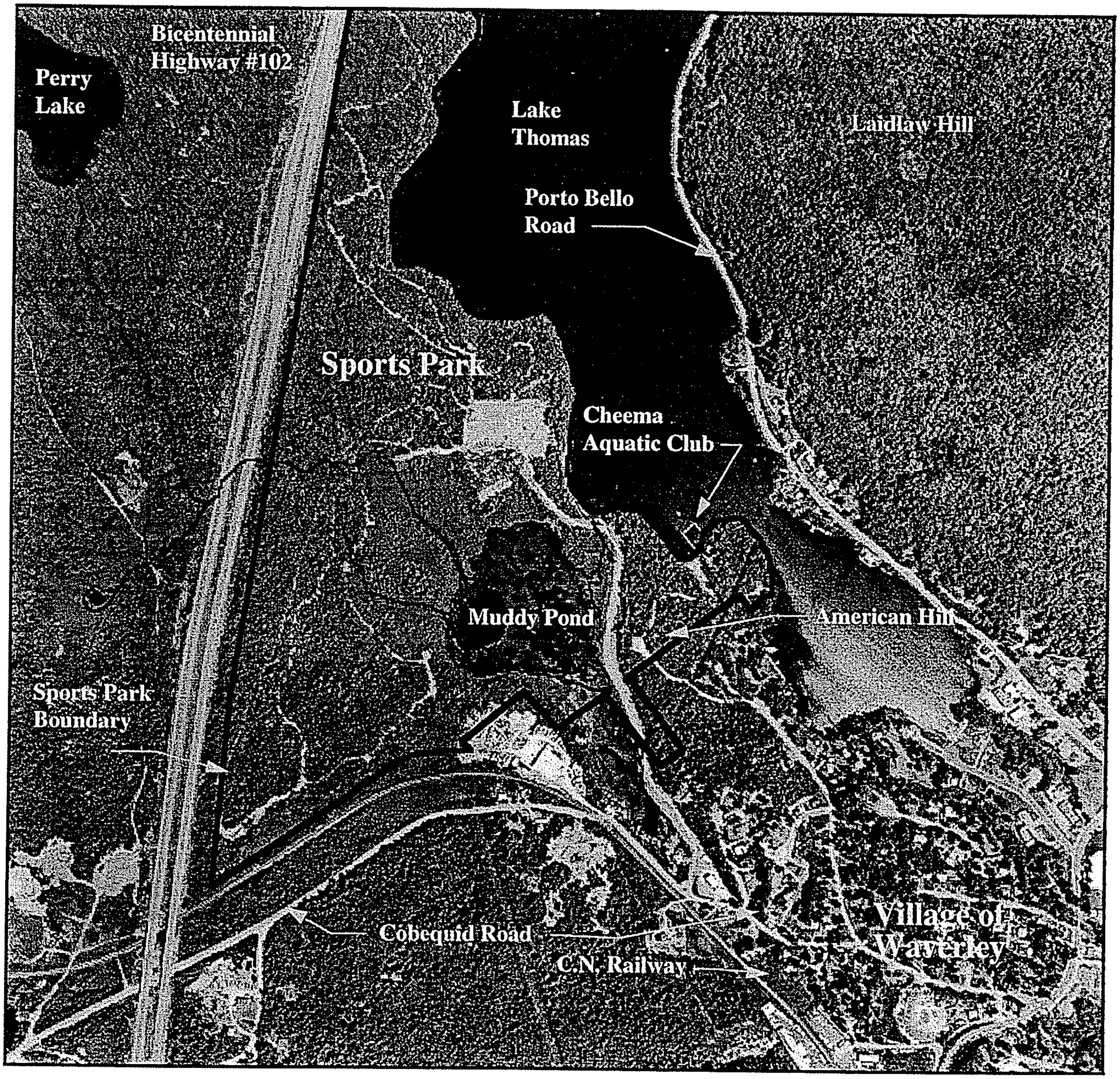
The Charles L. McDonald Sports Park (hereinafter referred to as the Park) is a typical representative of the landscape found within much of the Waverley area of Nova Scotia. As a dynamic system the landscape depicts the ever changing accumulation of systematic and interactive responses between geology, hydrology, landform, climatic conditions, flora, fauna and human involvement over time. An essential part of the Park's landscape, one whose absence may not only alter the ecology of the Park itself, but that of the greater landscape in which it lies, is that of Muddy Pond, a small wetland in the southern portion of the Park. This section, the Environmental Inventory, describes, in general terms, the existing site characteristics, basin geology, wetland hydrology, and the structural, functional and successional vegetative patterns which comprise Muddy Pond. In addition a brief description of the proposed development plans for the Charles L. McDonald Sports Park are provided.

The Setting

The setting of the Park is in keeping with the "healthy living lifestyle" the Village of Waverley symbolizes and has been the latest chapter in the ongoing pursuit of the Village Commission to provide access to sports for all its residents. This desire for community participation in sports dates back to the founding of the Waverley Amateur Athletic Association as early as 1919 and the Cheema Aquatic Club, founded in 1969. In support of the Council of the County of Halifax to acquire waterfront lands for public access to water, the Village of Waverley set aside the entire western shore of the southern half of Lake Thomas for a community sports park. (See Appendix (6.), *Waverley*).

Site Location

Located 44°47' N latitude, 63°37'W longitude, the Park is bound between the Bicentennial Highway No. 102 on it's western side and Lake Thomas on the east (Figure (1.) Park Context Map). The northern boundary of the Park is where the No.102 Highway crosses over Lake Thomas, while the southern portion of the Park is defined by the Canadian National Railway. Within the metropolitan area, the Park is accessible by highways from any of the centres of Halifax, Dartmouth, Bedford or Sackville. In the Village of Waverley access to the Park is from the Cobequid Road, originally built to provide access to the first gold mines in Waverley. (See Appendices 6 and 7).



Scale (meters):

0.0 100 200 300 400 500

Grid North

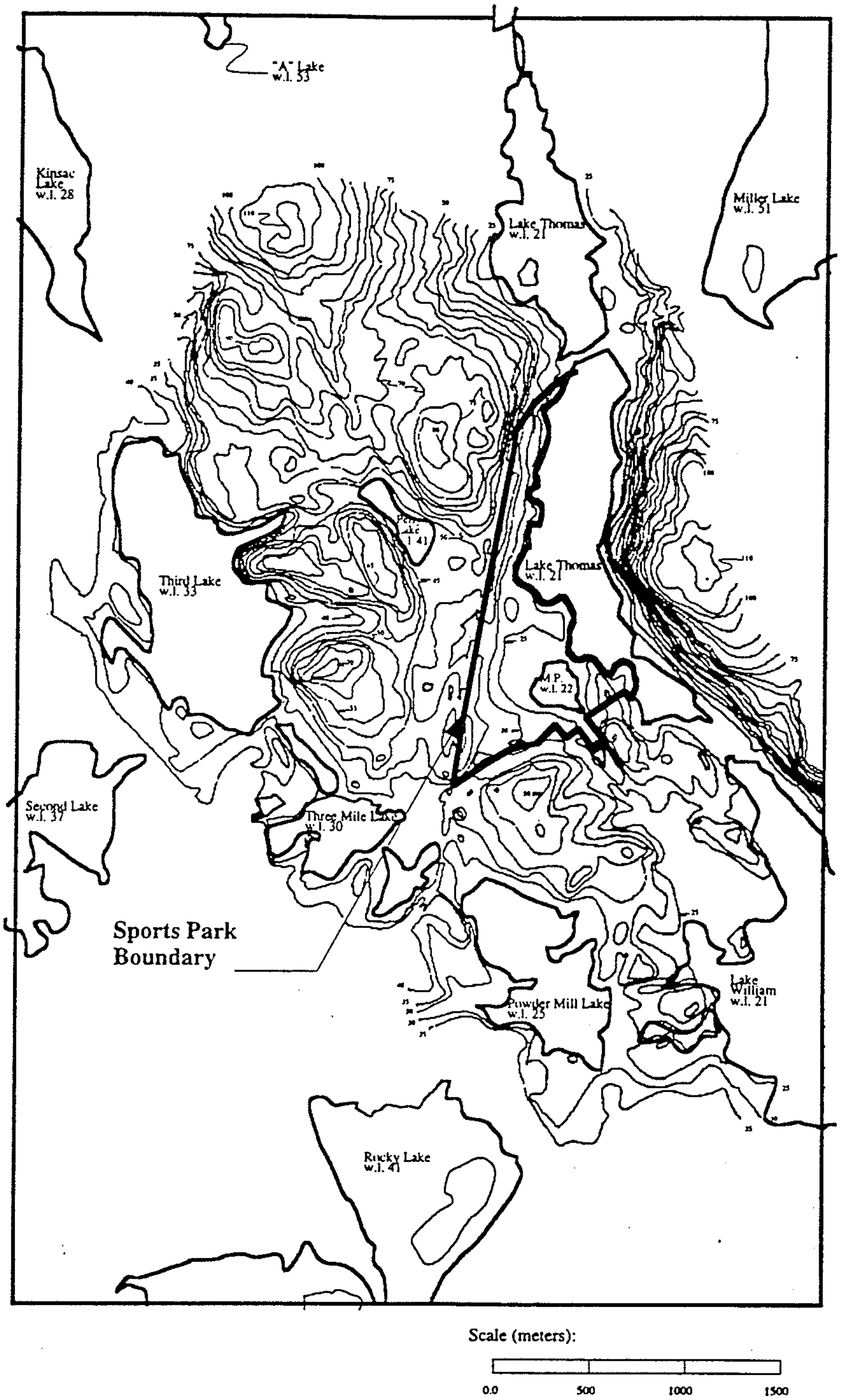
Sources: Nova Scotia Topographical Series: 11D/13-T1,
11D/13-T3, Waverley, Halifax County
Land Registration Information Series, 1975;
Air Photo flown 1992, L.R.I.S.

Fig. (1.) PARK CONTEXT MAP

Topography and General Site Description

Generally, the Park could be envisioned as a right-angle triangle, with an elongated, slender northern half and a wider southern base. Like the surrounding area, the topography of the Park is "gently undulating to gently rolling" (N.S. Soil Survey, 1963) with ridges and valleys. The width of the land varies in the northern half of the Park from 0 to 200 metres (650 feet), with most of it being between 60 metres (200 feet) and 90 metres (300 feet) wide. The site slopes down steeply from the Bicentennial highway to the lake over most of the northern half, with portions greater than 30 percent. The southern half of the site varies roughly between 400 metres (1300 feet) and 600 metres (2000 feet) in width. The elevation throughout the entire Park ranges from the water level of Lake Thomas, 21 metres (69 feet) to 49 metres (161 feet) along the Bicentennial highway, an elevation of 28 metres (92 feet) (Figure (2.) Elevation Map). The Park is clearly visible rising up from the western shores of Lake Thomas as one drives north along the Porto Bello Road Between Waverley and Fall River, especially in the morning when the shores catch the morning sun.

From within the Park, the prevailing summer winds come from the northeast, across Lake Thomas onto the shores. Inland a mixed forest of mature hardwoods and softwoods, which cover most of the Park, provide shelter from the winds offshore. Because of the undulating topography and the nature of the bedrock there are a variety of wet and dry areas. Trails throughout the Park provide exposure to several types of



Contour Interval: 5 meters

Sources: Nova Scotia Topographical Series: 11D/13-T1, 11D/13-T3, Waverley, Halifax County Land Registration Information Series, 1975

Fig. (2.) ELEVATION MAP

environments, and plant communities, created by dissimilarities in micro-climates, soil composition and drainage. These environments are best identified through their vegetation.

Laidlaw Hill (or more commonly known as Waverley Mountain), on the eastern shores of Lake Thomas, acts as a good reference point, especially when hiking along one of the many trails. Laidlaw Hill is the highest point in the area reaching a hieght of 112m (367ft). Also prevalent, while in the Park, is the noise from the dual carriage way of the Bicentennial Highway # 102, particularly in the northern section of the Park. What is perhaps less prevalent, but which plays an extremely important role in the ecology of the Park, is Muddy Pond, a wetland in the southern half of the Park (See Muddy Pond: Hydrology).

Presently, the Sports Park consists of a popular 10 kilometre trail system used year round for jogging and cross-country skiing, an access road, a natural beach area and about 2 to 2.5 hectares (5 to 6 acres) of scrubbed and cleared land in the centre of the Park for future development. Site reconnaissance (summer, 1994), after periods of rain, showed signs of soil erosion by surface water runoff into Muddy Pond from the loose surface access road and cleared area. Soil erosion is only an issue in this area where the vegetative layer has been removed, mainly as a result of heavy machinery.

2

Park Geology and Soils

Understanding the geophysical make-up of the area in which the Sports Park lies is an important part of interpreting the overall ecology of Muddy Pond. The type of bedrock and the processes which produced it (i.e. glaciation) influence, to a great degree, the type of drainage which can be expected over the landscape (Roland, 1984). The soils produced from the parent materials also govern the drainage and absorption of surface waters, which in turn influence nutrient availability, vegetation cover and wildlife habitat. While Appendix 5, *Lay of the Land*, describes the geophysical formation of south eastern Nova Scotia, this section addresses the geology and soil composition for the Waverley Area and the influence they may have on the ecology of Muddy Pond.

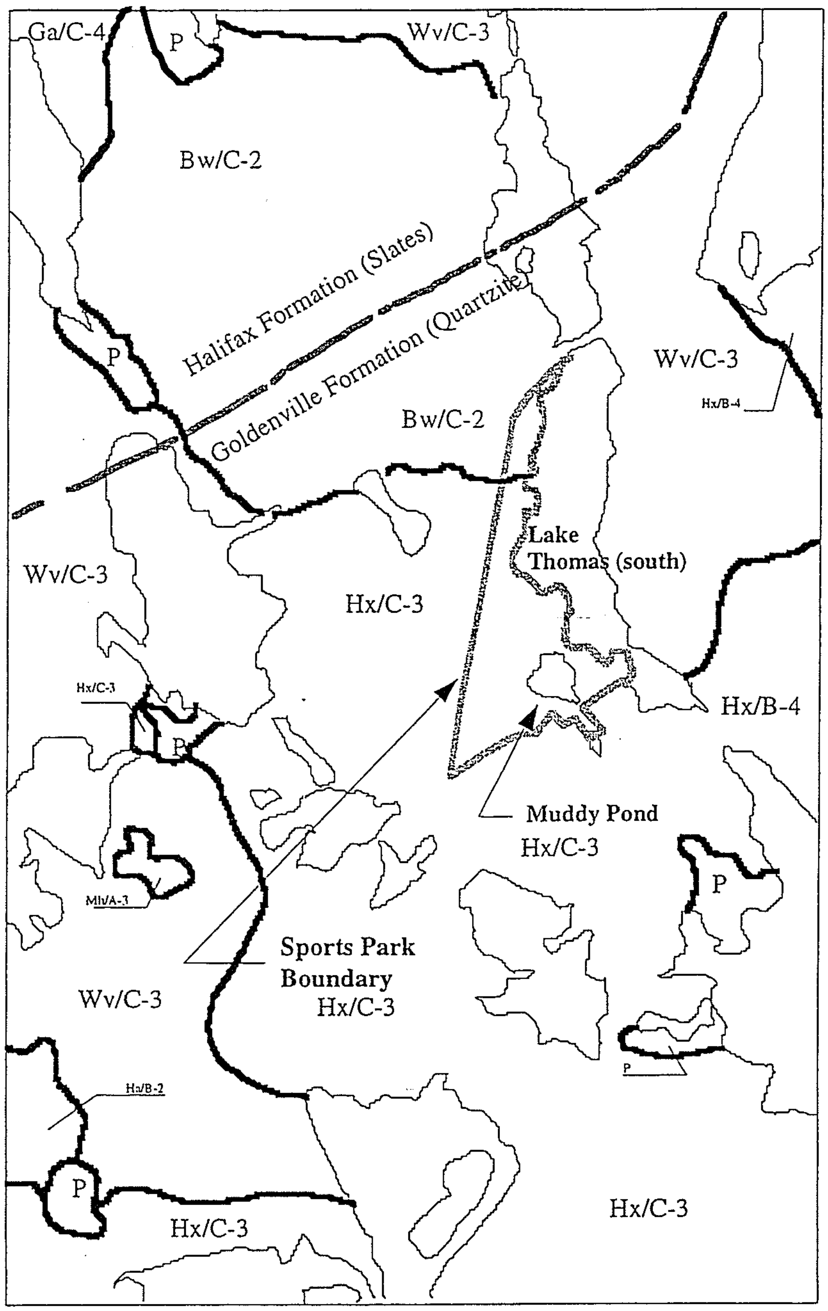
Geology

The bedrock geology of the Park, which is completely comprised of the Goldenville Formation known, as quartzite and sometimes called greywacke, is a very resistant quartz-rich rock containing some clay. The glacial till produced from the resistant quartzite is thin and rocky, with an average depth of 3 metres (10 feet) (Simmons, *et al.*, 1984). The other unit of the Meguma Group, which lies just north of the site, is the Halifax Formation, comprised of slates and known for their acidic properties when exposed to the air (Davis, 1994). Although not the underlying bedrock in the Park, the Halifax Formation does influence the soils in the northern part of the Park (Figure (3.) Geophysical Map)

Soils

At the odd scale of 1:63,360, the Nova Scotia Soil Survey for Halifax County (1963) identifies eight different soil series for the Waverley area. These are illustrated in figure (3.) Geophysical Map, and further described in Table (1.).

The soils found within the Park are mostly of the a Halifax Series (Simmons, *et al.*, (1984). The Halifax soils are podzolic and described as "brown sandy loam over yellowish sandy loam." The parent material is "moderately coarse textured", "olive to yellowish-brown stony sandy loam till derived from quartzite." The drainage in these soils are "good to excessive" (N.S. Soil Survey, 1963).



Scale (meters):

0.0 500 1000 1500

Soils Symbols

Bw/C-2: Bridgewater / 9-16% slope - Moderately stony
Ga/C-4: Gibraltar / 9-16% slope - Excessively stony
Ha/B-2: Hansport / 3-8% slope - Moderately stony
Hx/B-4: Halifax / 3-8% slope - Excessively stony
Hx/C-3: Halifax / 9-16% slope - Very stony
Mh/A-3: Mahone / 0-2% slope - Very stony
Wv/ C-3: Wolfville / 9-16% slope - Very stony
P: Peat

Grid North

Sources: Nova Scotia Topographical Series: 11D/13-T1, 11D/13-T3, Waverley, Halifax County Land Registration Information Series, 1975. Soil Survey, Halifax County. 1963. Report No.13. (Scale 1:63,360). N.S. Geology Map 1994. LRIS

Fig. (3.) GEOPHYSICAL MAKE UP

Table (1.) Geophysical Make-up of Waverley Area

Map Colour and Symbol	Soil Series or Land Type	Description of Subsurface and Subsoil	Parental Material	Topography	Percent slope and Stoniness	Drainage
Hx/C-3	Halifax	Brown sandy loam over yellowish sandy loam	Olive to yellowish brown stony sandy loam till derived from quartzite	Gently undulating to gently rolling	Rolling 9-16% and very stony	Good to excessive drainage
Hx/B-4	Halifax				Undulating 3-8% and Excessively stony	
Wv/C-3	Wolfville	Dark reddish brown loam to sandy clay loam over strong brown loam to sandy clay loam	Reddish brown loam to sandy clay loam till derived from shale and sandstone	Gently undulating to gently rolling	Rolling 9-16% and very stony	Good drainage
Bw/C-2	Bridgewater	Brown shaly loam over yellowish brown shaly loam	Olive shaly loam till derived from Precambrian slates	Gently undulating to gently rolling	Rolling 9-16% and Moderately stony	Good drainage
Mn/A-3	Mahone	Dark brown sandy loam over brown mottled sandy loam	Reddish brown sandy clay loam till	level to depressional	Level or nearly level 0-2% and very stony	Poor drainage
Ha/B-2	Hansport	Dark reddish brown sandy loam to sandy clay loam over reddish brown sandy clay loam	Reddish brown loam to sandy clay loam till derived from shales and sandstones	Gently undulating to gently rolling	Undulating 3-8% and Moderatley stony	Imperfect drainage
Ga/C-4	Gibraltar	Brown sandy loam over strong brown sandy loam	Pale brown coarse sandy loam till derived from granite	Gently undulating to gently rolling	Rolling9-16% slope and excessively stony	Good to excessive drainage
P	Peat	Brown 12" or more of semi-decomposed fibrous material over dark brown fibrous material chiefly sphagnum		Level to depressional		Poor drainage

Compiled from Nova Scotia Soil Survey for Halifax County, 1963.

Shay (1992) describes the podzolic order of soils as being highly leached due to acid conditions, with a grey (Ae) horizon and an accumulation of organic matter in the B horizon. Shay (1992) states that strongly leached soils such as podzols can result in layers which are impervious to water, thus creating a perched water table in an otherwise well drained site.

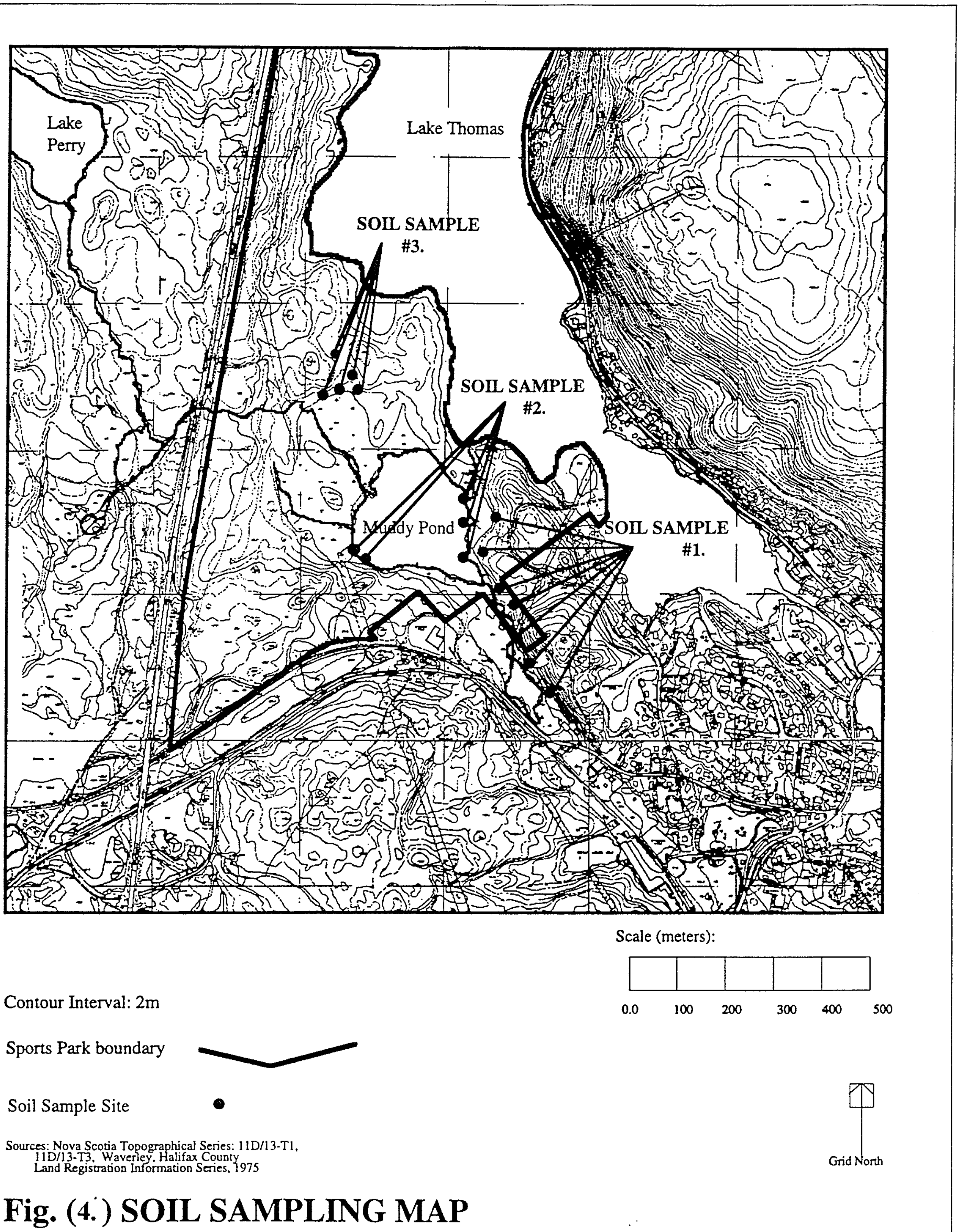
A small section in the northern most part of the Park has Bridgewater soils. Also podzolic these soils are described as "brown shaly loam over yellowish-brown shaly loam" (N.S. Soil Survey, 1963). It's parent material is described as "medium textured", "olive shaly loam till derived from Precambrian slates" and has good drainage (N.S. Soil Survey, 1963). While the soils produced from the slates allow for more vigorous vegetative growth, the soils produced from the quartzite do not. Generally the soils on the site are very permeable, strongly leached and highly acid (Simmons, *et al.*, 1984).

Site reconnaissance showed that, while not identified at the scale of the Soil Survey (1963), there is evidence of other soils on the site. While it is not the purpose of this exercise to identify the precise soil-makeup for the Park, it is important to understand the influence soils have on the drainage, vegetation and overall ecology of the Park.

The soils found in and around Muddy Pond fit best the description of the imperfectly drained Danesville soils, which are also podzols derived from the quartzite (N.S. Soil Survey, 1963). The Soil Survey (1963) also describes the Aspotogan soils, which are associated with wetlands throughout the area. Aspotogan soils are gleysols, where the water table is at or near the surface for much of the year. Organic deposits, or Peat, can be found on the north-west side of Muddy Pond in the fen portion of the wetland.

Soil Samples

Soil samples, from three different areas within the Park: 1) along the access road adjacent to Muddy Pond; 2) material from the bottom of Muddy Pond; and 3) outwash material from the disturbed, cleared area adjacent Muddy Pond (See Figure (4.) Soil Sampling Map) were gathered on August 29, 1994 and delivered to the Nova Scotia Department of Agriculture and Marketing for soil analysis (Appendix (2.) *Sampling Collection Procedures*). Table (2.) presents the results.



Sources: Nova Scotia Topographical Series: 11D/13-T1, 11D/13-T3, Waverley, Halifax County Land Registration Information Series, 1975

Fig. (4.) SOIL SAMPLING MAP

Table (2.) Soil Analysis from Charles L. McDonald Sports Park

Test	Access Road Sample #1	Muddy Pond Sample #2	Disturbed Clearing Sample #3
pH	4.8	5.1	4.9
Organic Matter (%)	7.4	39.6	6.1
Phosphate (mg/g)	0.015	0.028	0.014
Potash (mg/g)	0.017	0.025	0.056
Calcium (mg/g)	0.159	0.587	0.095
Magnesium (mg/g)	0.023	0.053	0.026
Boron (mg/g)	0.00009	0.0003	0.0001
Iron (mg/g)	0.174	0.108	0.182
Manganese (mg/g)	0.032	0.074	0.056
Copper (mg/g)	Trace	0.000.39	Trace
Zinc (mg/g)	0.0049	0.0038	0.002.4

Discussion of Soil Analysis

The pH for all three samples illustrate the acidic nature of the Park's soils, with the Muddy Pond sample being the least acidic at 5.1. The Muddy Pond sample also had the greatest amount of organic matter (39.6%) while the other two samples had less than 10%. Mitsch and Gosselink (1986) identify wetland soils with an organic matter content greater than 20 to 35 % as organic soils rather than mineral. Organic soils differ from mineral soils in several ways. Organic soils have a lower bulk density with at least

80% porosity. Mineral soils (except clays) generally have a greater hydraulic conductivity than organic soils, meaning that water is better able to pass through mineral soils. Organic soils are generally nutrient poor, having minerals in organic forms unavailable to plants. Organic soils have a greater cation exchange capacity, defined as the sum of exchangeable cations (positive ions) that a soil can hold. The cation exchange capacity in mineral soils is dominated by major ions such as Calcium, Magnesium, Potassium and Sodium (Mitsch and Gosselink, 1986). The analysis indicates that there was more phosphate, calcium, magnesium, boron, manganese and copper found in the Muddy Pond sediment than in the samples taken from the access road or the disturbed clearing, perhaps suggesting that the Muddy Pond soil, while high in organic matter, resembles, better, that of a mineral soil. Potash and iron were greatest in the sample taken from the disturbed clearing sediment, while the greatest amount of zinc was found in the sample taken from the access road.

Although there was not a thorough examination of the sediment from the bottom of Muddy Pond, it is not surprising to find, in those samples analysed, higher readings for many of the elements tested. Wetlands are traditionally characterized by poorly drained soils, with their development depending in part not only on the climate and surface configuration of the landscape, but also on the type of bedrock and soil conditions (Simmons, *et al.*, 1994). Most of the wetlands in Nova Scotia are Peatlands - wetlands characterized by an accumulation of peat and associated with organic soils. Peatlands which acquire nearly all of their nutrients and moisture from precipitation are called ombrotrophic bogs and are dominated by Sphagnum mosses (Simmons, *et al.*, 1994).

Those wetlands fed by water moving through mineral soils and dominated by sedges are known as fens (Simmons, *et al.*, 1994). Because wetlands function both as natural storage areas for carbon (in the form of peat) and as sinks for pollutants (Simmons, *et al.*, 1994), it would not be unusual to have such high readings for such tests as percent organic matter and Manganese (Chacko, 1995).

Organic deposits, or Peat, can be found on the north-west side of Muddy Pond in the bog area and may lead to speculation, that, at one time, Muddy Pond was part of an old lake bed (MacDougall, *et al.*, 1963). The Danesville and Aspotogan and Peat soils, believed to be associated with Muddy Pond, and perhaps elsewhere in the Park, could give an insight as to how the surface and ground waters behave. The hydrology of the Park is one of strongly leached soils, impermeable underlying bedrock and surface water collection in the form of the Muddy Pond wetland.

3

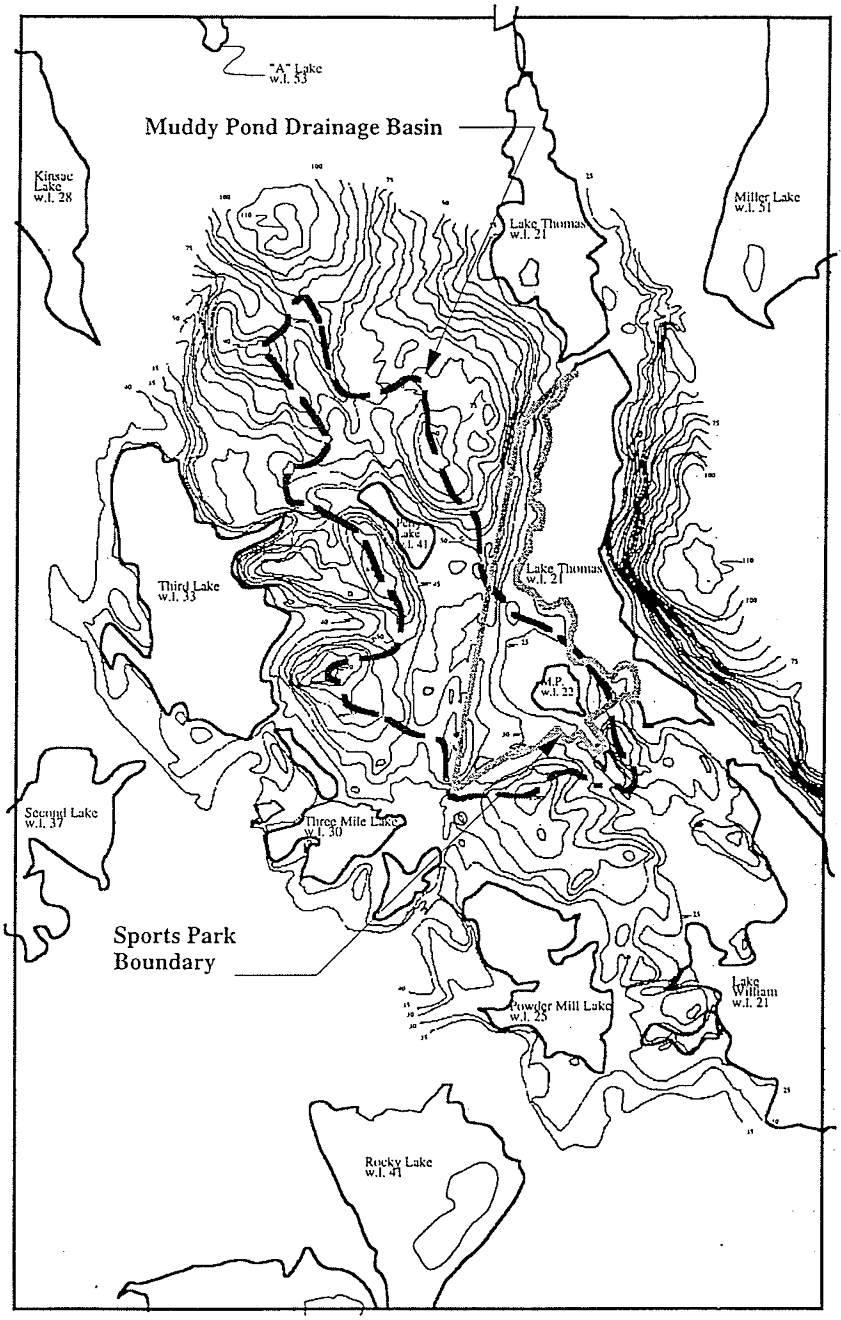
Muddy Pond: Hydrology

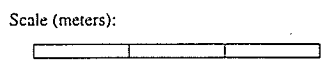
The understanding and management of Muddy Pond and indeed the entire Park is, to a great extent, dependent upon the understanding of the Park's hydrology. Wetlands are transitional areas between terrestrial environments and deep water environments, often exhibiting some properties of each (Simmons, *et al.*, 1994). Wetlands are considered "open systems" strongly influenced by external elements such as solar radiation, precipitation, nutrient loading and surface and ground water flows (Mitsch and Gosselink, 1986). Abiotic factors such as water availability, nutrient availability, soil conditions, water chemistry and water velocity are influenced by the wetland ecosystem and vice versa (Tyler, 1995; Hook, *et al.*, 1988). Biotic factors, particularly vegetation, influence water gain, water movement and water losses (Gilman, 1994).

Muddy Pond Drainage Basin

Although Muddy Pond lies within the Headwaters watershed of the Shubenacadie-Stewiacke River System (Appendix (4.) *Shubenacadie Headwaters*) it also has its own smaller watershed which connects to the headwaters system.

Figure (5.) shows the location of the Muddy Pond Drainage Basin in relation to the Sports Park. The Muddy Pond Drainage Basin (MPDB) is a second order drainage basin as defined by Marsh (1991). While not all of the Park drains into Muddy Pond (most of the northern half of the Park drains directly into Lake Thomas), the southern half does drain into the Pond and is the focus of attention in this project. Most of the lakes in the area drain into Lake William and do not drain into Muddy Pond (Figure (6.)). The MPDB drains an area of approximately 249± hectares (615± acres), most of which is undeveloped and forested and on the western side of the Bicentennial Highway, beyond the Park's boundary. Included in this minor watershed are the mine tailings from past gold mining activities as well as the soils from the Halifax slate formations. While the quartzite tailings are associated with naturally occurring arsenic, the slates are associated with naturally occurring acidic runoff when exposed to weathering. It is on these acidic slates, in the northern most part of the MPDB, that single family residential development is begining to occur (Figure (7.)).

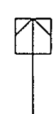




Area of Drainage Basin: 249 + hectares (615 + acres)

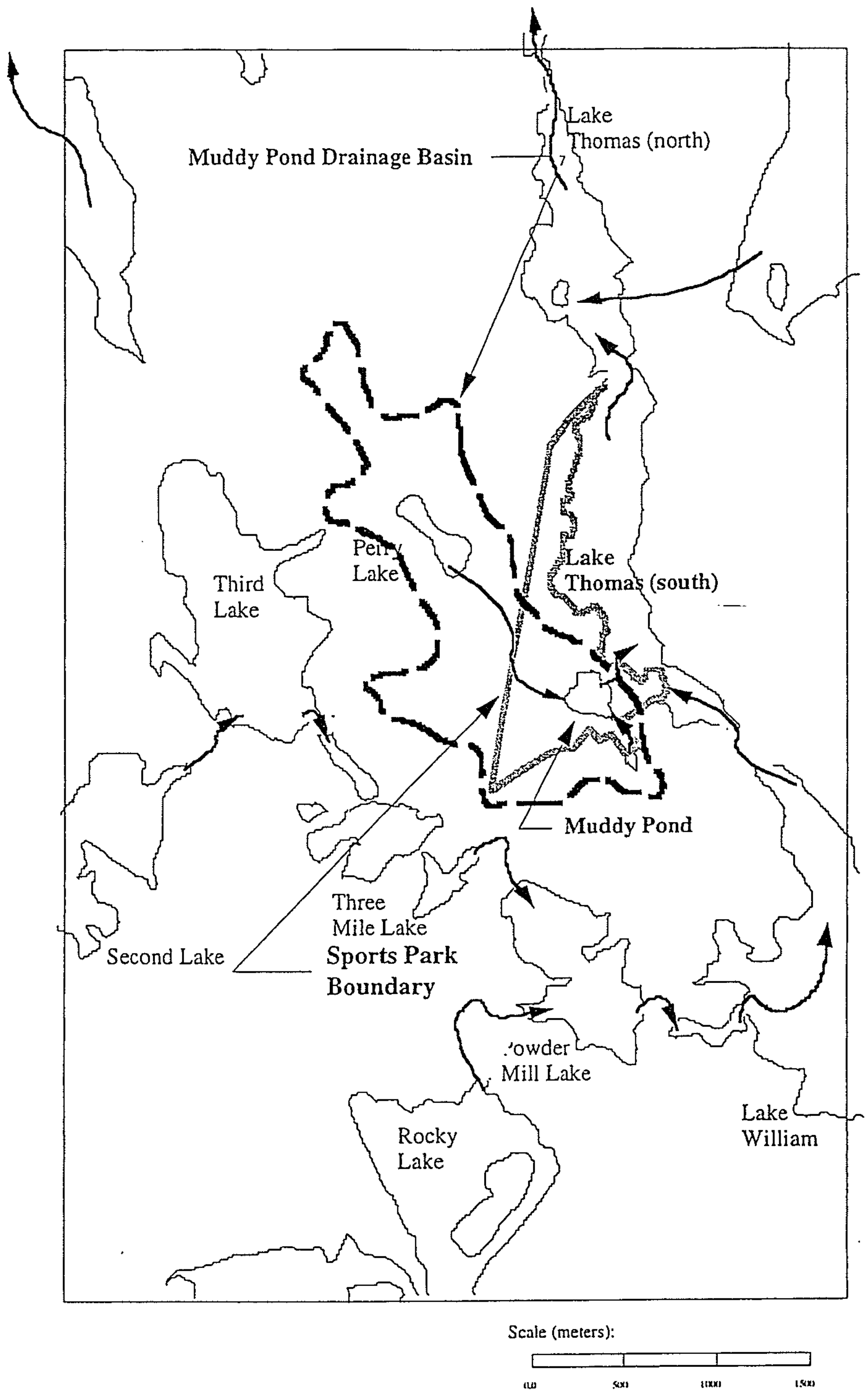
Contour Interval: 5 meters

Muddy Pond Drainage Basin: 



Sources: Nova Scotia Topographical Series: 11D/13-T1, 11D/13-T3, Waverley, Halifax County
Land Registration Information Series, 1975

Fig. (5.) MUDDY POND DRAINAGE BASIN



Area of Drainage Basin: 249 + hectares (615 + acres)

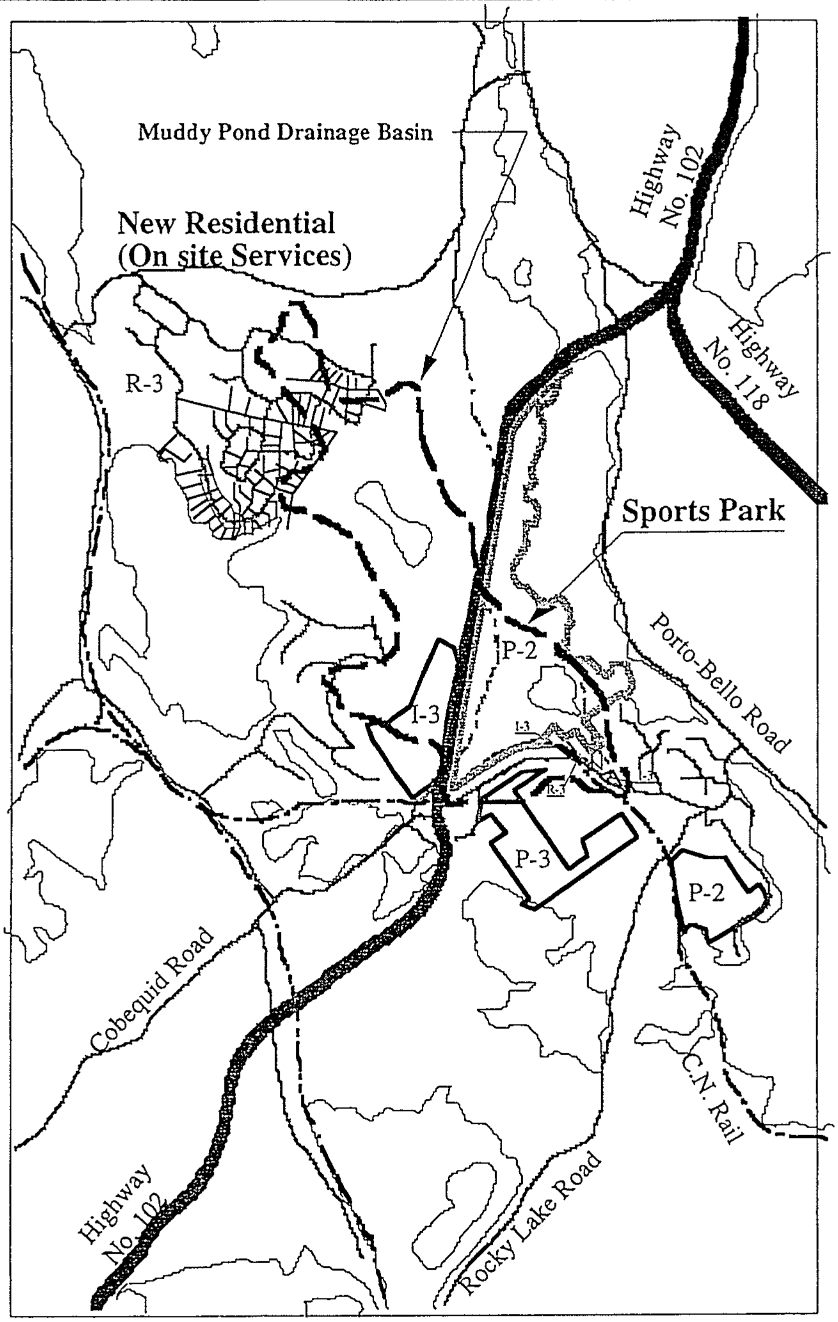
Muddy Pond Drainage Basin:

Direction of lake drainage

Sources: Nova Scotia Topographical Series: 11D/13-T1, 11D/13-T3, Waverley, Halifax County
Land Registration Information Series, 1975

Grid North

Fig. (6.) DIRECTION OF FLOW OF LAKE WATERS



Scale (meters):

Zone Symbols

I-3: Light Industrial
R-3 Single Family Residential
P-2: Community Facility
P-3: Park

Area of Drainage Basin: 249 + hectares (615 + acres)

Muddy Pond Drainage Basin:

Grid North

Sources: Nova Scotia Topographical Series: 11D/13-T1,
11D/13-T3, Waverley, Halifax County
Land Registration Information Series, 1975
Municipal Planning Strategy, Districts 14 & 17. Revised 1991.

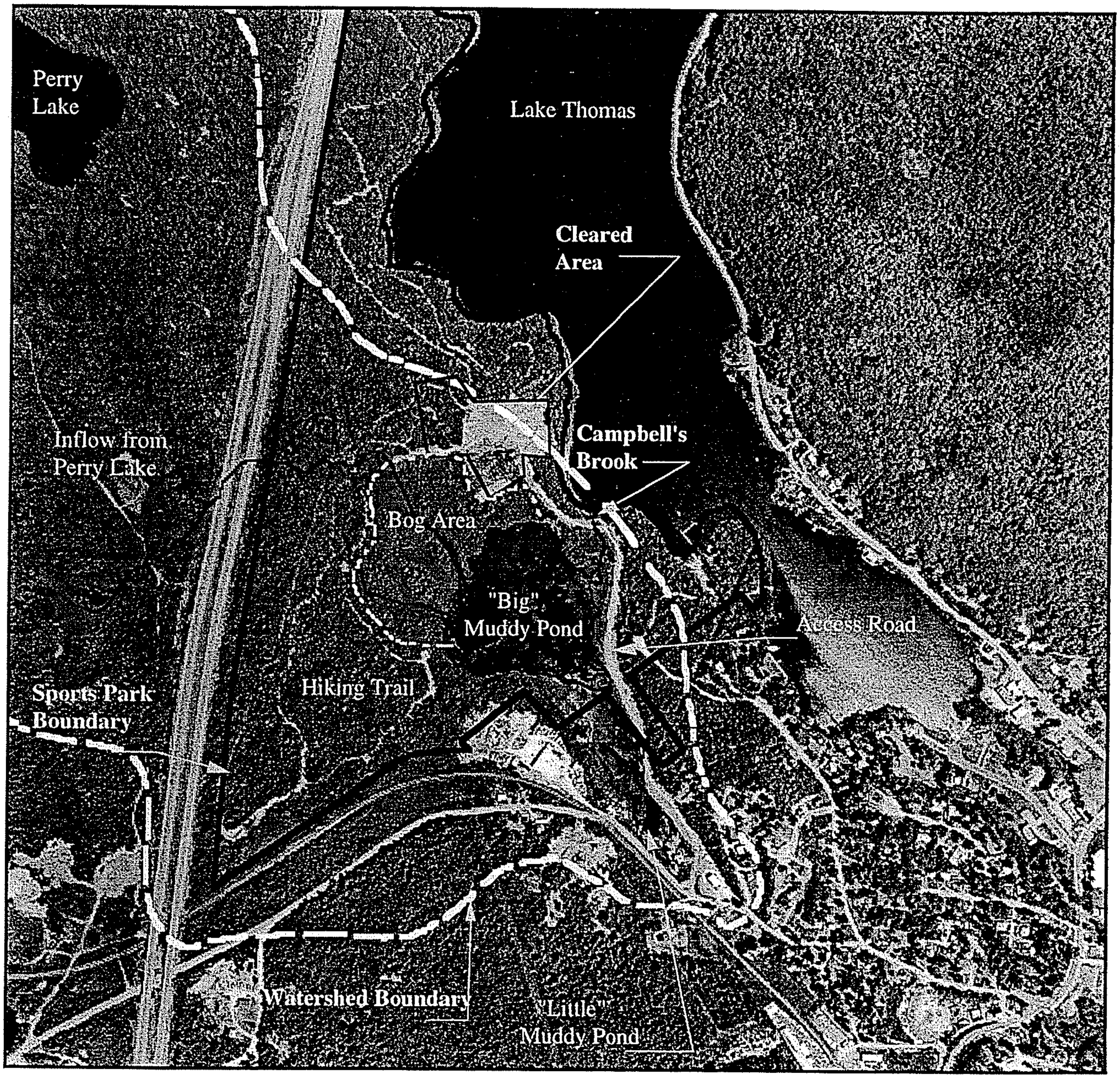
Fig. (7.) ROADS, RAIL & ZONING

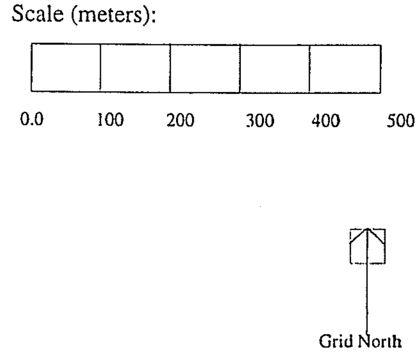
General Pond Description

Muddy Pond lies in the southern portion of the Park and is first evident as one enters the Park along the access road. The access road was constructed around 1989, following the edge of Muddy Pond along the base of American Hill and terminates just north of the Pond in the cleared area, where a recreational facility is proposed.

Muddy Pond is comprised of two ponds ("Big" Muddy Pond and "Little" Muddy Pond) approximately 5 hectares (12 acres) in size and a bog-like wetland of about the same size on the north west side (Figure (8.) Watershed Boundary and Site Features). The Ponds and the bog, together, make up what is known today as Muddy Pond.

Muddy Pond is fed by two small brooks which run from the other side of the Bicentennial Highway into the Park. One of these brooks is intermittent, while the other carries water from a single lake called Perry Lake. Inflowing water enters through the bog-like area into Big Muddy Pond, presenting the bog area with features unlike that of a true bog, but more like a fen (See Classifying Muddy Pond). Out flowing water from Muddy Pond exits through a small brook known as Campbell's Brook. Campbell's Brook is a small rock strewn brook about 100 metres (328 feet) in length which connects Muddy Pond to Lake Thomas. Campbell's Brook is believed to be the site of Nova Scotia's first gold claim (See Appendix (7.), *Gold*) The access road, into the Park, crosses over Campbell's Brook.





Sources: Nova Scotia Topographical Series: 11D/13-T1,
11D/13-T3, Waverley, Halifax County
Land Registration Information Series, 1975;
Air Photo flown 1992, L.R.I.S.

Fig. (8.) MUDDY POND WATERSHED BOUNDARY AND SITE FEATURES

Wetland Water Quality

The functional role of wetlands in water quality improvement has been identified as a compelling argument for wetland preservation (Horowitz, 1978, in Hook, *et al.*,1988). Wetlands, like Muddy Pond, because of their transitional state between land and water, have in the past only been viewed as suitable for dumping grounds for municipal and industrial wastes. Ironically however, wetland systems can often tolerate the conditions associated with wastewater input, such as oxygen depletion in water and sediment and effectively remove or transform nutrients and other wastewater contaminants. The impact of wastewater addition on wetlands is generally less than that on terrestrial or aquatic communities because wetland plants are preadapted to periods of standing water and water-logged soils, as well as to reducing conditions (Hook, *et al.*, 1988). It should be evident that water quality in wetlands is closely associated with the aquatic vegetation found in and around the wetland and is more than just the result of mechanics (See Muddy Pond: Vegetation).

At the site level the quality of the water in a wetland can suggest what is happening within the drainage basin which feeds the wetland. Being influenced by inflowing waters, surface runoff (land use activities), precipitation, ground water, and the vegetation in and around the wetland, the water quality of a wetland could suggest what nutrients, chemicals or pollutants are present within it's drainage basin.

Because wetlands can alter the quality of water passing through the wetland, they can have a significant influence on the quality of the water in the greater landscape. Simmons, *et al.*, (1994) state that highly productive freshwater marshes may disperse nutrients to the rest of the drainage system. Conversely, where wetlands have low productivity, such as peatbogs, water may become acidified and nutrients absorbed. Simmons, *et al.*, (1994) state that all wetlands generate dissolved carbon which increases colour, thus lowering light penetration and ultimately impacting on plant growth. In understanding better the ecology and importance of Muddy Pond the following two sections on Water Quality and Water Quantity of Muddy Pond are presented in some detail.

Muddy Pond Water Quality Analysis

Two separate sets of water samples were taken from Muddy Pond for analysis. (See Figures (9.) and (10.) Water Sampling Maps) The first set of samples, collected on September 2, 1994, were analysed for pH, conductivity, colour, hardness, acidity, and alkalinity, under normal laboratory conditions at the Federal Department of Fisheries and Oceans, in Halifax. The second set of samples, collected on September 16, 1994, were taken to the Environmental Chemistry Division of Clinical Chemistry at the Victoria General Hospital, in Halifax, for chemical analysis, including arsenic. While the sampling method, results and a detailed discussion of the water quality analysis for Muddy Pond are provided in the appendices, Table (3.) presents a summary of the analysis and compares them with results from previous surveys for both Muddy Pond and Lake Thomas over the

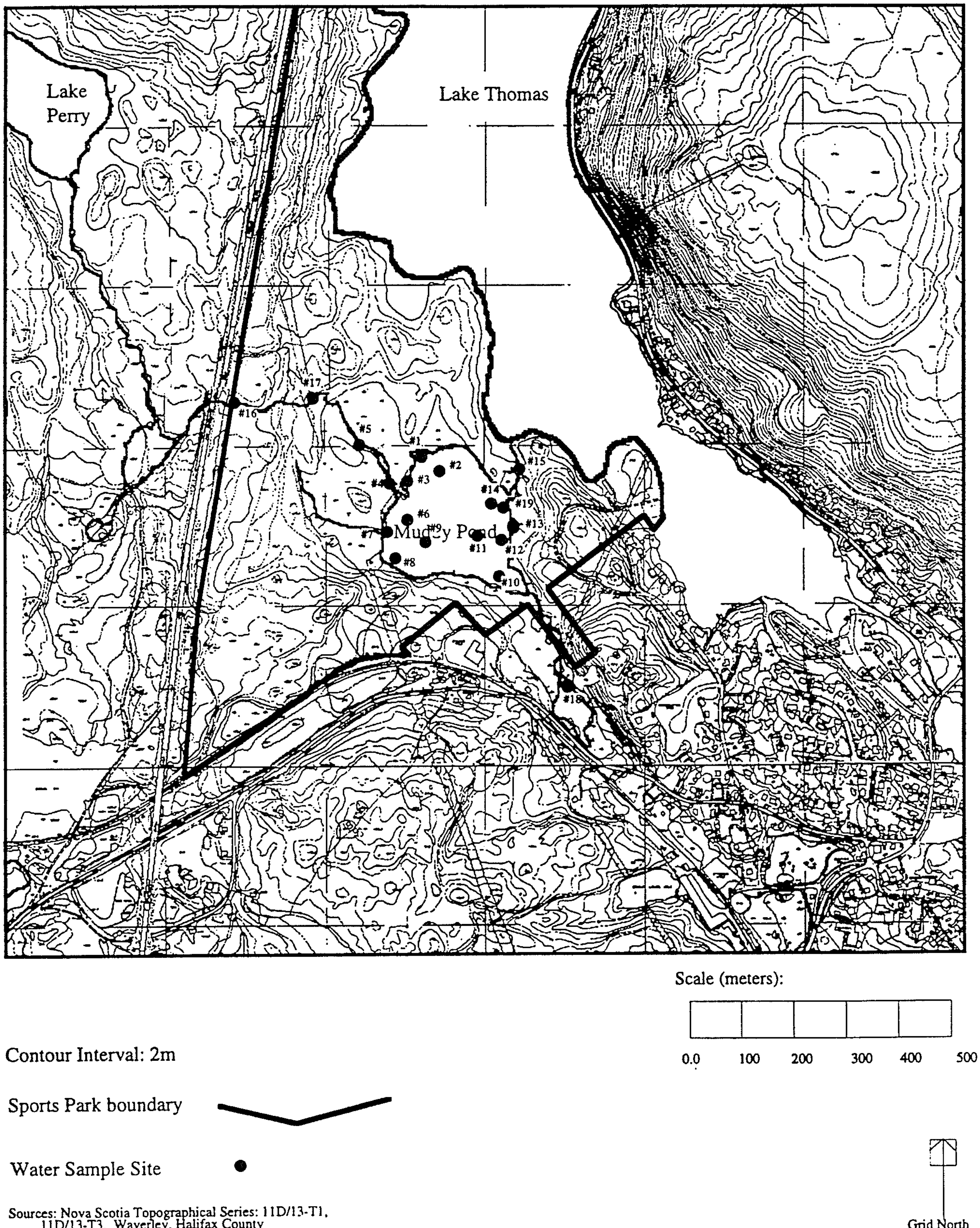
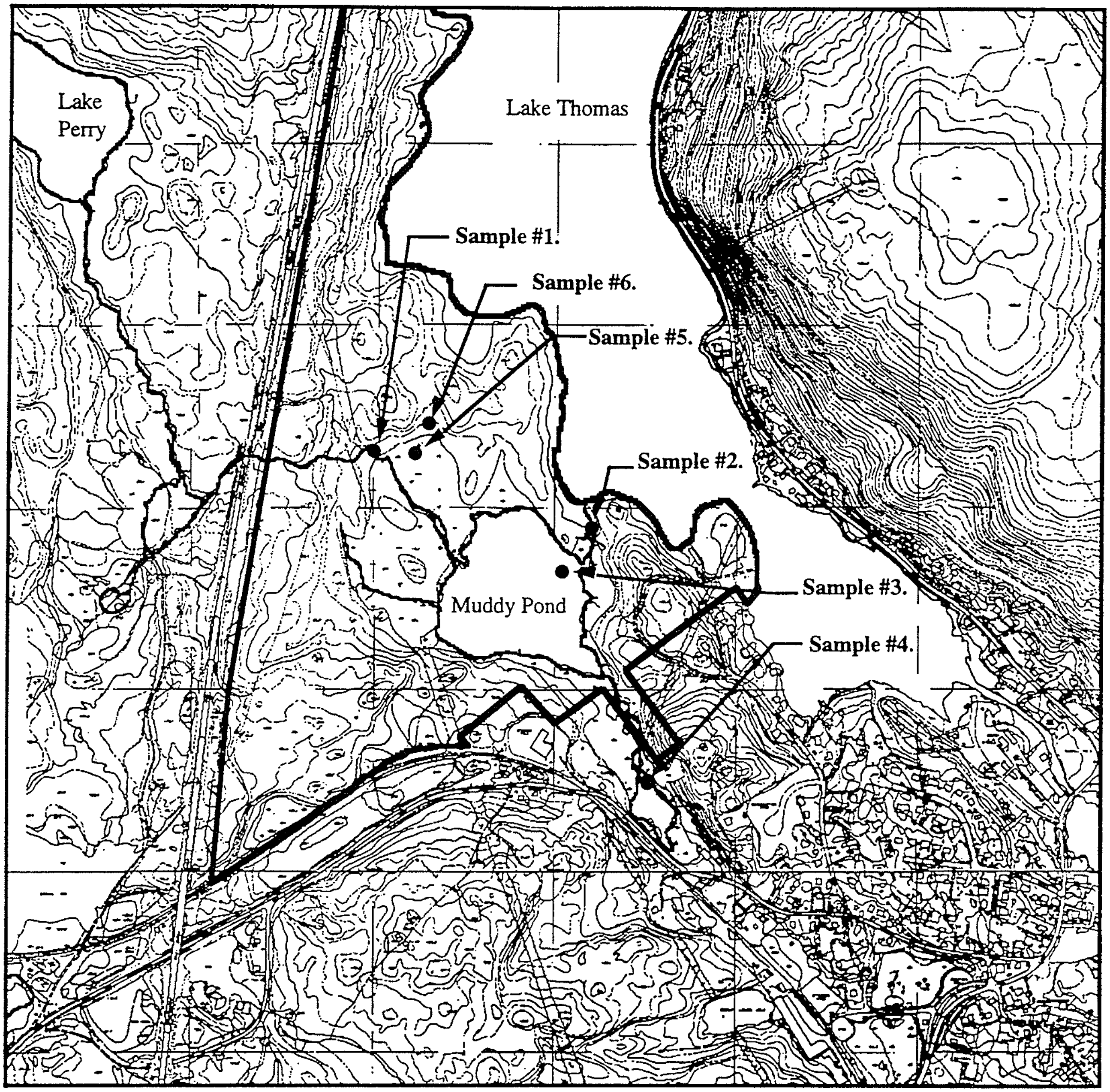


Fig. (9.) 1st. WATER SAMPLE MAP, SEPTEMBER 2, 1995



Scale (meters):

0.0 100 200 300 400 500

Contour Interval: 2m

Sports Park boundary

Water Sample Site

Sources: Nova Scotia Topographical Series: 11D/13-T1, 11D/13-T3, Waverley, Halifax County Land Registration Information Series, 1975

Grid North

Fig. (10.) 2nd. WATER SAMPLE MAP, SEPTEMBER 16, 1995

Table # (3.) Comparison of Water Quality Surveys for Lake Thomas and Muddy Pond between 1978-1994.

Analysis	Survey						
	Survey #1 (1978) Station 3. Lake Thomas Surface Water	**Survey #2 (1984)**		**Survey #3 (1990) Station 1.**		**Survey #4 (1991) Lake Thomas (#39.) Surface Water**	**Survey #5 (1994) Muddy Pond Surface Water**
		Lake Thomas	**Muddy Pond**	**Lake Thomas (mean)**	**Campbells Brook (mean)**		
pH (mean)	6.29	-----	-----	7.0	7.0	6.4	6.67
Conductivity uS/cm	73.25	-----	-----	129.6	213.3	153.7	237.4
Colour	6 apparent	-----	dk brown sediment 50 cm to peat	9.6 Hazen	19 Hazen	17.5 TCU	40.8 Hazen
Diss Oxy mg/l (mean)	7.9	17 at 4 m depth	18 at 1 m depth	6.7	-----	2.9 Dissolved organic carbon	-----
Acidity mg/L CaCO3	-----	-----	-----	-----	-----	-----	1.48
Hardness mg/L CaCO3	13.1 mean	-----	-----	20.8	-----	-----	22.3
Alkalinity mg/L CaCO3	3.74 mean	-----	-----	7.8	20.3	3.4 mean	21.30
Total P	0.016mg/l	8 $mg.m^{-3}$ (0.008mg/l)	18 $mg.m^{-3}$ (0.018mg/l)	0.0122mg/l	0.0172mg/l	0.009 mg/l	0.054mg/l
Total N	0.054mg/l(NO 2;N03 as N)	-----	-----	0.26mg/l	0.30mg/l	0.3 mg/l	0.3mg/l

Table (3.) Continued...

Analysis	Survey						
	Survey #1 (1978) Station 3. Surface Water	**Survey #2 (1984)**		**Survey #3 (1990) Station 1.**		**Survey #4 (1991) Lake #39. Surface Water**	**Survey #5 (1994) Muddy P. Surface Water**
		Lake Thomas	**Muddy Pond**	**Lake Thomas (mean)**	**Campbells Brook (mean)**		
Calcium	3.93mg/l	-----	-----	6.5 mg/l	-----	4.51 mg/l	9.38 mg/l
Magnesium	0.8 mg/l	-----	-----	1.1 mg/l	-----	0.79 mg/l	1.41 mg/l
Potassium	0.73 mg/l	-----	-----	0.86 mg/l	-----	0.7 mg/l	-----
Sodium	8.63 mg/l	-----	-----	19.6 mg/l	-----	16.8 mg/l	-----
Arsenic	-----	272 ug.g-1 (272mg/l)	6196 mg/l	<0.005	-----	1.7 mg/l	0.025 (av of samples 3-6)
Mercury	-----	0.07 ug.g-1	6.21 ug.g-1	-----	-----	-----	-----
Trophic Classifiation based on Phosphorus	-----	Oligitrophic	Mesotrophic	Mesotrophic	-----	Oligotrophic	-----
Total Coliform Count for August	-----	-----	-----	800	----	-----	-----

Survey #1 Interprovincial Engineering Limited, August, 1978: Water supply and wastewater management.
Survey #2 Mudroch and Clair, 1984: Impact of Gold Mining on Headwater Ecosystem.
Survey #3 Scott, et al., 1991: Water Quality in Headwaters between May and November 1990.
Survey #4 Keizer, et al., 1993: Synoptic Water Quality Survey on Dartmouth Lakes on April 16, 1991.
Survey #5 Pinks, September, 1994: Muddy Pond Surface Water and Sediment.

past ten years. While the documents can all be obtained from the Nova Scotia Department of Environment, analysing and comparing their results can be difficult due to inconsistencies in sampling techniques, time of sampling and units used for recording data. The time of day and the time of year will influence data as will how the data is collected. Care should be taken in using conventional units for ease of comparison with other data.

In analysing and comparing the water quality results for Muddy Pond and Lake Thomas (Table (3.)), it is important to remember that a complete water quality analysis involves several hundred, costly, individual tests and that the discussion here is subject to further analysis. Mr. Val Chacko from the Water Quality Branch of the Department of Fisheries and Oceans, Winnipeg, made the following interpretation based on the analysis.

In determining the presence of ground water, one looks at conductivity, hardness and alkalinity. Conductivity is based on the amount of Magnesium and Calcium and other major nutrients in the water, such as Potassium, Sodium and Chloride. Although the conductivity for the 1994 survey for Muddy Pond (Survey #5) is higher than that for the other surveys, the amount of Magnesium and Calcium is not significantly different than that of the other surveys, suggesting that the amounts of Potassium, Sodium and Chloride must be higher, although they were never measured. Chacko (1995) stated that one needs to know the water conductivity readings for the winter months to accurately determine the amounts of major ions in the water, and therefore the presence of groundwater in the Pond. Winter month conductivity readings were not acquired for this project.

The high readings for alkalinity and hardness, however, coupled with the high conductivity reading for September suggest that Muddy Pond, at least in part, is ground- water fed. Mandell (1994) also stated that the readings suggested the presence of ground-water.

The trophic status of Muddy Pond is associated with the amounts of Nitrogen and Phosphorus available to plants and animals in the system. Chacko (1995) states that the high reading for the 1994 Muddy Pond Survey would suggest that the wetland is eutrophic, especially when compared to the trophic levels given to Lake Thomas and Muddy Pond in previous surveys. However, while the Phosphorous reading is high, there is very little algae present in the Pond, suggesting, Chacko (1995) states, that the Phosphorous present is not bio-available. That is, the Phosphorous present is tied up in the system and is not easily available to the organisms. Chacko (1995) states that a breakdown of the types of Phosphorous in the water and in the soil (Refer toTable (2.) Soil Analysis) would assist in explaining where the Phosphorous is coming from. Since there is no agricultural activity, and possibly no septic fields within the drainage basin in question, the high reading for Phosphorous suggests that the Phosphorous present is naturally occurring in the environment.

Canadian Water Quality Guidelines

Water quality analysis can be conducted for aquatic life and recreational and aesthetic uses, as well as for consumption. Table (4.) presents a summary of the water quality analysis for Muddy Pond and compares them with the Canadian Water Quality Guidelines for Drinking Water (1993) and for Freshwater Aquatic Life (1987).

The 1994 water quality analysis for Muddy Pond met all the 1993 Drinking Water Quality Guidelines, with the exception of one water sample from Little Muddy Pond which had a Arsenic reading of 0.078 mg/l, while the 1993 guideline requires a maximum acceptable concentration of no more than 0.025 mg/l (Appendix (2.) *Detailed Water Quality Analysis*). Little Muddy Pond lies directly across the Access Road from a large pile of mine tailings known to contain naturally occurring arsenic.

Concerning the 1987 Guidelines for Freshwater Aquatic Life, readings for Lead, Copper, Chromium , Selenium and Cadmium were over the levels acceptable for aquatic life. Chacko (1995) stated that the levels for these elements were not significant to affect aquatic life. The larval stage of the Leopard Frog can tolerate a concentration of 0.060mg/l for Copper (Birge and Black, 1979, in Canadian Guidelines for Aquatic Life, 1987) for instance. Rooted vascular plants, like cattails, are considered to be relatively tolerant of metals such as Copper, both in the water and the sediment (Stokes, 1975, in Guidelines for Aquatic Life, 1987). Increases in pH and hardness decrease the toxicity of Chromium, Cadmium and Copper. Both Leopard Frogs and cattails can be found in Muddy Pond.

Table (4.) Comparison of 1994 Water Quality Analysis for Muddy Pond with Canadian Water Quality Guidelines for Drinking Water (1993), and Freshwater Aquatic Life (1987).

Test	Muddy Pond (average)	Drinking Water Guideline (1993)	Freshwater Aquatic Life Guideline (1987)
pH (mean)	6.67	AO6.5-8.5	6.5-9.0
Conduc. adjusted* (uS/cm)	237.40	-----	----
Colour	40.8 (hazen units)	AO15 TCU	-----
Acidity (mg/l) $CaCO_3$	1.48	-----	-----
Hardness (mg/l) $CaCO_3$	22.83	80-100 acceptable <200 poor	-----
Alk. (mg/l) $CaCO_3$	21.30	-----	-----
Total P (mg/l)	0.054	-----	-----
Total N (mg/l)	0.3	Nitrate MAC45.0	2.2 mg l^{-1} for Total Ammonia at pH 6.5
Calcium (mg/l)	9.38	-----	-----
Magnesium (mg/l)	1.41	-----	-----
Iron (mg/l)	<0.05	AO $\leq$0.03	0.3 mg l^{-1}
Manganese (mg/l)	0.03	AO $\leq$0.050	-----
Lead (mg/l)	<0.003	MAC0.0100	0.001 mg l-1**
Copper (mg/l)	<0.01	AO$\leq$1.00	0.002 mg l-1**
Zinc (mg/l)	<0.01	AO$\leq$5.00	0.03 mg l^{-1}
Arsenic (mg/l)	<0.025*	IMAC0.025	0.05 mg l^{-1}
Aluminum (mg/l)	<0.10	-----	0.1 mg l^{-1} for pH $\geq$6.5
Boron (mg/l)	<0.10	IMAC5.0	-----
Barium (mg/l)	0.027	MAC1.0	-----
Beryllium (mg/l)	<0.005	-----	-----
Chromium (mg/l)	<0.02	MAC0.05	0.02 mg l^{-1} for fish 0.002 mg l^{-1} for zooplankton
Cobalt (mg/l)	<0.05	-----	-----
Nickel (mg/l)	<0.02	-----	0.025 mg l^{-1}**
Antimony (mg/l)	<0.05	-----	-----
Tin (mg/l)	<0.05	-----	-----
Vanadium (mg/l)	<0.01	-----	-----
Selenium, Plasma (mg/l)	<0.1	MAC0.01 for Selenium	0.001mg l^{-1} for Selenium
Cadmium, Plasma (mg/l)	<0.01	MAC0.005 for Cadmium	0.0002 mg l^{-1} for Cadmium

* all arsenic samples are below acceptable limits with the exception of that from Little Muddy Pond which was 0.078 mg/l. AO = Aesthetic Objective
MAC = Maximum Acceptable Concentration; IMAC = Interim Maximum Acceptable Concentration (insufficient data to determine acceptable limit)
** Where Hardness is between 0-60 mg l^{-1} ($CaCO_3$)

Trout (also known to inhabit Muddy Pond (McDonald, 1995)) are often used as an indicator species for water quality. Chromium causes toxicity at 0.264 mg/l (Benoit, 1976, in Guidelines 1987) in Brook Trout, while Copper causes toxicity in Rainbow Trout at 0.110 mg/l (Birge and Black, 1979, in Guidelines, 1987). Cadmium causes toxicity at 0.001 mg/l for exposure of Rainbow Trout and 0.002 mg/l for Brook Trout. Selenium causes toxicity to Rainbow Trout at 8 mg/l. Aquatic insects are less sensitive to cadmium than zooplankton, while aquatic plants are affected at concentrations as low as 0.002 mg/l. The presence of Selenium has a protective effect against Cadmium toxicity to animals and aquatic plants. Acute Lead toxicity to Brook Trout is 4.820 mg/l and for rainbow trout is 2.448 mg/l, although acute toxicity to lead is decreased in hard water (U.S. EPA, 1985, in Guidelines, 1987).

Canadian Water Quality Guidelines for Recreation and Aesthetics (1992) focus mainly on visual aspects of the water, such as clarity, turbidity and the presence of aquatic plants. The guidelines state that the total Coliform count should not exceed 2000 *E. Coli* per litre, while the pH of the water should lie within 5.0 and 9.0 and is related to eye irritation with swimmers. Temperature should not cause an appreciable increase or decrease in deep body temperature. Water should be sufficiently clear that a Secchi disc is visible at a minimum of 1.2 m. Rooted or floating plants that could entangle swimmers should be absent, while dense growths of vegetation could also affect boating and fishing.

Summary

In summary Chacko (1995) stated that the quality of water in Muddy Pond was good, although the reading for colour was high. The conductivity reading was high suggesting the possibility of the presence of ground water. Recreationally, Muddy Pond would be too shallow for swimming purposes at only an average depth of 0.3m (1 ft) The same could be said for boating and fishing. Aesthetically, the water in Muddy Pond is very clear, and the presence of algae is virtually non-existent, suggesting that the Pond is not at a truly eutrophic level yet. There is little or no obnoxious odour coming from the Pond. The vast array of plants and wildlife inhabiting Muddy Pond including, trout and frogs, suggest the healthy condition of the Pond (Davis, 1994).

While it is not the intention of this project (nor is it necessary for the landscape designer) to fully comprehend all the affects of different toxins on wildlife, it is important to understand that toxins do affect wildlife and wildlife habitat and that water quality management is much more than mechanical -in fact it is ecological, addresing processes both physical and biological, some of which we have not even begun to comprehend yet (Wilson, 1995). It is in hope that by presenting the above information, future readers of this project appreciate the complexity of wetland and water quality management.

Wetland Water Quantity

The water cycle is responsible for the weather patterns; the water vapour produced through evapotranspiration, is a normal part of the Earth's atmosphere, invisible and remaining in the atmosphere until it is sufficiently cooled, condensed and returned to the Earth as precipitation. As the precipitation falls to Earth it takes different routes, some being intercepted by vegetation and some falling directly into the oceans. That which reaches the water table is known as recharge (Price, 1985) because it adds to the ground water. Only a small portion of the water taken up by the roots of plants is utilized in the growth process while the majority of it is evaporated (or transpired) through the leaves and stems of the plants. The combined effect of evaporation from open water and transpiration from vegetation in returning water to the atmosphere is commonly termed evapotranspiration. The role in which plants play (especially at the forest scale) in the hydrological cycle is crucial to our existence. Not only do they aid in returning water back to the atmosphere, but they also clean the water, retaining pollutants and bio-organics within their tissues. They are in fact "the lungs of the Earth".

Wetlands occupy an estimated 6 per cent of the world's land surface (Hook, *et al.*, 1988). Wetland development is influenced by numerous factors, especially climate. Climate determines the amount of water that different areas receive, while solar radiation influences the amount of evapotranspiration to occur, hence the amount of water remaining on the ground (National Wetland Working Group, 1988 (hereinafter referred to as NWWG, 1988)). Other factors influencing the development of a wetland are depicted in Fig (11.) and are all influenced by changing climate.

Interior Climatic Conditions

The climatic conditions in the Waverley area are typical of that which is found in the Atlantic Interior Region of Nova Scotia, as described in the *Natural History of Nova Scotia* (Appendix (5.)). Precipitation, in Nova Scotia, is influenced by the distance from the Atlantic Ocean and mean total annual precipitation ranges fall between 1200 and 1600mm (48 and 64 inches) (Simmons, *et al.*, 1984). Being inland and therefore sheltered from the coast, snowfall amounts, which make up only about 15% of Nova Scotia's total annual precipitation (Environment Canada, 1995), also vary with a mean total snowfall ranging from 152 cm to 250 cm (60 to 100 inches) or more further inland (Simmons, *et al.*, 1984). The Inland mean temperatures for January are between minus 4 and minus 6C, with the most significant aspect of winter being the marked day-to-day variation caused by the alternation of Arctic and Maritime air (Environment Canada, 1995). Interior summer temperatures reach around 25C.

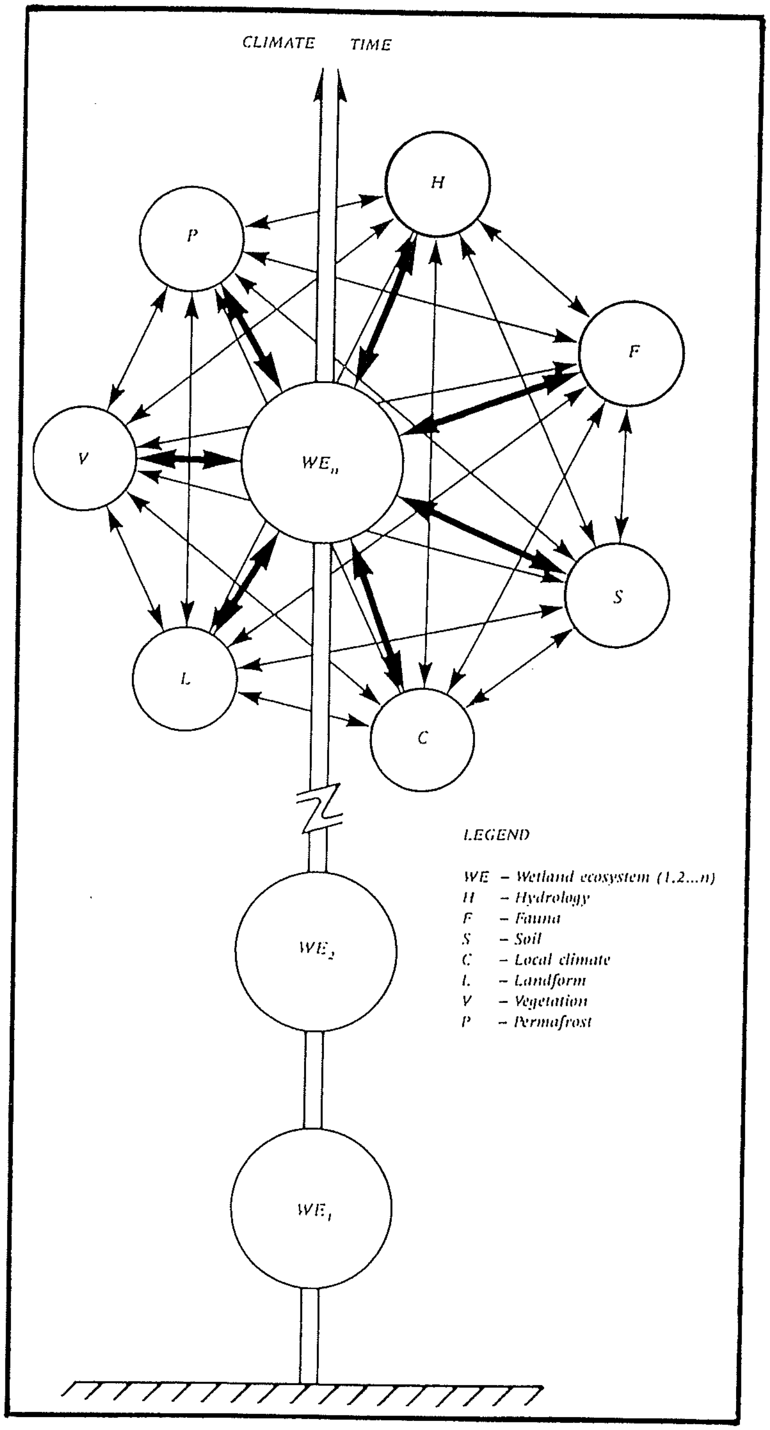


Fig.(11.) Diagram of interactions between environmental parameters and wetland ecosystems through time and changing climate (NWWG,1988).

Muddy Pond Water Quantity Analysis

During 1983-1984 the height of the water in Campbell's Brook was monitored by the Department of Environment, using a height gauge, as part of a larger study on the Shubenacadie Lakes. The average height of water in the brook between January 1983 and March 1984 are compiled from Kay (1984) and presented in Table (5.).

Table (5.) Average Gauge Height of Outflow in Campbell's Brook between February 1983 and March 1984 in metres.

Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec,	Jan.	Feb.	Mar.
0.219	0.377	0.375	0.197	0.217	0.126	0.163	0.196	0.188	0.311	0.335	0.339	0.352	0.371

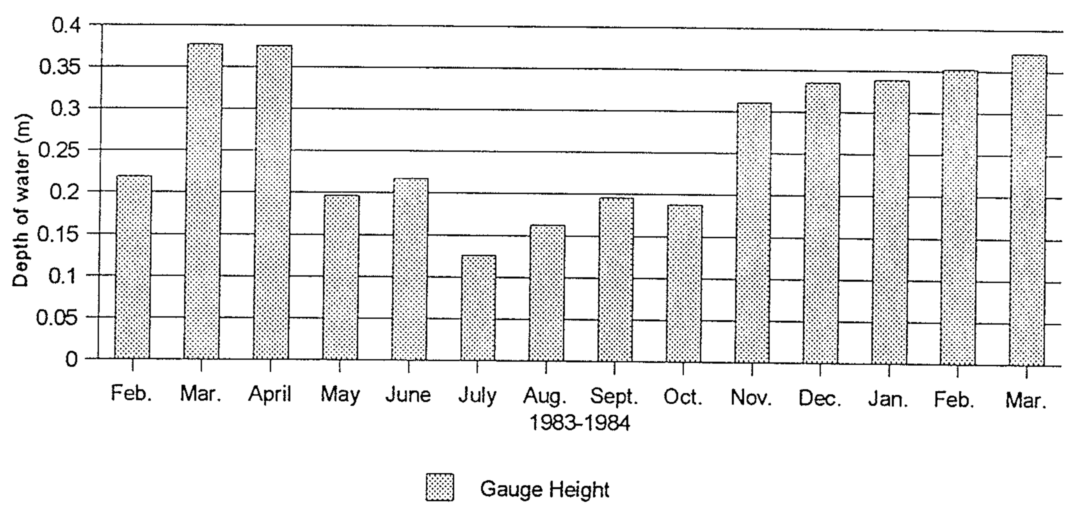


Figure (12.) Average Height of Water in Campbell's Brook between February 1983 and March 1984.

Figure (12.) illustrates that the water level in Campbell's Brook dropped from its highest level of 0.377m in March of 1983 to its lowest level of 0.126m in July 1983.

Visual reconnaissance during the summer of 1994 showed the water level in Muddy Pond to drop about 1m (about three feet). This fluctuation in Muddy Pond's water level is typical and a common annual occurrence (Blois, 1994), and in summer 1994, the water level dropped low enough to have water lilies (common to the pond) lying on the bottom of the pond -a pond characteristic known as draw-down (NWWG, 1988). Gilman, (1994) states that wetlands showing relatively high and constant water levels in winter and spring, followed by a decline in early summer, with a rise again in the autumn suggest that the wetland may be ground water fed. This would appear to be the case during the summer of 1983, according to the variation in the amount of discharge from Campbell's Brook.

Water temperature and depth to bottom were recorded on September 2, 1994 for Muddy Pond and are presented in Appendix (2.). While the average water temperature was 20.3C, the average depth to bottom was only 0.3m (13.3 inches) The maximum day temperature on September 2, 1994 was recorded at 19.1C (Environment Canada, 1995), while the normal for that time of year should be a maximum of 10.2C. The maximum recorded air temperature for September 1, 1994 was 14.0C while the air temperature for September 3, 1994 was 18.4 (Environment Canada, 1995). Because of the shallow water depth, the aquatic environment in Muddy Pond may be very much influenced by the local air temperature. The shallow nature of the Pond influences the temperature of the water and unlike larger and deeper lakes, there would be little to no gradient in temperature from the surface of the water to the bottom, hence, little to no mixing of the water (Amos, 1967), as is common in deeper waters.

Whether Muddy Pond is being fed exclusively by surface runoff, or supplemented by ground water intrusion is difficult to determine (Price, 1985). Theoretically, by comparing the amount of water entering and leaving the pond through the brooks and keeping in mind the loss to evaporation and transpiration, a rough determination as to whether groundwater is supplementing the quantity of water in the Pond should be possible (Marsh, 1991, Newbury and Gaboury, 1993). Appendix (3.) describes the rationale, measurement techniques and calculations used in determining the discharge from the minor watershed into Muddy Pond and from Muddy Pond to Lake Thomas. While it is difficult to measure all of the inputs and outputs from a wetland system (i.e. groundwater and evapotranspiration), Table (6.) presents the surface runoff, precipitation and channel inflow from Perry Lake and the outflow from Muddy Pond.

Table (6.) Summary of Calculations for Pond Inputs and Outputs, September, 1994.

Calculation	Q = (ft^3/sec)	cross-sec Area =(m^2)	Vt = using time trials (m^2 /sec)	v = based on gravity (m^2 /sec)	Q = based on Vt (ft^3 /sec)	Q = based on v (ft^3 /sec)	Q = (ft^3 /sec)
Runoff from Watershed	12.00						
Direct Precipitation	1.16						
Discharge from Perry Lake		5.48	0.248	0.476	48.02	92.17	
Total Inputs (Runoff + Precip. + Perry Lake Discharge)							106.09
Discharge from Campbell's Brook		9.78	0.189	0.410	65.33	141.62	
Total Outputs (Excluding Evaporation and Transpiration)							141.62

It would appear from Table (6.) that there is more water flowing from Muddy Pond than entering into it, suggesting that the wetland, in part, is being groundwater fed. The discharge from the two streams varies considerably depending on whether consideration is made for slope and channel resistance. Total Inputs entering into the Pond were calculated at 106.09 ft^3/sec., while total outputs from the pond were calculated at 141.62 ft^3/sec., even after taking into consideration the amount lost to evapotranspiration, which was not measured. With the 44 km^2 (17 square miles) of surface water in the Headwaters, Carter, *et al.* (1978) state that the average annual rate of discharge from Headwaters ranges between 141.3 ft^3/sec. to 707.4 ft^3/sec. The only numbers for discharge from the Shubenacadie River at Lake Thomas (Station No. 01DG007) were collected in January and February of 1984. The mean discharge for January and February were 235.5 ft^3/sec. and 253.9 ft^3/sec. respectively (Environment Canada, 1994). The drainage area for Lake Thomas is 130 km^2 (32123 acres) and the station would measure all waters draining into Lake Thomas, not just Muddy Pond. The drainage area for Muddy Pond is only 249$\pm$ hectares (615$\pm$ acres). Understanding the hydrology of the Park: the Pond's limnology, whether the water movement within the Pond is fast or slow, its chemical composition and productivity, helps to classify the wetland, making the ecology of the wetland more readily understood.

4

Muddy Pond: Vegetation

Freshwater macrophyte is a term, devoid of any precise taxonomic meaning but covers all the large plants visible to the naked eye, including algae, mosses and liverworts and ferns as well as the flowering plants (Jeffries and Mills, 1990). All these groups of plants grow together responding to the same environmental constraints, lending structure, architecture and fuel to the aquatic world. Mitchell (1974) groups the freshwater macrophytes into four groups: (1) those that are free floating (water soldier); (2) those which are submerged but attached (water milfoil); (3) attached with floating leaves (water lily) and (4) emergent or surface plants (cattail).

Blue-green algae, fungi, bacteria and others are often grouped apart from the macrophytes and are called, collectively, microflora (Jeffries and Mills, 1990). Grouped principally upon size, microflora consist of tiny, often single-celled organisms, many of which are far from being true flora. Divided into two main groups: the phytoplankton, normally living in the open water column, and the periphyton, living attached to a substrate, the productivity of the microflora is vital to sustaining life and moulding the overall form of the freshwater (Jeffries and Mills, 1990).

While it is not the intention here to provide a detailed analysis of all of the species which make up the aquatic world of Muddy Pond, this section will address the overall structure and functional roles of the wetland from the perspective of the macrophyte.

Pond Structure

While the vegetation of Muddy Pond can be described in reference to it's vertical and horizontal structure (Forman and Godron, 1986; Simmons, *et al.*, 1984; NWWG, 1988) it is enough to say here, that, although the vertical structure of the Pond is considerably less than that of the Park's forest, the horizontal structure is very pronounced. In ponds and other aquatic environments the structure is perhaps best expressed in what is referred to as the zonation of the pond. Ideally comprised of linear concentric rings of vegetation, the horizontal structure is based, primarily on the amount of water and oxygen in the soils (NWWG, 1988), although animal activity can influence structure too. Adaption of different life forms to different depths of water often results in a clearly marked zonation of aquatic vegetation from shore to deep water. A typical zonation pattern from the shore outward into the pond would include emergents nearest the shore, rooted with floating leaves a little further out, followed, still, by free floating and/ or submerged macrophytes nearing the deeper waters and finally, if not already covered over, open water at the pond's deepest. A vast number of factors, including succession, anthropogenic disturbances from dumping wastes and disturbance by animals such as beaver and muskrat, can alter the zonation of a pond making it more difficult to interpret (NWWG, 1988).

Zonation and Succession Patterns

As already mentioned zonation depends on water depth and the condition of the substrate. As organic matter accumulates and water depth decreases a temporal succession of plants will occur (Mitchell, 1974).

Succession varies from basin to basin and is influenced by depth of water, which in turn, regulates the amount of light penetrating the water column for photosynthesis. Water depth also regulates water temperature and hence stratification in deeper waters where the lower strata are often cooler than the surface waters. Jeffries and Mills (1990) state that, of the many measures of the depth of individual species or communities, two general trends emerge. First, angiosperms rarely descend to more than 9-11 m (30-36 ft) while algae and bryophytes are known to exist much deeper. Secondly, despite known depth tolerances of angiosperms, many species seldom occur in zones neatly explained by light alone. Jeffries and Mills (1990) suggest that other factors appear to limit distributions, within the overall light tolerance bands. They suggest such factors as acidification and changes in pressure and sharp thermoclines also govern plant distribution. Other factors such as basin slope, erosion, sedimentation and exposure of shoreline to wind and wave action also influence zonation patterns. Mitchell (1974) states that the zonation found in a large lake, exposed to wind and wave action, will be quite different than that of a small sheltered pond. Likewise, zonation in turbid water is likely to be different from that of a clear water. The plant life found in a fast flowing stream, influenced by the rate of flow, turbulence and the nature of the substrate, will differ from that of a slow meandering stream. Jeffries and Mills (1990) point out that the larger emergents, such as *Typha* and *Phragmities* are more resistant to such factors than are smaller macrophytes, including the water lilies. In summarizing what influences pond succession patterns Jeffries and Mills (1990) state the following:

> "As a general rule limitation of light and pressure form the extreme boundaries to species and community patterns. Erosion/sedimentation/exposure dominate where light and pressure are adequate. On substrate of equal exposure the precise composition, heterogeneity and nutrient content become important. Across all this hierarchy competitive interactions may resolve the final dominance."

Vegetation and the Functioning of the Wetland

Species composition within each zone is influenced by many environmental conditions and the ecological responses of those plants concerned. Aquatic plants, like their terrestrial counterparts, not only are influenced by their environment (such things as nutrient availability, light, temperature, pH and substrate), but also influence the environment in which they live. Macrophytes provide food and shelter from the hot sun and wind and a place to hide from predators to the many other organisms within the wetland ecosystem. While such factors as industrial toxins and excessive amounts of nutrients can have a detrimental impact on plant life, plant life, in turn, can also modify them (Mitchell, 1974; Laksmann 1977; Reddy and Smith, 1987; Cooper and Findlater, 1990; Knight and Pries, 1994). While Phosphorous is believed to increases the rate of eutrophication (a naturally occurring process in wetlands) (Marsh, 1991) the wetland macrophytes are capable of extracting the phosphorous from the wastewater and retaining it within the wetland system (Marsh, 1991). Not independent of its surroundings, a pond ecosystem may consist of plants and animals living in an aquatic environment provided by the pond and made up of its numerous physical and chemical parameters. Vegetation affects, and is affected by animal populations, both in turn influencing and being influenced by different environmental factors (Mitchell, 1974). While all these factors modify the composition of plant communities, they in turn are modified, bringing about a situation in which "the environment is almost as much a part of the community as the community is of the environment (Westlake, 1959, in Mitchell, 1974).

5

Conclusion: Classifying Muddy Pond

Where and when Muddy Pond received it's name is unknown, but it has always been perceived by the residents of Waverley as just that -a muddy, polluted pond of no value, with its only claim to fame being that of the site of the first gold find in Waverley and never seen as much else (Blois, 1994). The Pond is actually a very complex and dynamic system that acts as a bridge between the land and the water. Being dynamic and ever changing, it becomes difficult to neatly place the Pond into a specific wetland category. Muddy Pond is composed of a shallow open body of very slightly acidic water, with thick stands of cattails around the edge and with a Sphagnum mosses-larch-black spruce type bog at its north end. Water moves into this system from Perry Lake and out of this system via Campbell's Brook, making the pond more like a fen than a bog or pond. Wetlands are classified for management and conservation purposes and a number of classification systems are available. Three such systems are discussed here.

1) The Golet System of Wetland Classification

The Nova Scotia Department of Natural Resources, in conjunction with the Canadian Wildlife Service have conducted an extensive wetlands inventory classifying all wetlands 0.25 hectares or greater. The wetlands have been classified according to the dominant vegetative type and depth and permanence of surface water and are scored based on their wildlife value. This classification system was done by Golet, in 1973 (in Simmons, *et al.*, 1994) and included eight wetland categories: bog, shrub swamp, wooded swamp, deep marsh, shallow marsh, meadows, seasonally flooded flats and open water. Those wetlands scoring 65.0 or higher were identified in the Important Freshwater Wetlands and Coastal Wildlife Habitats Atlas (N.S. Dept. of Natural Resources, 1991, in Simmons, *et al.*, 1994). Under the Golet system, Muddy Pond was classified as # 92-1 Bog -Deep Marsh with a rating 66.5 (Important Freshwater Wetlands and Coastal Wildlife Habitats, 1988).

2) The Canadian Wetlands Classification System

The Canadian Wetlands Classification System (1988) represents a synthesis at the national level of several classification systems and is based on ecological factors. There are five basic classes identified under this system, those being: bog, fen, swamp, marsh and shallow open water. The National Wetlands Working Group (NWWG) (1988) identifies five wetland regions, including 10 wetland subregions for Atlantic Canada. Most of Nova Scotia, including the study site, lies within the Acadian Atlantic Boreal subregion of the Atlantic Boreal Wetland. The characteristics of the subregion include:

> "dommed bogs 5- 8 m (16- 26 ft.) deep and black spruce, tamarack and red maple-dominated basin swamps are common. Salt marshes occur in the Bay of Fundy. Fens are rare."

The Atlantic Boreal Region

The Atlantic Boreal region is described as having a "Maritime climate with cold winters, cool summers, and frequent fog. Precipitation varies from 950 - 1500 mm (37-58 inches) annually." Although Nova Scotia is spotted with many lakes, ponds and wetlands, only three percent of the land area of the province is considered wetland, while Manitoba has 41% wetland (NWWG, 1988).

In Atlantic Canada bogs and fens both form by the annual growth and accumulation of vegetation on poorly drained soils. **Bogs** are nutrient-poor (ombrotrophic), receiving their nutrition solely from atmospheric sources, like precipitation. **Fens,** which also receive nutrition from the atmosphere, receive additional nutrients from seepage waters from upland soils and are considered "minerotrophic" (NWWG, 1988). Bogs are predominantly vegetated by Sphagnum mosses, dwarf shrubs and lichens, while fens consist mainly of sedges and grasses.

Table (7.) illustrates the differences in the chemical properties of waters from North American bogs, fens and swamps and compares them with that found in Muddy Pond.

The National Wetlands Working Group defines **marshes** as:

"wetlands that are periodically inundated with standing or slowly moving waters; rich in nutrients; subject to a gravitational water table but maintaining water in the rooting zone of its plants; waters are usually circumneutral to slightly alkaline; with a relatively high oxygen saturation; characterized by an emergent vegetation of reeds, rushes or sedges; often a high fluctuation in water level, with declining levels exposing drawdown zones or matted vegetation or mudflats; and vegetation showing a distinct zonation according to water depth, drawdown frequency and salinity."

and **Shallow open waters** are defined as:

"relatively small, non-fluvial bodies of standing water representing a transitional stage between lakes and marshes; the surface waters impart an open aspect, free of emergent vegetation, but floating, rooted, aquatic macrophytes may be present; water depth is usually less than 2 metres (6.5 ft.) at midsummer."

Weller (1994) defines a **fen** as "a unique and localized sedge-moss wetland produced where slightly alkaline water emerges at the surface. Bogs have similar types of vegetation but tend to be acid." Weller (1994) further defines a **marsh** as "a community of water-tolerant, soft-bodied emergent plants and associated animals usually found in a basin of shallow water, or on saturated soils fed by underground water sources."

Freshwater marshes make up about 30% of the wetlands in Nova Scotia and are found where sufficient nutrient-rich sediments have accumulated (Weller, 1981, in NWWG, 1988).

Table (7.)

Comparison of chemical properties of waters from North American Wetlands* and Muddy Pond

Wetland Class	No. of samples	pH	Conductivity us/cm	Exchangeable cations	
				Calcium mg/l	Magnesium mg/l
Bog	18 13 10	4.0 (3.7-4.4) (4.6-5.1) (3.8-4.4)	----- (35-62) 31	2.3 (1.2-3.7) (0.2-0.8) 0.2	0.4 (0.2-0.9) (0.1-0.2) 0.1
Fen (poor)	193 14 1	(4.6-5.2) (4.7-5.5) 5.0	(18-59 49 -----	(0.4-4.8) 0.3 2.4	(0.1-0.7) 0.2 0.4
Fen (moderately poor)	42	5.2	65	1.1	0.2
Fen (intermediate to rich)	9 21 5	7.2 (6.8-7.9) 6.1 (5.2-6.9) 6.5 (5.4-7.1)	281 (140-456) 59 (33-128) -----	28 (18-37) 10 (4-18) 43 (7-124)	11 (4-28) ----- 10 (2-15)
Swamp (coniferous treed)	12	7.2 (6.9-7.8)	-----	40 (22-52	12 (8-17)
Muddy Pond	19 2	6.67 (5.9-7.1) -----	237.4 (187.2-530.4) -----	----- 9.38	----- 1.41

* From National Wetlands Working Group, 1988

The NWWG (1988) have identified three types of freshwater marshes in Canada: (1) Catchment basins (terminal basin form), (2) Fluvial marshes (floodplain, stream, channel and active delta forms), and (3) Lentic marshes (shore form). Catchment basins are "usually well defined; fringed with robust emergent vegetation; water is less than 1 metre and is supplied by snowmelt, runoff, small brooks and ground water seepage; the bottom soils are mucky and organic, suitable for supporting submergent and floating aquatic plants." Fluvial marshes are "usually associated with deltas and flood ways, subject to flooding and silt deposition and supports a diversity of rushes, sedges and grasses." Shore marshes are marginal basins formed by wind, wave and ice action depositing sand, gravel and soil along lake shores. Water moving through the watershed becomes entrapped and nutrients are supplied from the lake.

Hammer (1992) states that **bogs** are dependent upon stable water levels and are characterized by acidic, low-nutrient water and acid-tolerant mosses, while fens have more neutral waters and are dominated by sedges. Hammer (1992) describes freshwater marshes as being dominated by herbaceous plants. With submerged and floating plants often present, it is the emergent plants which distinguish freshwater marshes from other aquatic environments.

It is difficult to place Muddy Pond into any one of the many wetland categories developed by the National Wetlands Working Group (1988). By understanding the formation of the Chain Lakes, into which Muddy Pond drains, it might be reasonable to interpret that Muddy Pond was at one time part of Lake Thomas (Davis, 1994; Tyler, 1994) (Appendix (4.) *Shubenacadie Headwaters*). As it is with all lakes and ponds (with the exception of those artificially cleaned and maintained), which are slowly but continuously evolving through a filling-in process, moving toward their own extinction (Riemer, 1984), Muddy Pond could be a part of the bigger lake basin that is gradually filling in.

3) Landscape Context Classification System

A third classification system, focused on wetland classification in Nova Scotia assesses wetlands based on their landscape context: "A landscape Approach to the Interpretation, Evaluation and Management of Wetlands" (Manuel, 1992). While this system is based on peatlands, it divides the province into 14 wetland regions (6 of which have been further subdivided) with the dominating wetland type characterizing the region. Changes in the amount of landscape covered by wetlands and major differences in the geology delineate the subregions.

Classifying Muddy Pond

Muddy Pond appears to have characteristics of all three wetland types: bog, fen and freshwater marsh. Davis (1994) described Muddy Pond as a fen, rather than a Pond or bog, having both inflowing and out flowing water points. However, the main part of the wetland is closer to a marsh with clear linear and concentric vegetative patterns and robust emergent macrophytes. Adjacent to the marsh is a bog of about equal size, although no attempt to distinguish the type of bog was made because of the diverse array of Sphagnum mosses used to categories them. The bog-like area is dominated with larch and black spruce. Fresh water moves through the bog into the marsh. This fen-like attribute makes the bog no longer a bog by definition. Bogs typically only receive atmospheric water inputs and not inputs from streams. While there is little literature on water output from the marsh, other than evapotranspiration, the literature does state that marsh wetlands will eventually evolve into a wet forest. Muddy Pond has water leaving the marsh area through Campbell's Brook. This attribute alone seems to separate it from much of the discussions about bogs in their true sense. And while there is no question that Muddy Pond is a complex wetland, with several components and many complicated but valuable processes occurring, that may be all that is necessary to understand the important role that wetlands have to play in the greater landscape.

Appendix Two: Sample Collection Procedures and Detailed Water Quality Analysis for Muddy Pond.

Soil Sampling Procedures

Soil samples were collected by using a spade and digging down about 8 to 15 cm (3 to 6 inches). Soil removed from the hole at this depth was placed in a bucket and mixed with other soil samples in the same area to get a more uniform soil representation of the area. There were from 5 to 9 holes dug in each area (with the exception of Muddy Pond). Collecting soil samples (or 'muck') from the bottom of Muddy Pond was difficult using the spade, under water. The sample # 2. would represent the muck like sediment on the bottom of the Pond and not necessarily 8 to 15 cm down. The final mixed sample of about 500 ml (2 cups) was bagged in zip-locked bags and labelled. Samples were refrigerated overnight and delivered to the Provincial Agricultural and Marketing Lab in Truro, Nova Scotia for analysis.

Sample #1 was collected from soils along the edge of the access road; Sample # 2. was collected from the edge of Muddy Pond. The soil was completely submerged at time of collection; Sample # 3. was collected from silt deposited from erosion runoff from the cleared area directly adjacent to Muddy Pond.

Water Sampling Procedures

Water samples were collected on two different dates, September 2, 1994 and September 16, 1994. The first set of water samples required placing a rowboat into the

Pond itself, while the second set of samples were collected from the edge of the Pond or stream. All samples were collected in plastic water sampling bottles, previously prepared for sampling.

All samples taken, probably do not follow proper sampling methods, but samples were collected with care only to collect water and not bottom sediment. Samples collected from the boat were done by leaning over the front of the boat and placing the bottle into the water, rinsing it and then reaching down into the water up to the elbow. Where water depths were too shallow, samples were taken as close to the bottom as possible without collecting sediment. The samples were taken from the front of the boat, so as not to disturb the bottom of the pond before sampling. All samples were marked and refrigerated until analysis was conducted (two to three days later). Laboratory analysis of the first set of samples (Table (1.)) were performed at 20 degrees C.

Detailed Water Quality Analysis

While the nineteen water samples (shown in Table (1.)) were collected between 11:45 am and 2:20 pm, perhaps the hottest part of the day, results show, with the exception of samples 5, 16, 17 and 18, a sample from the bog-like area, a stream sample near the highway, a stream sample in the forested Park and a sample from Little Muddy Pond respectively, that the temperature ranged between 18 °C and 24 °C, with a mean temperature of 20.3 °C. Similarly, the depth to the bottom of the Pond ranged from 15 cm to 457 cm (6 inches to 180 inches (15 feet)) at its deepest. The deepest part of the Pond was near the centre of the most open part of the Pond (visible on the Air Photo). With the exclusion of the deep part of the Pond, the average water depth in the Pond was 34 cm (13.3 inches). The bottom of the Pond was easily visible throughout most of the Pond, with sunlight penetrating to the bottom of the pond basin. This is further illustrated in the Hazen colour units observed for the water samples. The Hazen colour units ranged from 15 to 70 with the forest stream sample #17 having a reading of 15, while sample #13 having the reading of 70. The average Hazen colour unit for all nineteen samples was 40.8. The Guidelines for Canadian Drinking Water Quality (1993) suggest an aesthetic objective of 15 TCU for colour. Conductivity readings ranged from 187.2 uS/cm to 530.4 uS/cm, with the stream sample #16, near the highway, having the highest conductivity. The average reading for the nineteen samples being 237.40 uS/cm. The pH for the nineteen samples ranged from 7.1 to 5.9, with sample #5, from the bog-like area, being the most acidic. The mean pH for the water was 6.67, within the 1993 Guidelines for Canadian Drinking Water Quality (aesthetic objective of 6.5-8.5). The range in Acidity readings went from 0.19 mg/L to 12.00 mg/L, with all but the first two readings being below 2.00 mg/L. Excluding samples #1 and #2 then, the mean acidity of the remaining samples was 1.48 mg/L. Alkalinity ranged from 7.97 mg/L to 155.87 mg/L with sample #13 being the highest reading. All the other readings were below 62.3 mg/L. Therefore excluding sample #13, the average alkalinity reading for the water was 21.30 mg/L. Testing for water hardness was done for the first nine samples only, with an average reading of 22.83 mg/L.

Table (2.) shows the results from chemical analysis performed by the Chemistry Division of the Victoria General Hospital. Although the samples were collected on September 16, 1994, they were not analysed until September 19 and might have affected results of certain tests. Results show that all tests were below the acceptable limits set out in the Canadian Drinking water Guidelines (1993), with the exception of Sample # 4. Sample # 4. had an Arsenic reading of 0.078 mg/L., while the Guidelines (1993) allow only for 0.025 mg/L. Sample # 4. was taken from Little Muddy Pond, a portion of the greater Muddy Pond wetland which is separated from the main body of water by a raised grassland. Little Muddy Pond lies directly across the access road from a large pile of tailings and old mine shafts from the past gold mining operations. It appears, from site observations that this tailings pile is the biggest and closest at about 20 metres (65 ft.)) to Muddy Pond and any leachate from the rock would flow directly into Little Muddy Pond. There is little to no through flow, or circulation in Little Muddy Pond, as there is in"big" Muddy Pond, but water from Little Muddy Pond does move into "big" Muddy Pond via a swale or ditch, which has evidently been there long before the access road was installed, due to the size and type of vegetation present. The ditch and much of the "grassland" between the two bodies of water are filled with a thick stand of cattails and when the water level in the Pond rises, the two ponds are connected again.

Table (1.) pH, Conductivity, Colour, Acidity, Hardness and Alkalinity of water samples from Muddy Pond (September 2, 1994)

Sample #	Collection Location**	Depth to Bottom (inches)	Temp. at Collection (°C)	pH	Conduc. adjusted* (uS/cm)	Colour (Hazen units)	Acidity (mg/L) $CaCO_3$	Hardness (mg/L) $CaCO_3$	Alk. (mg/L) $CaCO_3$
1	pond edge	8	20	6.4	187.2	60	12.00	21.25	12.45
2	pond	8	20	6.6	192.4	40	6.25	20.43	11.95
3	pond edge	12	18	6.65	187.2	35	1.81	20.73	13.45
4	1st. inlet+	8	18	6.2	190.32	30	1.78	19.33	9.46
5	bog++	36	15	5.9	195.52	50	1.93	19.00	10.46
6	pond	12	20	6.65	195.52	35	1.49	21.88	12.45
7	2nd. inlet	24	18	6.65	222.56	40	1.45	22.63	12.95
8	pond edge	8	21	6.8	202.8	45	1.41	43.25	12.95
9	deep pond	180	18	6.8	197.6	45	1.51	17.00	12.95
10	pond	12	20	6.5	211.12	40	1.44	-----	20.92
11	pond	7	24	6.9	211.12	40	1.51	-----	30.38
12	pond	48	18	6.65	236.08	40	1.90	-----	53.78
13@	pond edge	6	24	7.0	447.2	70	0.19	-----	155.87
14	pond	8	22	7.1	201.76	25	1.34	-----	23.90
15	outlet	-----	22	7.0	197.6	40	1.42	-----	19.40
16	highway	-----	15	7.1	530.4	40	1.56	-----	30.37
17	forest	-----	15	6.1	260.0	15	1.32	-----	7.97
18	little pond	-----	-----	6.9	242.32	50	1.60	-----	62.2
19	pond edge	12	22	6.85	201.76	35	1.46	-----	25.4
Average*		13.3	20.3	6.67	237.40	40.8	1.48	22.83	21.30

Table (1.) Continued...

Collection Location**:

pond edge = within 1 m (3 ft.) from shore;
pond = large Muddy Pond unless specified;
deep pond = deepest part of Pond;
outlet = head of Campbell's Brook, cloest to Pond;
highway = stream sample from Perry Lake outflow taken near cul-de-sac on east side of Bicentennial Highway #102;
forest = stream sample from Perry Lake outflow taken near cul-de-sac of a trail in mixed forest area

Conduc. adjusted* (uS/cm):

Conductivity meter readings for 20°C; adjusted for temperature of samples in lab(22°C) :adjustment factor was 1.04 X

1st. inlet+ = refers to mouth of inflow to pond
bog++ = refers to inflow to pond, in bog area
13@ = refers to quality of sample #13. Very oily sample taken from pond edge

Average*: See text to explain average readings

Table (2.) Chemical analysis of water samples from Muddy Pond, September 16, 1994.

Test	Sample #1. mg/L	Sample #2. mg/L	Sample #3. mg/L	Sample #4. mg/L	Sample #5. mg/L	Sample #6. mg/L
Calcium	8.99	9.78	-----	-----	-----	-----
Magnesium	1.41	1.41	-----	-----	-----	-----
Hardness	28.2	30.2	-----	-----	-----	-----
Iron	< 0.02	0.09	-----	-----	-----	-----
Manganese	0.02	0.04	-----	-----	-----	-----
Lead	< 0.002	0.004	-----	-----	-----	-----
Copper	< 0.01	< 0.01	-----	-----	-----	-----
Zinc	< 0.01	< 0.01	-----	-----	-----	-----
Aluminum	< 0.10	< 0.10	-----	-----	-----	-----
Boron	< 0.10	< 0.10	-----	-----	-----	-----
Barium	0.042	0.012	-----	-----	-----	-----
Beryllium	< 0.005	< 0.005	-----	-----	-----	-----
Chromium	< 0.02	< 0.02	-----	-----	-----	-----
Cobalt	< 0.05	< 0.05	-----	-----	-----	-----
Nickel	< 0.02	< 0.02	-----	-----	-----	-----
Antimony	< 0.05	< 0.05	-----	-----	-----	-----
Selenium, Plasma	< 0.1	< 0.1	-----	-----	-----	-----
Tin	< 0.05	< 0.05	-----	-----	-----	-----
Vanadium	< 0.01	< 0.01	-----	-----	-----	-----
Cadmium, Plasma	< 0.01	< 0.01	-----	-----	-----	-----
Total* Phosphorous	-----	-----	0.066	0.042	-----	-----
Total Nitrogen	-----	-----	0.24	0.36	-----	-----
Arsenic	< 0.002	0.015	0.014	0.078	< 0.002	0.006

Sample #1 = inflow from Perry Lake; Sample #2 = outflow from Campbell's Brook; Sample #3 = Big Muddy Pond; Sample #4 = Little Muddy Pond; Sample #5 = Bog Area; and Sample #6 = from edge of Bog Area near disturbed cleared area.
* Phosphorous = UV low range

Appendix Three: Rationale and Calculations for Stormwater Runoff:

-Determining Presence of Groundwater in Muddy Pond
-Calculations for Retention Pond Holding Capacity

Determining Presence of Groundwater in Muddy Pond

Knowing whether Muddy Pond is fed solely by surface runoff from its watershed or supplemented by groundwater intrusion is important in the management of the Pond and Park hydrology. While both surface and subsurface inflowing water contribute to the quantities of minerals, macro and micronutrients and organic matter, influencing wetland productivity, surface inflows play the main contributing role. Groundwater flows generally have small amounts of minerals with little or none of the fixed energy and nutrients brought in by surface flows (Hammer, 1992).

A simple method to determine intrusion by groundwater flow would be to calculate and compare the total water inputs with the total water outputs for the Pond. If the output, or discharge, from the pond is greater than the inflow to the Pond, then it could be speculated that water is entering the Pond from somewhere else -notedly groundwater intrusion. It should be remembered however, that correlation does not necessarily lead to causation (Mandell, 1994). Water quality analysis of the deepest part of Muddy Pond would also aid in groundwater determination.

Hammer (1992) states that while direct precipitation, surface inflows and subsurface inflows make up the total inputs, the major input to the wetland is surface runoff. Like wise, with the total outputs being surface outflows, subsurface outflows and evapotranspiration, the main output influencing the wetland system is surface outflows.

The Problem of Calculating Evaporation and Evapotranspiration

The calculation for the amount of water lost from the Pond through evaporation is too complex for this study. Evaporation is influenced by several factors including, pond surface temperature, relative humidity of the air in direct contact with the water surface, wind by removing saturated air and by creating waves, increasing water surface area, as well as the amount of algae absorbing light and converting it to heat, (Gloyna and Eckenfelder, 1968). Since few ponds lack vegetation cover to some degree, evaporation alone rarely is adequate for water loss in ponds or wetlands. Evapotranspiration is the combination of water evaporated from the surface water and the moisture that is transpired through plants to vaporize into the atmosphere, known as transpiration. Hammer (1992) states that most studies have shown that evapotranspiration rates from wetlands range from 30 to 90% of losses from unvegetated or open water areas, with an average of approximately 80% of Class A pan evaporation rates for that region. Hammer (1992) states that wetland evapotranspiration and lake evaporation are roughly equal since Class A pan evaporation is 1.4 times lake evaporation. (I do not have these pan evaporation rates for my area). To determine overall water budget for the Pond, calculations are provided for surface inflow, direct precipitation and surface outflow (discharge from Campbell's Brook). In addition the stream water discharge flowing from Lake Perry to Muddy Pond is calculated for stream discharge comparison.

INPUTS

Surface Inflow or Surface Water Runoff

Q = CiA**

Q = surface runoff from watershed (cubic feet/hr)

C = coefficient of runoff for wooded land (20% = 0.20)

i = intensity of rainfall+ (0.008 ft/hr)

A = area of watershed (615 acres = 26789400 sq ft)

*(** from Marsh, 1991)*
(+ Since stream flow measurements for Campbell's Brook were conducted in September, 1994, the average Extreme Daily Rainfall for the Halifax International Airport for the month of September (30 yr. mean) was used. The airport is about 6 miles from the site. i = 59.4 mm/day = 0.096 in/hr = 0.008 ft/hr = 2.3 in/day (average day in September).

Q = 0.20 X 0.008 ft/hr X 26789400 sq ft

Q = 42863.04 cubic feet/hr

Q = 12 cubic feet/ sec

Direct Precipitation onto Pond

Q = iA

Q = direct rainfall on Pond (cubic feet/hr)

i = intensity of rainfall (0.008 ft/hr)

A = area of Pond (12 acres = 522720 sq ft)

Q = 0.008 ft/hr X 522720 sq ft

Q = 4181.76 cubic feet/hr

Q = 1.16 ft^3/sec

Total Inputs = 12 ft^3/sec + 1.16 ft^3/sec = 13.16 ft^3/sec.

Stream Water Discharge Measurements and Calculations for Lake Perry Stream and Campbell's Brook.

On September 16, 1994, two streams were measured for rate of flow: (1) stream flowing from Lake Perry into Muddy Pond, (2) Campbell's Brook flowing from Muddy Pond into Lake Thomas. Because the measurements were done in September, the water column in both streams were typically low. Measurements were conducted for stream profile and general slope, mean cross sectional area of water column in the channel and velocity of water column for a typical section of the stream. The methodologies for each of these measurements are explained below.

Stream Profile and General Slope

A line was strung down the centre of the stream, parallel and above the section of stream to be measured. The line was levelled off using a level. Vertical distance from the line down to the stream bed and width of channel were taken every metre. Measurements were recorded in a notebook. Table (1.) presents the measurements and calculated slopes for the two stream sections.

Cross-Sectional Area of Water Column and Velocity of Water Flow in Channel

Because the level of water in the channel was very low, a one metre section of each stream was selected where flow was least obstructed by protruding cobbles and stones for the purpose of measuring velocity of flow. The one metre section was divided into 10 cm (4 inch) increments and measurements for depth of water at centre of flow and width of water's surface were recorded every 10 cm (4 inches). A small piece of Styrofoam (about 5 cm square) was floated down the section and the time to travel one metre was recorded using a stop watch. The greatest velocity in a column of water is actually at the deepest part of the channel, just below the water's surface. Newbury (1993) states that the mean velocity can be estimated by measuring the velocity with a current meter held at 0.4 times the depth. Where Styrofoam was used, because of the shallow depth of the column, Styrofoam sits on top of the water column and is easily influenced by wind. An orange sitting lower in the water column is a little more accurate if a current meter can not be sought (Newbury, 1990). Tables (2.) and (3.) present the measurements and time trials and the calculated mean cross sectional area and mean velocity for each stream.

Discharge or Rate of Flow for a Column of Water

The discharge from a stream can be calculated by multiplying the velocity of the column of water with the average cross-sectional area of that column of water. Based on time trials and velocities calculated (See Table (3.)), the discharge from the two streams can be calculated as:

Q = Vt X A

Q = discharge (m^3/s)

Vt = average velocity based on time trials (m/s)

A = average cross-sectional area of water column (m^2)

Discharge from Perry Lake

$Q = 0.248$ m/sec X 5.48 m^2

$Q = 1.36 \text{ m}^3/\text{sec}$ ($48.02 \text{ ft}^3/\text{sec}$)

Discharge from Muddy Pond

$Q = 0.189$ m/sec X 9.78 m^2

$Q = 1.85 \text{ m}^3/\text{sec}$ ($65.33 \text{ ft}^3/\text{sec}$)

Consideration for Slope and Stream Channel Resistance

Newbury and Gaboury (1993) state that average velocity and depth of water flowing through a sample reach are governed by gravity, expressed as the slope of the reach and the resistance of the stationary channel boundaries on the wetted perimeter of the flow. More precisely:

$Q = v \text{ X } A$ Where:

$v = \dfrac{R^{2/3} \text{ X } s^{1/2}}{n}$ Where:

$R = A/p$

Where:

v = average velocity (m/sec)
R = hydraulic radius of flow (m)
s = average reach slope ....(See Table 3.1)
n = Manning's roughness factor (0.6).......(See Newbury, 1993)
A = cross-sectional area of flow (m^2).......(See Table 3.2)
p = wetted perimeter of flow....................(See Table 3.2)

Discharge from Perry Lake, when considering Gravity

$Q = v X A$	Where:
$R = A/p$	$s = 0.045$
$A = 5.48\ m^2$	$n = 0.6$
$p = 3.46\ m$	
$R = 1.58\ m$	

$$v = \frac{1.58^{2/3} X 0.045^{1/2}}{0.6}$$

$$v = \frac{1.36 X 0.21}{0.6}$$

$v = 0.476$ m/sec
$Q = 0.476$ m/sec X $5.48\ m^2$
$Q = 2.61\ m^3/sec$ ($92.17\ ft^3/sec$)

The discharge, or rate of flow from the stream coming from Perry Lake into Muddy Pond, when considering gravity is $2.61\ m^3/sec$.

OUTPUT

The output from Muddy Pond when considering Gravity:

$Q = v X A$	Where:
$R = A/p$	$s = 0.022$
$A = 9.78\ m^2$	$n = 0.6$
$p = 4.64\ m$	
$R = 2.11\ m$	

$$v = \frac{2.11^{2/3} X 0.022^{1/2}}{0.6}$$

$$v = \frac{1.64 X 0.15}{0.6}$$

$v = 0.410$ m/sec
$Q = 0.410$ m/sec X $9.78\ m^2$
$Q = 4.01\ m^3/sec$ ($141.62\ ft^3/sec$)

The discharge, or rate of flow from Muddy Pond, when considering gravity is $4.01\ m^3/sec$.

Table (1.) Measurements of Stream Channel Sections for Slope

INFLOWING WATER: Perry Lake Stream Section			OUTFLOWING WATER Campbell's Brook Section		
Station (m)	Depth to bottom of Channel (m)	Width of Channel (m)	Station (m)	Depth to bottom of Channel (m)	Width of Channel (m)
0	0.92	2.65	0	0.30	1.76
1	1.18	2.90	1	0.38	1.80
2	1.32	3.00	2	0.52	1.96
3	1.08	2.00	3	0.58	2.50
4	1.14	1.75	4	0.58	2.00
5	1.10	1.81	5	0.56	2.50
6	1.19	1.64	6	0.44	2.00
7	1.22	1.88	7	0.44	1.56
8	1.40	1.90	8	0.46	1.91
9	1.40	1.80	9	0.46	2.00
10	1.45	2.40	10	0.38	2.00
11	1.32	1.83	11	0.35	2.50
12	1.39	1.78	12	0.32	2.50
13	1.55	2.00	13	0.44	3.00
14	1.68	2.40	14	0.42	1.50
15	1.61	2.20	15	0.62	2.00
16	1.61	2.00	16	0.56	0.80
			17	0.64	0.80
			18	0.68	1.10
			19	0.74	0.80
Slope = 1.68 - 0.92 = 0.76/17 = 0.0447 = 4.5%			Slope = 0.74m - 0.30 = 0.44/20 = 0.022 = 2.2%		

Table (2.) Average Cross-sectional Area of Water Column

INFLOWING WATER: Perry Lake Stream Section (one metre)				OUTFLOWING WATER: Campbell's Brook Section (one metre)			
Station (cm)	Depth of Water Column (cm)	Width of Water Column (cm)	Cross-Sectional Area (cm^2)	Station (cm)	Depth of Water Column (cm)	Width of Water Column (cm)	Cross-Sectional Area (cm^2)
0	10.4	38.10	396.24	0	6.8	142.24	967.24
1	8.2	35.56	291.60	1	6.2	152.40	944.88
2	7.6	53.34	405.38	2	6.2	165.10	1023.62
3	6.6	81.28	536.44	3	7.4	165.10	1221.74
4	6.4	111.76	715.26	4	3.2	160.02	512.06
5	7.2	83.82	603.50	5	6.6	162.56	1072.90
6	7.8	88.90	693.42	6	9.2	139.70	1285.24
7	6.4	109.22	699.00	7	8.0	137.16	1097.28
8	6.4	104.14	666.50	8	8.0	142.24	1137.92
9	6.0	96.52	579.12	9	5.4	109.22	589.78
10	8.8	50.80	447.04	10	7.6	119.38	907.28
Average Width of Water Column = 73.04 cm				Average Width of Water Column = 132.28 cm			
Wetted Perimeter =(73.04 cm x 2)+200 cm = 346.08 cm				Wetted Perimeter =(132.28 cm x 2) + 200 cm = 464.56 cm			
Average Cross-sectional Area 6033.50 cm^2 /11 = 548.5 cm^2				Average Cross-sectional Area 10759.94 cm^2 /11 = 978.18 cm^2			

Table (3.) Average Velocity of Water Column for the Two Streams

INFLOWING WATER: Perry Lake Stream Section (one metre)		OUTFLOWING WATER: Campbell's Brook Section (one metre)	
Trial	Time (sec)	Trial	Time (sec)
1	3.80	1	4.32
2	3.87	2	5.17
3	4.25	3	5.25
4	5.10	4	6.36
5	4.25	5	5.03
6	3.73	6	6.08
7	3.40	7	5.80
8	5.51	8	6.21
9	3.49	9	7.21
10	3.30	10	8.27
11	3.57	11	5.44
		12	3.79
		13	3.35
		14	3.95
		15	3.36
		16	4.21
		17	3.81
		18	4.78
		19	5.51
		20	7.61
Average Velocity = 0.248 m/sec		Average Velocity = 0.189 m/sec	

Calculations for Retention Pond Holding Capacity

Design alternative (B) for the Parking Lot requires that all surface water runoff from the parking lot as well as the roof of the Field House be captured in a retention pond. Calculations for the retention pond are for a ten-year storm, of one hour duration.

Impervious Asphalt Area	=7968 m^2
Roof Surface	=6087 m^2
Total Impervious Area	=14055 m^2
Discharge for 10 yr. Storm*	=0.368 m^3/sec
Detention Volume Required**	=140 m^3

(*) Calculation for Discharge from Impervious Area

Q= CiA

Q = surface runoff from Impervious Area (cubic feet/hr)
C = coefficient for impervious surfaces 100% = 1)
I = intensity of rainfall$^+$ (4in/hr)
A = area of Impervious Surface (3.5 acres = 14055 m^2 = 151296 sq ft)

($^+$) To determine intensity (I)
Extreme Daily Rainfall for the Halifax International Airport for the month of September (30 yr. mean) = 2.3 in/24 hrs. This measurement does not take into consideration surface friction, slope or length of travel distance from wetted perimeter to retention pond.

Tt = is the time it takes for precipitation to travel from perimeter of area to outfall point (retention pond). Tt = 5.75 minutes
Tt is determined based on Airport data and site data (slope, etc.) As 5.75 minutes.
In Nova Scotia, for 1 inch of precipitation to travel a concentration time of 5.75 minutes, intensity for a ten year storm is about 4 inches/hr or 0.33 ft/hr.

Therefore Q = CiA
= 1 x 0.33ft/hr x 151296 sq ft
= 49928 ft^3/hr
= 13.8 ft^3/sec = 0.368 m^3/sec

(**) Calculation for Detention Volume required for a Ten Year Storm

$Q_{volume} = Q \times Tt \times 60$

$= 13.8\ ft^3/sec \times 5.75\ min \times 60 sec/min$

$= 4761\ ft^3$ or about $5000\ ft^3 = 141 m^3$

$$Volume = \frac{Area_{Permanent} + Area_{Temporary}}{2} \quad X\ Depth$$

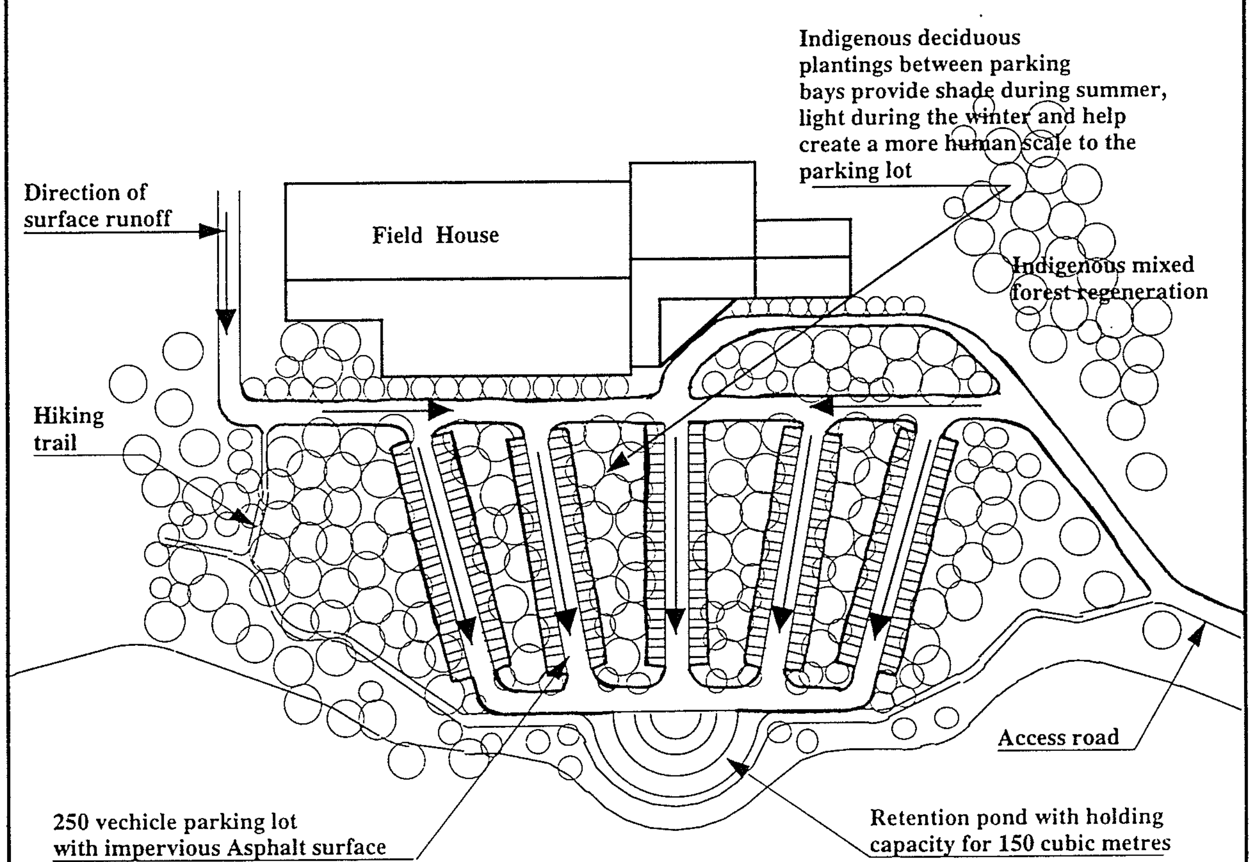
Requirements for Emergents to grow include water depths no greater than 1 metre. Side slopes of the retention pond can be no greater than 3:1, with more shallow slopes better suited for emergent vegetation and ecological processes.

Therefore to achieve a side slope of about 5:1 at a depth of 1 metre, the detention volume will cover an area of 210 m^2 at the surface.

$$150 m^3 = \frac{90\ m^2 + 210\ m^2}{2} \quad X\ 1\ m$$

To construct the circular pond calculate the radius from the area of the circle
Area of circle = πr^2
Once the radii are found for each area, they must be doubled, since the final design configuration is actually half a circle.
Figures (1.) and (2.) show the retention pond in both plan and section.

Impervious Asphalt Area = 7968 square meters
Roof Surface = 6087 square meters
Total Impervious Area = 14055 square meters (3.5 acres)
Discharge for 10 yr. storm = 0.368 cubic meters/sec.
Detention volume required = 140 cubic meters



See Fig. (2.) for Sectional view of retention pond

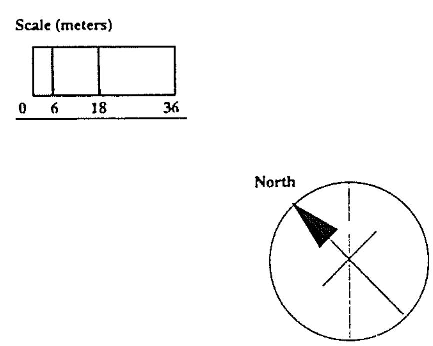
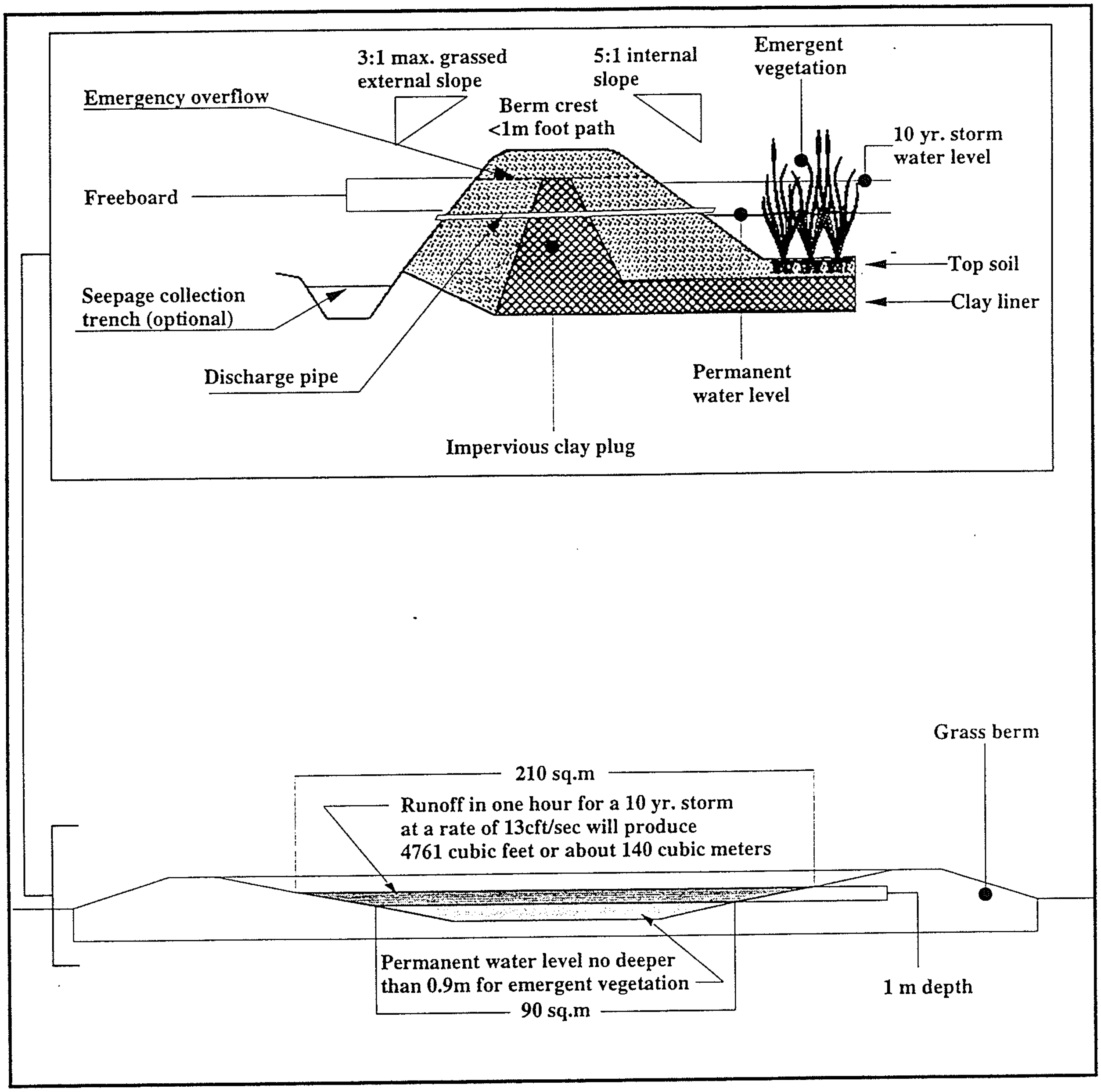


Fig.(1.) PARKING LOT DESIGN: ALTERNATIVE (B) RETENTION POND



(DRAWINGS NOT TO SCALE)

Fig. (2.) RETENTION POND HOLDING CAPACITY AND BERM DETAIL

Appendix Four: The Shubenacadie Headwaters: A look at the Quantity, Quality and Resource Use.

Surveying the Headwaters

The lakes of the Shubenacadie Headwaters area have been and continue to be surveyed for their potential as potable water resources, although the initial surveys were conducted as a result of arsenic findings in drinking water. Much of the information and issues complied by the "surveyors" is supported by each other, while specifics pertaining to water quality and quantity tend to vary between surveys. Listed below are the surveys and the people involved:

Interprovincial Engineering Limited. August, 1978. Draft report to the Shubenacadie - Stewiacke River Basin board on water supply and wastewater disposal management.

Carter, *et al.* December, 1980. Final report to the Federal Department of Environment on their recommendations for enhancement and management of the Shubenacadie - Stewiacke River Basin.

Kay, L. February, 1984. A sampling survey to the Inland Waters Directorate of Environment Canada and the Shubenacadie Lakes Study Group on water quality and quantity in the Shubenacadie headwaters.

Mudroch and Clair, 1984. A joint federal - provincial study on the impact of past gold mining activities on the Shubenacadie River headwaters ecosystem.

Scott, *et al.* April, 1991. Report to the County of Halifax Municipality on water quality in the headwaters of the Shubenacadie River system.

Keizer, *et al.* 1993. Canadian data report of fisheries and aquatic sciences # 914, by the Federal Department of Fisheries and Oceans on the *Synoptic Water Quality Survey of Halifax/Dartmouth Metro Area Lakes on April 16, 1991.*

Vaughan Engineering. May, 1993. A study to the County of Halifax Shubenacadie Lakes Planning/Pollution Control Task Force on the planning/pollution control in the Shubenacadie lakes.

The Shubenacadie-Stewiacke River Basin

The Shubenacadie-Stewiacke River Basin is the largest watershed in Nova Scotia encompassing an area of about 2800 square kilometres (1000 square miles) (Carter, *et al.*, 1981). The Basin stretches from Dartmouth in the south to Cobequid Bay in the north and from Pictou County in the east to the Rawdon Hills in the west. The River Basin flows from within five miles of the Atlantic Ocean, at the north end of the City of Dartmouth, north-west to Cobequid Bay at the head of the Bay of Fundy. The Basin can be divided into three main watersheds: the Shubenacadie Headwaters, the Shubenacadie River and the Stewiacke River (Carter, *et a.*, 1981). The Charles L. McDonald Sports Park, including Muddy Pond, lies within the Shubenacadie Headwaters. While the scope of this project is concerned only with the Headwaters area, it is important to remember that what happens in this part of the greater watershed will impact what happens further downstream.

The Shubenacadie Canal System

The Shubenacadie-Stewiacke River Basin is perhaps best known for its engineering marvel of the 1800s -the Shubenacadie Canal System. The Shubenacadie Canal System is an inland waterway made up of a series of natural lakes and rivers linked together by locks, channels and ponds. The waterway is 138 km (86 miles) long and once guided the seasonal movements of the Mik'-mak people . The canal system is the only one in Canada which joins two salt water bodies. Started in 1826 and completed in 1861, the canal was used as a shortcut in transporting goods from Halifax to Saint John, New Brunswick (The Shubenacadie Canal Commission, 1989). The Canal was used during the early part of the gold rush in Waverley as gold bearing quartzite was transported to Halifax for processing.

The Shubenacadie Headwaters

The Headwaters make up about 15 percent or 375 square kilometres (145 square miles) of the total extent of the Shubenacadie-Stewiacke River Basin. While most of the Shubenacadie-Stewiacke River Basin is dominated by rolling topography, deep soils overlying sedimentary bedrock such as sandstone, limestone and gypsum and few lakes and ponds, the headwaters of the Shubenacadie River are considerably different (Interprovincial Engineering Limited (IEL), 1978).

The Headwaters are an intricate mixture of almost 70 lakes, ponds, streams, rivers and other wetlands (Carter, *et al.*, 1981) interlaced between ridges which rise almost 122 m (400 feet) above geodetic datum (IEL,1978). There are, however, no wetland areas in the Headwaters which exceed twenty hectares (49.4 acres) in size (Carter *et al.*, 1981). Muddy Pond, in comparison is only about 10 hectares (25 acres). The quantity of surface water in the Headwaters occupies about 44 square kilometres (17 square miles) or almost twelve percent of the Headwaters area (Carter, *et al.*, 1981). Although the average annual rate of flow from the Headwaters varies from a monthly mean high of 20 m^3/sec (707.4

ft^3/sec) in April, to only 4 m^3/sec (141.3 ft^3/sec) in July, the average residence time for water in the major lakes (Loon, Charles, William, Thomas, Fletcher and Grand) is between four and five months. This period varies depending on hydrological conditions and is important because, the longer the water remains in the reservoir, the more chemicals, nutrients and sediment the reservoir will accumulate (Carter, *et. al.*,1981).

Geology and Surficial Geology of the Shubenacadie Headwaters

For the most part the Headwaters are almost completely underlain with matasedimentary or metamorphic rock of the Meguma Series of Ordovician Age (IEL,1978). The Meguma rock formation is famous for it's gold occurrences. More recently the Meguma formation has been considered as the host rock for arsenic in the Waverley area and other parts of the Province (IEL, 1978). The Meguma Series of rock, through the process of metamorphism have become highly inundated with the one time porous sandstone beds now tightly sealed.

Within this corrugated landscape of the headwaters of the Shubenacadie-Stewiacke system lies the Chain Lakes: Loon, Charles, William, Thomas, Fletcher and Grand, running east-west bisecting the area in a central valley. On each side of the chain lie other lakes and ponds, such as Muddy Pond, which drain into the central valley and there flow through Grand Lake and into Shubenacadie River, northward to the Bay of Fundy.

With slopes typically exceeding 5 to 10 percent and in excess of 20 percent along more than two thirds of the length of the lake shorelines (IEL,1978), the major surficial overburden or soil in the Headwaters consists mainly of glacial till. Overburden depths vary throughout the Headwaters from as little as five feet thick to fifteen feet thick. The tills, produced from granite and quartzite are of a consistent mixture of a wide range of particle sizes, from fine silts and clays to boulders. These tills are considered unsuitable for cultivation. Drumlins, found in the west of the Headwaters are comprised of a more sandy clay loam till derived from the softer Windsor group of rocks. The soils produced from this till are called Wolfville soils and cover more than half of the Headwaters area, mainly in the central and western sections. The Drumlins are roughly parallel to each other with their long axis pointing in a southeasterly direction -indicating the direction of glacier movement in the area. Drumlins are considered areas of groundwater recharge and are also commonly cultivated (Davis, 1994).

Other soil types found within the Headwaters area are the Halifax soils, brown sandy loam over yellowish sandy loam, with good to excess drainage, the darker brown Bridgewater soils with good drainage and the darker brown Danesville soils with imperfect drainage capability (MacDougall, *et al.* 1963).

Formation of the Chain Lakes

Normally water flows along the path of least resistance. This is true of young river beds. It would make sense then, in a corrugated landscape of hard resistant rock, heaved and twisted by the forces of the earth, that the flow of water would be parallel to the folded rock. This is not the case, however, with the Chain Lakes, leading to certain speculation as to their formation.

The Shubenacadie system runs northwest- southeast, across Nova Scotia perpendicular to the rock strata. Roland (1984) reports that there are numerous remnants of ancient erosion channels throughout the province, that drained northward off the Scotian Shelf to the Gulf of St. Lawrence over 100 million years ago. This was a period of intense erosion, but as the coastal shelf subsided to its original position, before the formation of the super continent of Pangea, the gradient of these rivers gradually decreased and the flow became sluggish. As the rivers began to back up Cretaceous clays were deposited impeding drainage and forming shallow lakes, hence the chain lakes. While most of these ancient rivers reverted there flow southward to the Atlantic Ocean as the coastal shelf subsided, the Shubenacadie continued to flow northward. Understanding the origins of the Chain Lakes may help explain the conditions of these lakes and the watershed today.

Groundwater as Well Water in the Headwaters: Quantity and Quality.

Because of the tightly sealed nature of the Meguma Series, there is little to no intergranular porosity in this bedrock, thus no aquifers commonly associated with this type of reservoir (IEL, 1978). Fractures in the bedrock, referred to as `joints' provide the only porous zones in the Meguma Group. They are typically deep within the rock, closely spaced together and produce low yields of about 4 to 40 litres per minute (1 to 10 gallons per minute) (IEL, 1978; Carter *et al.*,1981). Yield is dependent upon frequency and size of joints. Areas of intense fracturing, referred to as faults can on occasion produce yields as high as 200 litres per minute (50+ gallons per minute). In the Headwaters area there are no major faults recorded but IEL (1978) suggest that high yields from drilled wells in the area are from wells intersecting multiple minor zones of fracturing produced from the tightly folded nature of the rock.

Permeability within the surficial till overlying the Meguma Series is low due to fine silt particle size, especially in the Wolfville soils of the drumlins where clay is present. Shallow wells excavated in these tills produce around 2 to 3 gallons per minute and commonly go dry during the late summer period of low precipitation.

Groundwater quality in the Headwaters area is quite scarce and not until 1976 when concerns over arsenic in well water prompted a survey of wells in the area, was there any organized information. In 1976 the Department of Health and Environment conducted a water quality analysis and an arsenic survey which consisted of samples from existing drilled wells in various areas throughout the Headwaters. Where wells were not available, then dug well samples were used For the arsenic survey, 120 samples were collected (IEL, 1978).

Results of the 1976 water analysis showed that in general groundwater quality was fairly good within the Headwaters area. The only parameters which exceeded Canadian Drinking Water Standards (1968) were Manganese, with an average of about 0.3 parts per million and colour which on average was between 15 and 25. Canadian Drinking Water Standards for Manganese and colour are <0.01 to 0.05 and 5 to 15 respectively (IEL,1978). High colour is more likely to be found in shallow dug wells rather than drilled wells, and is usually the result of surface runoff from nearby bogs where wells are poorly constructed.

Iron bearing minerals were found to be common to the area. They can be leached out in the environment but only considered a nuisance factor because of staining.

In the 1976 analysis, the pH of the groundwater in the Headwaters area was found to be quite low due to the acidity of the bedrock and associated soils. In areas of boggy terrain, the pH can be very low. Carter, *et al.* (1981) report that iron, manganese and acidity are high in most of the groundwater and that high concentrations of arsenic have been found in localized areas. High colour has been found in some wells, particularly shallow dug wells.

Comparison of groundwater to surface water in the Headwaters area showed that groundwater colour was frequently excessive while surface water colour was rarely excessive (IEL, 1978). The 1976 study also showed the pH of many of the lakes being below the Canadian Drinking Water Standard of 6.5 (1968). Water samples from Lake

Thomas showed an excess of iron. Interprovincial Engineering Limited (1978) suggest that the best drinking water in the area would be from drilled wells into the Meguma bedrock. In the final report, by the Shubenacadie-Stewiacke River Basin Board, Carter, *et al.* (1981) report that the Headwater Lakes are typified by mild turbidity, high colour and slightly acidic conditions, but give no statistics. Carter, *et al*, (1981) also report bacteriological contamination from faecal coliform counts being observed in some of the lakes, especially during the summer, when flows are low. While these instances of contamination by microorganisms each summer may in part, be considered `natural' occurrences caused by high populations of ducks, they are also signs that the ground and surface waters of the Headwaters area, as a resource, are under growing pressures from development.

Arsenic in Well Water

Arsenic contamination in well water was first detected early in 1976. Arsenic, thought initially, only to be associated to those areas of old gold mining activities, has been found to have a wide distribution in rock areas not necessarily associated with gold mining. Old gold mining practices exposed large quantities of crushed bedrock (tailings) to the atmosphere. Oxidation of the tailings, and consequently leaching and the associated acid drainage problems which arise, have traditionally led to speculation that arsenic contamination was only associated with gold mining areas. Arsenic is found in sulphide bearing rocks throughout Atlantic Canada. In the Headwaters area, Waverley, and more specifically the study area itself, the underlying bedrock is Quartzite, of the Goldenville Formation. Quartzite is the main gold bearing formation in the province. In quartzite, arsenic occurs in the form of arsenopyrite. Arsenopyrite occurs commonly with the gold in the quartz veins, but is not limited to the gold districts.

Grantham and Jones (n.d., in IEL,1978) report the widespread occurrence of arsenic in groundwater throughout the Meguma Series in southern and eastern Nova Scotia. Grantham and Jones (n.d.,in IEL, 1978) state that arsenic is thought to move within the environment through the oxidation of sulphide minerals and subsequent production of sulphuric acid. The leaching of arsenic from exposed rock is thought to be bacteriologically stimulated. Grantham and Jones (n.d., in IEL, 1978) report four possible sources of arsenic contamination in wells: from leachate from tailings and waste rock coming into the well as either surface water or groundwater, from groundwater which has passed through an area of extensive underground workings, such as mine shafts before entering the well itself, from mineralization of primary geology as a result of oxygen being introduced during pumping of the well, and from construction of infrastructure such as highways, or even wells themselves using waste rock. In conclusion to their report on water supply and wastewater management, IEL (1978) recommended that:

> "in the Waverley area, groundwater cease to be used as a source of water for human consumption and for cooking, and that an alternative source of water be found by an immediate detailed study".

Heavy Metal Contamination of Lake-Bottom Sediment

Carter, *et al.* (1981) report that high levels of both mercury and arsenic have been detected in lake sediment from Powder Mill Lake, Lake William, Lake Thomas and Lake Fletcher. While the presence of mercury is result of old gold mining activities in the area, arsenic is believed to be associated with the sulphide bearing rocks of Atlantic Canada Carter, *et al.* (1981) report no evidence of `abnormally high levels of chemicals' in the other lakes. Sediment taken from the beach area of Powder Mill Lake and from the shores of Muddy Pond also indicate high levels of metals and arsenic (Carter, *et al.* 1981). Soil samples from Muddy Pond were collected in September 1994 for analysis

Soil disturbance associated with economic activity around the lakes in the Headwaters area are to blame for an increase in rate of sedimentation since 1960. Carter, *et al.* (1981) report that the rate of sedimentation is now over ten times as great as the average rate between 1860 and 1950.

Water Use in the Headwaters

The primary use of water in the Headwaters area is to meet the supply requirements of residential areas, commercial and to a lesser extent, light industry (Carter, *et al.* 1981). Water also plays a large part in the recreational activities of the people who reside in areas like Waverley and Fall River (Garner, 1994). Agricultural need in the Headwaters area is small in comparison to other uses, due mainly to poor terrain and soil conditions.

Rural Residential Use

With the exception of developments in those portions of Dartmouth and Sackville which fall within the Headwaters area, most of the urban land use pattern is linear, along the main roads, especially where the roads run adjacent to the shores of the lakes. Both Dartmouth and Sackville have their own water supply outside the Headwaters area. In the remainder of the Headwaters most of the water supplies comes from groundwater. There are a few small private developments, households and public institutions which collect water from a variety of surface water sources however (Carter, *et al.* 1981).

Wastewater from those areas of Dartmouth and Sackville, lying within the Headwaters area is exported out of the watershed via central sewage systems. The primary method of wastewater disposal in the rest of the Headwaters area is the septic tank. There are a few small sewage treatment plants in the area servicing institutions and subdivisions and a large treatment plant north of Waverley at the Halifax International Airport. These plants discharge into the surface waters. Carter, *et al.* (1981) report no major water management problems from disposal of solid wastes within the Headwaters area.

Recreational Use

The Chain Lakes, which bisect the Headwaters area make for great canoeing. Highly praised, these lakes attract canoe enthusiasts from all over to paddle the old Shubenacadie Canal System, built some 150 years ago. Sixty percent of the population (approximately 12000 people) considered boating and canoeing to be the most popular activities, followed by swimming and more distantly, fishing. Carter, *et al.* (1981) report that residents felt outdoor recreation to be the most important water use in the area. It is believed that with an increase in population in the surrounding Metropolitan area, there will be greater pressures placed on the Headwaters area for recreational use (Garner, 1994). The use of the Headwaters area for recreational purposes will be dependent on the amount of shoreline set aside and the effects that growth and development and sewage disposal will have on water quality.

Mining Activities

There are several mining operations within the Headwaters area. Carter, *et al.* (1981) report that the largest operation in the area is associated with the production of crushed stone. One quarry near Rocky Lake produces approximately one million tons of crushed rock and 99,000 tons of washed gravel per year. Carter, *et al.* (1981) state that reserves for this mining operation alone are sufficient to maintain the existing rate of production for the next one hundred years.

Tailings from gold mining operations have been used in construction projects, although it is now closely monitored by the provincial Department of Environment.

Water Management Issues in the Headwaters

Water resource management is concerned, not only with how we use water, and the impact which that use has on the resource, but also how we use the land resource surrounding the water. From a socioeconomic perspective problems arise in water resource management when either water quantity or quality does not meet the standards required to support human activities. Carter, *et al.* (1981) state that such problems can be generated directly by water uses themselves, or by activities related to land resource uses such as logging and construction or by natural conditions. The chain lakes are a resource for the communities of Waverley and Fall River. The main water management issues are: eutrophication; arsenic contamination of drinking water; arsenic and mercury contamination of beach sediments; acidic drainage from exposed slate bedrock; and management of the Shubenacadie Canal. These issues are as much ecological problems as they are social or economic. Activities like erosion and sedimentation and eutrophication can adversely affect the ecology of the lakes, which will in turn, affect both the social and economic qualities of the resource and the entire community.

Carter, *et al.* (1981) state that generally physical and chemical qualities of the surface waters in the Headwaters are suitable for all requirements. There are, however, some specific concerns listed below for the management of the resource:

- high bacterial counts attributed to high concentrations of swimmers, disposal of wastewater and surface runoff from urbanized areas. High bacterial counts usually result in closure of swimming areas. Treatment of wastewater before disposal can reduce contamination from microorganisms.

- high levels of arsenic contaminating domestic water supplies from groundwater sources in some areas. Levels found exceed acceptable levels set out in the Canadian Drinking Water Standards (1968) and therefore render the water supply unsuitable.

- accelerated eutrophication in the surface waters resulting from the release of phosphorous through wastewater disposal. It is both expensive and difficult to remove the high levels of phosphorous required to control eutrophication.

- high levels of suspended sediment in lake waters as a result of inadequate soil erosion control measures, usually associated with subdivision, pipeline and road development. High levels of suspended sediment affect light penetration, photosynthesis, primary production and fish habitat.

Phosphorous Loading and Wastewater Disposal in the Headwaters

Phosphorous is the main nutrient that controls the rate of eutrophication in the Headwater lakes (Carter, *et al.* 1981). Eutrophication is a natural process in lake systems and lakes are capable of assimilating phosphorous without accelerating the process. Eutrophication is greatly enhanced, however, with the discharge of wastewater. Most of the wastewater disposed in the Headwaters is through the use of septic tanks, while a few package wastewater treatment plants are used for institutions and small developments. Carter, *et al.* (1981) state that properly functioning on-site wastewater disposal systems set back 300 metres from a lake's edge will control phosphorous entering surface waters and eliminate the possibility of bacteriological contamination of water resources. This distance is dependent upon the volume of soil between the disposal system and the lake's edge and is not always adequate in the headwaters area.

Carter, *et al.* (1981) report that, package wastewater treatment plants operating properly do not remove phosphorous. While larger municipal wastewater treatment plants can remove about ninety percent of the phosphorous load in advanced tertiary treatment, they are considered one of the most serious threats to the trophic status of the lakes. Because larger treatment plants service greater areas they also discharge greater amounts of phosphorous into the water than would similar sized areas using on site septic systems. Carter, *et al.* (1981) point out that standard advanced tertiary treatment plants generally cannot remove as much phosphorous as soil. The removal of phosphorous from wastewater is as much a financial issue as a health issue for the communities involved.

Appendix Five: The Lay of the Land: A description of the landscape of the Atlantic Interior Region of Nova Scotia, based on the Natural History of Nova Scotia.

The Text

The *Natural History of Nova Scotia* was written in 1984 under the direction of Derek Davis, Curator of Natural History for the Museum of Nova Scotia (now called the Nova Scotia Museum of Natural History). The text, in two volumes, describes the various topics and habitats found within the province and divides the Province into nine theme regions based upon regional climates and regional geology. This is unlike the early Biophysical Land Classification System, first proposed by Lacate in the sixties (Simmons, *et al.*, 1984), whose Land Regions were based on regional climate as expressed through regional vegetation.

Each of the nine Theme Regions are subdivided into Districts defined by , "a distinctive landscape pattern." This pattern may be a reflection of the geology, surficial materials, soils, hydrology, relief or vegetation, but with only one being the dominant element used as the defining characteristic. The third and smallest geographical division in the *Natural History of Nova Scotia* is the Unit. Units are generally fairly homogenous areas within Districts, reflecting recurring patterns in landform, soils or vegetation. The *Natural History of Nova Scotia* describes the study site as lying within the Quartzite Barrens District of the Atlantic Interior Region, more readily referred to as 413(a).

400-The Atlantic Interior Region

The Atlantic Interior Region is divided into six Districts based on morphology, surficial deposits and vegetation characteristics. The study site falls within the first of these districts, 410-Quartzite Plains, while the other districts are 420-Slopes and Ridges, 430-Drumlins, 440-Granite Barrens, 450-Granite and 460-Bays. The Quartzite Plains District will be discussed following a description of the Atlantic Interior Region.

The Atlantic Interior Region covers close to half of the Province and is characteristic as being inland from the coastal forest, with slightly warmer summers and cooler winters with less wind exposure. The planed surface of the old hard rock carries some of the Provinces longest river systems southeastwardly. The many lakes in this region are the result of glacial action, while the vegetation varies from mature spruce-hemlock-pine forests, associated with the drumlins to heath vegetation on the granite barrens.

The Geology of the Region

Within the Atlantic Interior there are three main groups of rocks: the Meguma Group which is widely exposed across the region, the White Rock Formation which is most prevalent in the southern Yarmouth area and not discussed here and the Granite which stretches in a huge arc from Yarmouth to the Annapolis Valley and around to Halifax.

Meguma Group

The Meguma Group of rocks are Cambrian to Silurian in age and are divided into two units: the Goldenville Formation made up of greywacke (a quartz-rich rock containing some clay) and the Halifax Formation made up of slates. The strata are widely exposed across the region and were deposited in an offshore basin where conditions were consistent over a long period of time producing a highly uniform texture and colour throughout the region. The total thickness of the Meguma Group is unknown due to the constant erosion of its top, while its base cannot be seen. Various sections throughout the region have been measured and suggest that the Meguma varies in thickness from as little as 1000 meters to 6000 meters. The Quartzite Formation consists of a series of sedimentary strata which were mainly quartz-feldspar sandstones metamorphosed to quartzite or greywacke (Interprovincial Engineering Limited (IEL) 1978).

The Granite Group

The Granite Group is actually comprised of a variety of rocks types, but all of which share the characteristically large greyish or pink crystals of potash feldspar in a matrix of smaller crystals comprised mainly of quartz and mica. The granite was formed during the later stages of the Acadian Orogeny, when hot molten rock or magma rose and penetrated the overlying Meguma strata. The heat given off the from intrusion and subsequent cooling of the magma baked the surrounding meguma rock creating a narrow contact aureole between the two groups.

The Topography of the Atlantic Interior Region

Following the Acadian Orogeny and granite intrusion a period of rapid erosion carried away several miles thickness of material, exposing large areas of granite which now form domes or high rounded hills throughout the region. The overlying folded greywacke and slates were eroded and now exist mainly around the edges of the more resistant granite cupolas and domes. Although the region is considered relatively uniform in elevation there is some distinction between the eastern and western portions. Where the southwestern part of the region has not been influenced by faults, the area east of Halifax has. Innumerable faults and intensely folded strata riddle the Meguma here creating an intricate coastline with some of the best natural harbours in the world, penetrating inland as much as 24 km (15 miles). Here, also, the river valleys run deep below the surface, while the upland surface above the rivers maintain a uniform height. In the southwest there is little relief with the land relatively flat over large areas.

The entire region slopes southeastwardly toward the Atlantic Ocean, with some variation again between east and west. The highest elevations can be found near the northern border of the Atlantic Interior where several granite knolls over 275m (900 feet) mark the divide between streams draining north and those flowing south.

Most of the Interior is covered by the massive, resistant granite rock. It is the granite which produces the highest elevations forming low rolling hills and irregular ridges some 20m (65 feet) above sea level generally. The low lying areas are too irregular to be valley-like. Drainage is poor in the granite with sluggish streams and rivers meandering aimlessly over the landscape from one shallow lake to the next.

In the eastern portion of the Interior the greywacke can be seen lying in long, low ridges running east and west. Large angular blocks of greywacke cover the ground and the soil is acid. The low lying areas between the ridges are swampy and have their long axes oriented parallel to the strike of the strata. Drainage is typically impeded by glacial deposits while river channels are shallow because they run perpendicular to and cut across the resistant folded strata. Waterfalls and rapids are common in the southwestern portion of the Interior where streams tend to cut across bands of harder rock.

Climate

The climate of the Atlantic Interior is basically that of an inland lowland regime, sheltered from the marine influences which coastal shorelines would experience. The regime is characterised by cold winters and warm summers, with temperature and precipitation being influenced by the distance from the Atlantic coast and by the degree of latitude north.

The mean annual temperature range varies from 19 C (34 F) in the southwest to 23 C (42 F) and higher in the more inland areas. The January mean temperature for most of the region is below-5 C (23 F) with more mild conditions near the coast. By the end of March the temperatures are beginning to rise above freezing, with the Interior warmed up to a mean temperature in excess of 17.5 C (63.5 F) in July. The Atlantic Interior begins receiving freezing temperatures again around the second week in December.

While the mean total annual precipitation ranges between 1200 and 1600mm (48 and 64 inches) the mean total snowfall ranges from 150cm (60 inches) near the coast to 250cm (100 inches) or more further inland. Snow cover varies with about 110 days in the south to over 130 days further north. Overall, the drier areas are found near the southwestern tip of the Province and further inland.

The frostfree period varies from less than 100 days in the interior to over 140 days in the southwest, with the southern portion of the Interior having the greatest number of accumulated growing degrees days (Simmons, *et al.*,1984).

Soils

The resistant granite and quartzite bedrock and the undulating and poorly drained terrain of the Atlantic Interior are the key factors affecting soil development in this region. There is a thin boulderly till covering most of the region due to strong glacial scouring and transportation. Covering the rocky till are areas of humo-ferric podzols, gleysols, rockland and peat, the podzols being predominant. While the granictic areas can be associated with more coarse boulderly sandy loams, quartzite areas are associated with a more fine textured stony, sandy loam. Where soils developed from slates allow for vigorous vegetative growth to occur, this is not the case with soils from quartzite. The soils in this region are generally very permeable, strongly leached and highly acid. Drainage in this region is not impeded by the soils but rather the underlying bedrock. The soils formed in the drumlin fields, an important feature of the region, are often deeper and better drained, finer textured and more fertile than those not associated with drumlins.

Vegetation and Habitat

The Atlantic Interior falls within three of the zones that O. L. Loucks identified in 1961 in his book *A Forest Classification for the Maritime Provinces.* With the largest area being covered predominantly by the Red Spruce- Hemlock-Pine zone, the rest of the region falls within the Sugar Maple-Hemlock-Pine zone or the Sugar Maple-Yellow Birch-Fir zone (Simmons, *et al.*,1984). Vegetation in this region is influenced mainly by warmer inland climate, sandy acid soils and mixed drainage conditions. Disturbances by fire and logging, common throughout the region also influence vegetation patterns.

In the southern portion of the region (west of Halifax) slightly higher temperatures and better drainage provide for Red Spruce and Hemlock to be found in association with Red Oak and White Pine. Balsam Fir and Red Maple are common on once disturbed sites, with Balsam Fir being the prime candidate for the Christmas tree industry in Nova Scotia. Beech has been reduced to only the drier ridges, while Ash is found on seepage slopes, especially associated with drumlins. Bogs and Swamps are very common in this part of the region.

The northern half of the region (east of Halifax) Red Spruce and Hemlock are found with Black Spruce and Balsam Fir, due to poorer drainage and slighter cooler summer temperatures. Sugar Maple and White Pine are found on rolling hills, while Red Maple, Aspen and Wire Birch are most predominant on burned over areas. Black Spruce swamps and peat bogs are extensive throughout the northern section of the region due to poor drainage.

While softwood and mixed wood forest habitats predominate, disturbance is widespread and very few areas of mature forest exist today. New growth on areas burned or cut provide good forage for wildlife. What little agriculture in the region is associated with drumlins, while bogs and inland barrens are much more common. Lakes and streams are prolific throughout the region but their very acid and deeply coloured waters support little diversity in freshwater fauna. The *Natural History of Nova Scotia* (1984) describes this region as supporting a fauna of a more boreal association, than that of an Acadian Forest Region (Hosie, 1969) and that the small mammal diversity is low to moderately high, depending upon the habitat.

410-Quartzite Plains and the Quartzite Barrens

The Quartzite Plains are divided into three Units based on surficial deposits and are: 411-Southwest Schists, 412-Mersey Meadows and 413-Quartzite Barrens (within which lies the study site). All three units are predominantly underlain by one of two resistant metamorphic rocks; greywacke or schist. Because the Quartzite Plains lies at the lowest part of the tilted planation surface, the elevation is low and there is little relief. The average elevation in the southwest is about 50m (150 feet), while the highest elevations are found in the southeast averaging around 150m (500 feet). What little relief there is is evident in the low parallel ridges and valleys eroded from the folded strata.

Drainage within this District is governed by glacial lineations and deposits. The drainage pattern, which occurs, reflects the relationship between the glacial direction and the folded structure beneath. In the west the drainage pattern is parallel to the folded structure, while in the east it is perpendicular, following the lineations of the last glacier.

The bedrock, for the most part, is covered by a thin layer of sandy till, but is exposed in areas where the surficial material has been scraped away. It is within the bedrock of the Quartzite Barrens that the most productive gold mining has occurred in Nova Scotia, with mines at Goldboro, Goldenville and Waverley.

Within the Quartzite Barrens Unit (413) the thickness of the sandy glacial till ranges from 1 -10m (three to thirty feet) thick with an average depth of less than 3m (ten feet). Drumlins and other "unmoulded" patches of reddish Lawrencetown till (Wolfville soils) can be found scattered throughout the Quartzite Barrens as a result of glacial erosion and deposition of reddish sandstones and siltstones of the Carboniferous and Triassic areas to the north and Antigonish Highlands.

The main soils found here are the Halifax soils -well drained, stony, sandy loams, developed on till derived principally from quartzite. Poorly drained Danesville soils, in association with Aspotogan soils and Peat can also be found in areas of low relief. Less prevalent are the Bridgewater soils, derived from slates, the Wolfville soils, associated with drumlins and the Herbert, Cumberland and Chaswood soils associated with alluvial and outwash material, mostly along the St. Mary's River.

The high and dry ridges of the Quartzite Barrens are vegetated predominantly by Beech, Yellow Birch, Red Maple and Sugar Maple. Lower down mixed stands of Red Spruce and White Spruce grow with Yellow Birch, Balsam Fir and Hemlock. Black Spruce and Larch swamps and sometimes drier patches of sand and White Pine are common in the depressions between the ridges. Slow moving streams, common to the landscape, are bordered by broad swampy areas and Balsam Fir, Red Maple and Black Spruce. While Wire Birch, Red Maple and Aspen are present on the more shrub-dominated barrens, Black Spruce and White Pine can also be found, depending on soil and drainage conditions.

Wildlife in the Barrens include a high population of Snowshoe Hare and consequently, Bobcat. Browsing conditions for deer are enhanced by forest practices. Stream habitat provide good conditions for small mammal diversity, as do the higher, well-drained areas of mixed and hardwood forests. Small mammal diversity in most other areas within the Quartzite Barrens is comparatively lower.

Appendix Six: Waverley -Home of the Gold Rush.

Introduction

In 1986 Waverley was incorporated as an autonomous village with a population of 1600. One hundred and twenty five years earlier Alexander Taylor made the first gold discovery, in Waverley, on August 23rd, 1861. The discovery was made on the western side of the village behind Muddy Pond on American Hill. In that same year, around the same time as Taylor's find and in close proximity to the first, Cornelius Blois made a second gold discovery. Blois' find is believed to be on the opposite side of Muddy Pond, on the other side of the present Cobequid Road. In 1865, when these two men sold their claim, numbered 166, to a Boston miner for $12,250.00, it was the largest amount ever paid for a gold claim in Nova Scotia. Still, another gold discovery was made on September 14th of that same year, this time on the eastern side of the village up on Laidlaw Hill (more commonly referred to as Waverley Mountain). It was made by a farmer named James Skerry who was travelling along the Old Dartmouth to Truro coach road, when he stopped to water his horse at Willis' Brook. Skerry found a large nugget of gold in the bed of the Brook. The rest, they say, is history!

Waverley Before the Fever and the Roads

Only 20 kilometres from Halifax,the provincial capital, Waverley is part of the metropolitan area of Halifax and Dartmouth, the two largest cities in Nova Scotia. Waverley is also part of a local government district (District 14 -population 9100) in the municipality of Halifax County (Hartlen, 1988). In 1862 the government of Nova Scotia declared Waverley as a "Gold Distric". Unlike other mining towns in Nova Scotia, however, Waverley was already a rural community before the fever struck. An agricultural community with limited access to Halifax, Waverley was spread out along the valley which contained Lakes William and Thomas. There was already as many as 20 farms houses, a school and a successful furniture business at Fall River (Waverley's neighbouring community), which was established by Charles P. Allen around 1830.

It was Allen's success that gave Waverley it's name. With the profits from his growing furniture factory, Allen was able to purchase 700 acres in the centre of Waverley in 1847. There he built a large farm, complete with gardens and an orchard. The house (still standing today) faced the bridge leading into the village. Because Allen was fond of the Scottish writer, Sir Walter Scott, and his Waverley novels, he named his farm Waverley and it is from here that Waverley adopted the name. The 700 acres, which Allen purchased included American Hill and Muddy Pond.

The Old Cobequid Road

In 1778 the second long distance road, in Nova Scotia, was opened for wagons travelling between Halifax and Cobequid (now Truro), about 96 km (60 miles). The Old Cobequid Road came close to Waverley, but not to Waverley, from Lower Sackville. The Old road turned north at Windsor Junction and followed along the western bank of Lake Thomas to where Lake Thomas flows into Lake Fletcher. The portion of the road from Lower Sackville to Waverley later became a properly paved road, while the rest of the Old

Cobequid Road was lost to the dense bush of the western shores of the lakes.

Today, portions of the Old Road can still be seen on the landscape as a subtle reminder of our past. A careful eye can identify the Old Road through changes in vegetation patterns using the aid of aerial photography. A small section of the Old Road lies within the study site and today has been incorporated into the park's trail system. Nothing less than a surprise when you first come upon the trail, you are immediately enshrouded in a cathedral like corridor of diffuse light. Completely soothing to the eye, the road appears as a swath of fescue and other fine grasses all a glow as they rise and fall over the terrain. All around is the thick dense bush. This is a good example of how, over time, nature can forgive and blend the ugliness of our doings into something so perfect.

Porto Bello Road and Rocky Lake Drive

A second road was built in 1815 on the eastern side of the valley on the high ground, coming from Dartmouth and exiting the valley at Fall River's falls. Another road (the Porto Bello Road) running along the floor of the valley, connecting Waverley to Dartmouth also, was completed in 1829 (Hartlen, 1988). This road was built to aid in the construction of the Canal, and hence became known as the Canal Road. The `beautiful ten mile drive' ran along the eastern shores of Lakes Charles and William and eventually connecting to the Old Cobequid Road in Fall River. It was not until 1843 that Waverley finally became connected to Bedford via what is now referred to as Rocky Lake Drive.

The Shubenacadie Canal System

The poor conditions of the roads at that time led to the creation of a waterway for the transportation of heavy goods from one side of Nova Scotia to the other; the Shubenacadie Canal System. The Shubenacadie Canal Company was established and a canal system was designed for the natural water route which the Micmac people (Mi'Kmag) had used for generations in their seasonal migrations from the Minas Basin to the Atlantic coast. The 'Chain Lakes': Charles, William, Thomas, Fletcher and Grand, are part of the Shubenacadie Canal system and due to the topography of the Province, locks had to be constructed to elevate the water over the land. It took over thirty years of planning, surveying and fund raising to build the system. The first sod was turned in 1826 by Lord Dalhousie and by the time the first boat finally steamed through the locks in 1861, steam power was about to change the landscape with the onslaught of the train (Shubenacadie Canal Commission, 1989).

The Chebucto Gold Mining Company (formed, September 2, 1861 at Halifax), before erecting a crusher at Waverley, used the Subenacadie waterway to ship gold quartz to a crusher in Halifax (Hartlen, 1988).

Gold Rush

In the summer of 1861, Waverley had a population of 296 males and 290 females. There was a road to Dartmouth and one to Bedford and the village was very near the road to Truro. There was a school, a furniture business and numerous farms. The area, then known as the Truro Road was peaceful and quiet, with the occasional wagon from Bedford or boat coming up the Canal. Then gold was found in the hills!

In Halifax, the news of the gold finds in Waverley was so popular that eventually the Honourable Joseph Howe drove out and paid the rural community a visit to examine the finds personally. In a letter Joseph Howe described the American Hill site (which overlooks Muddy Pond).

> "...and found that hundreds of dollars worth of gold had been taken out of the loose quartz boulders lying about the hill some 50 acres in extent, rising rather abruptly from a small lake and marsh on its western side and sloping away toward Lake Thomas one of the shubenacadie chain which half surrounded it on east and north."
>
> (Clark, *et al.*, 1972).

The result of Howe's visit was the building of a new road which connected Rocky Lake Drive with Muddy Pond. The new road was called the Diggins Road (McClelland, 1986) and was later extended to meet the Old Cobequid Road at Third Lake and the Windsor Junction Railway Station. The Diggins Road is now called the Cobequid Road.

Cornelius Blois and Alexander Taylor were both recognized by the Gold Commissioner when the two men had leased a single claim on May 3, 1862. The right of first discovery claim, assigned to them by the mines office meant that their claim was free of land rent or gold royalty payments for twenty-one years, according to the gold discovery claim provisions of the 1862 Gold Fields Act. The act states that a One Class claim measuring 45 m to 76m (150 feet by 250 feet) was to be issued to the discoverer of each new gold mine that was not a stream bed mine. This first free claim was at the edge of Muddy Pond, on American Hill, Waverley (Hartlen, 1988). There was no free claim for Skerry as his find was in Wilis's Brook. Hartlen (1988) states that the small brook which now flows about 100 metres from Muddy Pond to Lake Thomas was likely built or enlarged by gold miners. Records show an Assemblyman named Alexander Campbell made an application on July 5, 1862, to drain Muddy Pond for alluvial gold. His application was approved on August 21 of that year. Hartlen (1988) speculates that the Pond was never drained or bottomed completely but that the rock strewn appearance of the brook suggests that someone had tried. It is probable that these same rocks, in what Hartlens now calls 'Campbell's Brook', are the same loose boulders with which Howe makes reference to as Blois and Taylors' free claim laid next to the brook.

News of the gold finds also reached Britain and appeared in the *Illustrated London News* on December 6th, 1862. By the mid 1860s miners, experienced in hard rock mining came from California,Cornwall, Australia and Germany (Hartlen, 1988). By 1864, the area around the Diggins Road was known as Germantown and by 1867 the population of Waverley alone had reached 2000.

In five short years Waverley had grown from a tranquil rural community to a full-fledged mining town, complete with four hostelries and a temperance hall to sober up in, three dry good and grocery stores and a variety store, a baker, two blacksmiths, several mining engineers and contractors, a shoemaker and a surgeon. Most of the miners lived in wooden shanties among their claims and when they were not mining they were drinking. The liveliness of the village's night life was perhaps all but desirable for the local inhabitants of the once peaceful valley community.

By 1871 the first of the gold rushes had run its course and the population dropped to about 600 inhabitants. Hartlen (1988) notes a second gold rush from 1900 to 1903 with a brief revival in 1935. Very small scale independent mining could be traced up until at least 1962. Waverley soon became a summer resort for Haligonians. The roads to the outside world allowed for Sunday drives and afternoon teas on shores of the lakes. Charles P. Allen's house became a tea house called 'Green Acres' and in 1930, lunch was only 30 cents. Gold mining continued with decreasing enthusiasm up until around 1933.

Community Profile: "A healthy living lifestyle"

Today the Village of Waverley is once again a peaceful community, which prides itself in its beautiful lakes and graceful rolling landscape full of magnificent autumn colour. Close proximity and greater accessibility to the major urban centres of Halifax, Dartmouth and Bedford (with the construction of the Bicentennial Highway # 102) has made Waverley a desirable residential area. The residents, old and new, have a strong united desire to keep Waverley a beautiful place to live. This desire is most evident in their incorporation of the Village of Waverley as an independent, legal entity within the County of Halifax and their continued support for a community park.

The Village of Waverley -Incorporated

The Village of Waverley is governed by a Village Commission in many of its affairs, while remaining a part of the Municipality of the County of Halifax on broader issues. There are five commissioners elected by the residents of Waverley and a series of operating committees who oversee such administrative duties as recreation, planning, culture, services and publicity. The Commission can appoint a Village Clerk and may employ operational staff, including firemen and a by-law enforcement officer. A By-law, which has already been adopted allows the residents more direct involvement in areas such as planning and development and environmental protection.

Appendix Seven: Gold, Plate Tectonics and the Meguma Group.

Pangea and the Creation of the Meguma Group Rocks

Just about all of the gold found in Nova Scotia is that associated with vein deposits in the Meguma Group rocks of the southern mainland (Bates, 1987). The richest veins have been found formed on the domes where the curvature of the vein is greatest, while the largest veins found in the tightly folded plunging anticlines where the strata has been fractured by folding. One hypotheses, popular among geologists today, in the formation of the rich veins includes the super continent Pangea, plate tectonics and metamorphism.

The Meguma Group is composed of slates and greywackes 10 to 14 km (six to nine miles) thick folded upon each other due to continental drift and collision. Over 500 million years ago, off the shores of Northwestern Africa, underwater landslides deposited sands and clays which became greywackes and slates respectively. The rich gold bearing veins found in the Meguma Group were composed of quartz. Supporting the theory of continental drift, Africa and North America collided about 400 million years ago resulting in the formation of the Appalachian Mountain range and the formation of a new land mass called Pangea. As the two land masses collided, the sand and clay sediments became compressed into tight folds of anticlines and synclines. Because of the great pressure created in the collision the sands and clays were metamorphized into greywackes and slates (Bates, 1987). Also due to great friction, around 370 million years ago, the metamorphic rock of the Appalachian Mountains melted and intruded upward into the folded rock, still deep below the earth's surface. The magma cooled and became what is known today as the Granite Group of rock. Today the South Mountain and

Musquodoboit Batholiths are two of the major granite bodies found within the Appalachian Range.

Around 160 million years ago Pangea began to separate and the Meguma Group rocks separated from Africa to form the southern portion of Nova Scotia along the Cobequid-Chedabucto Fault. The Meguma Group is unique in that it is the only remnant of Africa left in North America.

Upon this folded and heat treated rock structure came the last glacier during the Pleistocene period. Much of the till today was produced by glacial scouring of the bedrock as recently as 10,000 years ago. The glacier, with a grinding action of ice on rock produced the till and topography one sees today.

Gold Bearing Veins

The Gold found in Nova Scotia is found in quartz veins largely associated with the folded structures of the Meguma Group. While records show that most of the gold bearing, or auriferous veins were found in the slate beds of the Meguma Group (Bates, 1987) Waverley's successful gold rush laid within the greywacke beds of the Meguma Group. Most of the veins are parallel to the original sediment layers and are often folded or corrugated like the beds themselves. As mining prospered the quartz veins developed names describing their orientation within the rock. Barrel quartz -first termed by miners in Waverley referred to an vein orientation resembling a series of casks laid side by side and end to end. While the veins, themselves, varied in length (100s to 1000s of meters), their vertical extension below the earth's surface and thickness were also as varied. Whatever the orientation of the auriferous veins, it is unclear how the veins were formed. One hypotheses suggests that the veins are deposited from solutions arising deep within the lower areas of the rock, which then penetrated up through the fractures and along the bedding planes (Nat. His. N.S., 1984). Bates (1987) suggests another hypotheses -that where gold particles were being deposited at the same time and rate as the clays and sands were settling to the bottom of the ancient sea. The gold particles became entrapped with further deposition of sediment which became compacted, hardened and turned to rock. The gold bearing veins formed depended on the quantity of gold to clay and sand. The veins were then parallel to the layers in the bed material and folded and fractured along with the host rock.

Gold Mining in Nova Scotia

Early findings of gold in Nova Scotia can be traced back as far as 1578 when the explorer Sir Humphrey Gilbert was given a patent to search for gold and silver in the New World. It was not until the 1860s, however, that gold mining claims began to spread like a fever. The fever spread and within half a year in 1861, small towns and villages all along the Eastern Shore changed 'overnight' as buildings were erected and miners and their families came from all over and moved in. Early findings of gold were in quartz boulders and quartz veins where the gold extraction involved the physical separation of the quartz from the surrounding bedrock and crushing the quartz. The first underground gold mine was at Tangier in 1860 where the quartz ore was brought to the surface and crushed with stones and the gold extracted.

Three methods in practice used during the several gold rushes included gravity, mercury amalgamation and cyanidization. process. Gravity separation relied on weight difference as the crushed sediment from the quartz ore was transformed into a slurry in a sluice box or jig.

Mercury Extraction

Mercury amalgamation involved the dissolving of gold in mercury. Mercury was added to the crushed ore and absorbed the free gold (gold physically separate from the impurities). The mercury-gold amalgam was then placed in a leather bag and squeezed to remove excess mercury. A closed system then heated the amalgam to evaporate the mercury and the gold was melted into a saleable form (Bates, 1987). In the 1880s cyanidization replaced amalgamation as a more efficient process of extraction. Of the 1,198,618.9 Troy ounces of gold produced in Nova Scotia between 1862 and 1982, Waverley produced 72,566.6 ounces (1862-1940) (Bates, 1987). Hartlen (1988) points out that out of the 65 gold districts during the peak of the rush, Waverley placed fourth in gold production, After Sherbrooke, Caribou and Oldham. Waverley was not the largest producer of gold, but over one third of the gold produced before 1867 was produced in Waverley -about 34,000 ounces.

References Cited

Amos, W. 1967. *Our Living World of Nature: The Life of the Pond.* Published by McGraw-Hill Book Company. New York. Pp. 232.

Anonymous. 1987. Guidelines for Freshwater Aquatic Life, in *Canadian Water Quality Guidelines.* Fifth Edition. Published by Inland Waters Directorate, Environment Canada and by Canada Communication Group. Ottawa, Ontario.

Anonymous. 1993. Guidelines for Canadian Drinking Water Quality, in *Canadian Water Quality Guidelines.* Fifth Edition. Published by Inland Waters Directorate, Environment Canada and by Canada Communication Group. Ottawa, Ontario.

Basso, A. April, 1994. *A Strategy for Landscape Planning in the County of Parkland, Alberta.* Natural Resources Institute. Practicum Pr.B153. University of Manitoba. Winnipeg, Manitoba. Pp. 133.

Bates, L. E. 1987. *Gold in Nova Scotia.* Published by the Department of Mines and Resources. Halifax, N.S. Pp. 48.

Beer, A. 1990. *Environmental Planning for Site Development.* Published by E. & EF.N. Spon. London. Pp. 320.

Blois, A. 1994. Personal communication about the Village's perception of Muddy Pond throughout the history of Waverley. Blois is a long time resident and local historian for the Village of Waverley.

Bradshaw and Handley, 1982. An ecological approach to landscape design - principles and problems. *Landscape Design.* No. 138. pp. 30-34.

Carter, C., Dohaney, V., Anthony, B. and N. MacEachern. 1981. *Shubenacadie-Stewiacke River Basin Board: Final Report.* A joint federal provincial project. Published by the Nova Scotia Department of Environment. Pp. 73.

Chacko, V. 1995. Personal communication with Mr Chacko concerning the interpretation of water quality testing. Water Quality Branch, Department of Fisheries and Oceans, 269 Main Street, Winnipeg, Manitoba.

Clark, I., Johnson, S. and E. Handforth. 1972. *This is Waverley Nova Scotia.* Published by the Waverley Ratepayers Association. Waverley, N.S. Pp. 40.

Cooper, P. And B. Finlater (eds.) *Constructed Wetlands in Water Pollution Control.* Published by Pergamon Press, Oxford. Pp. 587.

Darnell, R. November, 1978. Impact of human modification on the dynamics of wetland systems. *Wetland Functions and Values: The state of our understanding.* pp 200-209.

Davis, D. September, 1994. Personal Communication. Davis is former Curator for the Nova Scotia Museum of Natural History and Professor in the Environmental Planning and Design Program, Nova Scotia College of Art and Design. Halifax, N.S.

Deslouges, B. January, 1990. *Waverley Community Development Plan.* Innerspace Planning and Design.

Ducks Unlimited Canada. Spring, 1993. *Purple Loosestrife: The biological pollutant.* A pamphlet on the Manitoba Purple Loosestrife Project. Published, in part by Ducks Unlimited Canada. Manitoba.

Environment Canada. 1994. Information from Provincial Water Monitoring Station for the Shubenacadie River at Lake Thomas. Station No. 01DG007. Bedford, Nova Scotia.

Environment Canada. June 20, 1995. Telephone conversation with Bedford Weather Office. Bedford, Nova Scotia.

Forman, R. and M. Godron. 1986. *Landscape Ecology.* Published by John Wiley and Sons. New York. Pp. 619.

Garner, F. 1994. Executive Director for the Charles L. MacDonald Sports Park. Waverley, Nova Scotia. Waverley Amateur Athletic Association. Personal Communication.

Gersberg, R., Elkins, B., Lyon, S. and C. Goldman. 1986. Role of aquatic plants in wastewater treatment by artificial wetlands. *Water Research.* Vol. 20. No. 3. pp.363-368.

Gibbs, R. 1978. *Red Deer River: A Corridor for Recreation and Conservation.* Department of Landscape Architecture. Practicum Pr.G29. University of Manitoba. Winnipeg, Manitoba. Pp. 131.

Gilman, K. 1994. *Hydrology and Wetland Conservation.* Published by John Wiley and Sons. Chichester, England. Pp.101.

Gloyna, E. and W. Eckenfelder, Jr. 1968. *Advances in Water Quality Improvement.* Published by the University of Texas Press. Austin, Texas. Pp.513.

Goldsborough, L.G. 1993. Responses of marsh algal communities to controlled nitrogen and phosphorous enrichment. *University Field Station (Delta Marsh) Annual Report.* Vol. 28. pp. 35-40.

Greenall, J. 1992. Effect of seasonal burning on marsh plant communities. *University Field Station (Delta Marsh) Annual Report.* Vol. 27. pp. 50-54.

Grese, R. 1992. *Jens Jensen.* Published by the John Hopins University Press, Baltimore. Pp. 304.

Hammer, D. 1992. *Creating Freshwater Wetlands.* Published by Lewis Publishers. Boca Raton. Pp. 298.

Hansen, A. and F. di Castri. 1992. (Eds.). *Landscape Boundaries: Consequences for Biotic Diversity and Ecological Flows.* (Ecological Studies 92). Published by Springer-Verlag. New York.

Harris, C. And N. Dines. 1988. (Eds.). *Time-saver Standards for Landscape Architecture.* Published by McGraw-Hill Book Company. New York.

Hartlen, J. June, 1988. *Gold: The Wealth of Waverley.* Published by Lancelot Press. Hansport, Nova Scotia. Pp. 148.

Henderson, C. 1987. *Landscaping for Wildlife.* Published by the Minnesota Department of Natural Resources. Pp. 147.

Hills, A., Love, D. and D. Lacate. 1970. *Developing a Better Environment: Ecological land-use planning in Ontario -a study of methodology in the development of regional plans.* Published by the Ontario economic Council for the Graduate Department of Forestry, University of Toronto. (Reprinted 1973). Pp. 175.

Holland, M., Risser, P. And R. Naiman. 1991. (Eds.). *Ecotones: The role of landscape boundaries in the mangaement and restoration of changing environments.* Published by Chapman and Hall. New York. Pp. 142.

Hook, D., McKee,W., Jr., Smith, H., Gregory, J., Burrell, V., Jr, DeVoe, M., Sojka, R., Gilbert, S., Banks, R., Stolzy, L., Brooks, C., Matthews, T.and T.Shear. 1988. *The Ecology and Management of Wetlands: Volume 1 -ecology of wetlands.* Published by Croom Helm. London. Pp. 592.

Hosie, R. 1969. *Native Trees of Canada.* Published by the Canadian Forestry Service, Department of the Environment. Ottawa. Pp. 380.

Hough, M. 1984. *City Form and Natural Process.* Published by Routledge, New York.

House, J. 1991. *Monet.* Published by Phaidon Press Limited, London, Englang. Pp. 126.

Huebert, D. 1992. *The effect of biological and chemical factors on the uptake and toxicity of cadmium in the duckweed Lamna trisulca L.* University of Manitoba Doctor in Philosophy in Botany Thesis Dafoe H8685.

Interprovincial Engineering Limited. August, 1978. *Draft Report to the Shubenacadie-Stewiacke River Basin Board on Water Supply and Wastewater Disposal Management.* In Association with Geo-Limnos Consulting, Nolan, White and Associates Limited and H.J.Porter and Associates Limited.

Jeffries, M. and D. Mills. 1990. *Freshwater Ecology Principles and Applications.* Published by Belhaven Press. London. Pp. 283.

Jensen, J. 1939. *Siftings.* Published by Ralph Fletcher Seymour, Chicago. Pp.110.

Kay, L. February, 1984. *Water Quality and Quantity Sampling Surveys to the Shubenacdie Lakes Study Group and the Inland Waters Directorate of Environment Canada* on Water Quality and Quantity in the Shubenacadie Headwaters. Unpublished Report No. 1.01. Nova Scotia Department of Environment.

Keizer, P., Gordon, D., Jr., Rowell, T., McCurdy, R., Borgal, D., Clair, T., Taylor, D., Ogden, III, J., and G. Hall. 1993. *Synoptic Water Quality Survey of Halifax/Dartmouth Metro Area Lakes on April 16, 1991.* Canadian Data Report of Fisheries and Aquatic Sciences 914. Department of Fisheries and Oceans, Bedford Institute of Oceanography. Dartmouth, Nova Scotia.

Knight, R. And J. Pries. August 22, 1994. A CH2M Hill Engineering Ltd. Workshop on Constructed Wetlands for Wastewater and Stormwater Treatment. A Conference held in Truro, Nova Scotia. Organized and Funded by Nova Scotia Department of Agriculture and Marketing.

Kobriger, N., Dupuis, T, Kreutzberger, W., Stearns, F., Guntenspergen,G. And J. Keough. November 1983. *Guidelines for the Management of Highway Runoff on Wetlands.* National Cooperative Highway Research Program Report 264. Transportation Research Board, National Research Council. Washington, D.C.

Koh, 1982. Ecological design: a post-modern design paradigm of holistic philosophy and evolutionary ethic. *Landscape Journal.* Vol.1. No.2. pp. 76-84.

Lakshman, G. 1977. It came from the swamp. *Harrowsmith.* Vol. 2. No.10. pp. 101-2.

Lee, B. 1980. *In Search of an Environmental Planning Method: A review of Great Lakes initiaties.* Department of Landscape Architecture. Practicum Pr.L19. University of Manitoba. Winnipeg, Manitoba. Pp. 126.

MacDougall, J., Cann, D. and J. Hilchey. 1963. *Nova Scotia Soil Survey for Halifax County.* Published by the Department of Agriculture and Marketing. Report No. 13. Truro Nova Scotia. Reprinted 1981.

Mandell, P. 1994. Federal Department of Fisheries and Oceans, Lower Water Street, Halifax, Nova Scotia. Personal Communication concerning water quality testing and analysis.

Manning, O. 1982. Designing for man and nature. *Landscape Design.* No. 140. pp. 30-32.

Manuel, P. September, 1992. *A Landscape Approach to the Interpretation, Evaluation and Management of Wetlands.* Dalhousie University. Halifax, Nova Scotia.

Marsh, W. 1991. *Landscape Planning: Environmental Applications.* Second Edition. Published by John Wiley and Sons, Inc. New York. Pp. 339.

Matthess, G. 1982. *The Properties of groundwater.* Published by John Wiley and Sons, New York. Pp.406.

McClelland, R. 1986. *Waverley Then and Now: Waverley in the 1860s.* Published by the Waverley Ratepayers Association. Waverley, N.S. Pp.20.

McCormick, K. October, 1991. We don't do wetlands. *Landscape Architecture.*

McDonald, R. May 1995. Personal Communication with the Son of Charles L. McDonald about the wildlife found in and around Muddy Pond.

McHarg, I. 1969. *Design with Nature.* Published by Doubleday and Company. Garden City, N.Y.

Milne, L. and M. Milne. 1980. *The Audobon Society Field Guide to North American Insects and Spiders.* Published by Alfred A. Knopf, New York. Pp.989.

Mitchell, D.1974. (Ed.). *Aquatic Vegetation and its Use and Control.* Published by the Unitd Nations Educational, Scientific and Cultural Organization, Place de Fontenoy, Paris. Pp. 135.

Mitsch, W. and J.Gosselink. 1986. *Wetlands.* Published by Van Nostrand Reinhold Company. New York. Pp. 539.

Moss, M. 1988. *Landscape Ecology and Management: Preceedings of the first symposium of the Canadian Scoiety for Landscape Ecology and management:* University of Guelph, May, 1987. Published by Polyscience Publications Inc., Montreal, Canada. Pp. 240.

Mudroch, A. and T. Clair. 1984. *The Impact of Past Gold Mining Activities on the Shubenacadie River Headwaters Ecosystem.* Published by the Inland Waters Directorate of Environment Canada.

Municipality of the County of Halifax; Department of Planning and Development, Policy Division. September, 1994. Personal Communication.

National Wetlands Working Group. 1988. *Wetlands of Canada.* Ecological land Classification Series, No. 24. Published by Sustainable Development Branch, Environment Canada, Ottawa, Ontario, and Polyscience Publications Inc., Montreal, Quebec. Pp. 452.

Naveh and Lieberman, 1994. *Landscape Ecology: theory and application.* Second Edition. Published by Springer-Verlag. New York. Pp. 360.

Newbury, R. and M. Gaboury. 1993. *Stream Analysis and Fish Habitat Design - a field manual.* Published by Newbury Hydraulics Ltd and the Manitoba Habitat Heritage Corporation. Pp. 256.

Newbury, R. 1990. Personal Communication during Field Course Water in the Landscape. Offered through the Department of Landscape Architecture, University of Manitoba. Winnipeg.

Niering, W. and N. Olmstead. 1984. *The Audubon Society Field Guide to North American Wildflowers.* (Fifth edition). Published by Alfred A. Knopf, New York. Pp. 887.

North American Wetlands Conservation Council (Canada). March 1992. *No Net Loss: Implementing "no net loss" goals to conserve wetlands in Canada.* Published by the Canadian Wildlife Service of Environment Canada and Wildlife Habitat Canada. Ottawa, Ontario. Issues Paper, No. 1992-2. Pp. 35.

North American Wetlands Conservation Council (Canada). March 1992. *Wetland Evaluation Guide.* Published by the Canadian Wildlife Service of Environment Canada and Wildlife Habitat Canada. Ottawa, Ontario. Issues Paper, No. 1992-1. Pp. 121.

North American Wetlands Conservation Council (Canada). 1993. *Wetlands A Celebration of Life: Final report of the Canadian wetlands conservation task force.* Published by the Canadian Wildlife Service of Environment Canada and Wildlife Habitat Canada. Ottawa, Ontario. Issues Paper, No. 1993-1. Pp. 67.

Nova Scotia Round Table on Environment and Economy. February, 1992. *Sustainable Development Strategy for Nova Scotia.*

Nova Scotia Museum of Natural History, Department of Education. March, 1994. *Frogs.* Halifax, Nova Scotia. Info-pamphlet.

Nova Scotia Department of Lands and Forests. 1980. *Notes on Nova Scotia Wildlife.* Published by the Nova Scotia Department of Lands and Forests. Province of Nova Scotia

Nova Scotia Department of Natural Resources, Wildlife Division. 1988. *Important Freshwater Wetlands and Coastal Wildlife Habitats.* Nova Scotia Museum of Natural History.

Nova Scotia Department of Lands and Forests, Survey Division. December 5, 1988. Survey of lands comprising the Charles L. MacDonald Sports Park. Drafted by A. MacKay.

Nova Scotia Department of the Environment. 1992. *Designing Strategies for Water Supply Watershed management in Nova Scotia.* Published by the Nova Scotia Department of Government Services.

Parker, B. January, 1987. *The Development and Application of Ecological Design Principles - A Case Study: King's Park, Winnipeg.* Department of Landscape Achitecture. Practicum Pr.P16 c2. University of Manitoba, Winnipeg. Pp. 130.

Prey, J. June, 1994. On-site controls for urban stormwater pollution. *Public Works.* Vol. 125. no.7. pp. 52-53.

Price, M. 1985. *Introducing Groundwater.* Published by George Allen and Unwin Ltd., London, UK. Pp.195.

Pries, J. February,1996. Engineer of CG&S (formerly CH2MHill Ltd.) Waterloo, Ontario. Telephone communication.

Province of Nova Scotia Wildlife Advisory Council. 1993. *Living with Wildlife: A Strategy for Nova Scotia.* Published by the Nova Scotia Department of Government Services.

Reddy,K. And W. Smith. 1987. (Eds.). *Aquatic plants for Water Treatment and Resource Recovery.* Published by Magnolia Publishing Inc. Orlando, Fl. Pp. 153.

Riemer, D. 1984. *Introduction to Freshwater Vegetation.* Published by Avi Publishing Company, Inc. Westport, Connecticut. Pp. 207.

Roger, K., Breen, P. and A Chick. Nov/Dec, 1991. Nitrogen removal in experimental wetland treatment systems: evidence for the role of aquatic plants. *Research Journal of the Water Pollution Control Federation.* Vol. 63. No. 7. pp. 934-941.

Roland, A. 1984. *Geological Background and Physiography of Nova Scotia.* Published by the Nova Scotia Institute of Science. Halifax, Nova Scotia. Pp. 311.

Roland, A. And E. Smith. 1969. *The Flora of Nova Scotia.* Published by the Nova Scotia Museum. (Reprinted in 1983). Halifax, Nova Scotia. Pp. 746.

Scott, R., Hart, W., and D. Waller. April, 1991. *Water Quality in the Headwaters of the Shubenacadie River System.*

Selman, P. and N. Doar, 1992. An investigation of the potential for landscape ecology to act as a basis for rural land use plans. *Journal of Environmental Management.* Vol. 35. pp. 281-299.

Shay, J. 1981. Wetland Protection in the 80's. In *Proceedings, Ontario Wetlands Conference.* A. Champagne, (Ed.) Federation of Ontario Naturalists. September 18-19, 1981. Toronto, Ontario. pp. 19-25.

Shay, J. 1992. Landscape Field Ecology Notes for field course at Delta Marsh and Star Lake, Manitoba. August 23 to September 5. Pp. 60.

Shubenacadie Canal Commission. 1989. *Shubenacadie Canal Guide.* Published by the Shubenacadie Canal Commssion and the Province of Nova scotia. Pp. 30.

Simmons, M.,Davis, D., Griffiths, L and A. Muecke. 1984. *Natural History of Nova Scotia.* Nova Scotia Department of Education and Department of Lands and Forests. Halifax, Nova Scotia. 2 Vols. Pp. 807.

Simmons, M.,Davis, D., Griffiths, L and A. Muecke. 1994. *Natural History of Nova Scotia.* Nova Scotia Department of Education and Department of Lands and Forests. Halifax, Nova Scotia. Unpublished Revisions to existing text.

Smith, R. January, 1964. Experimental control of Purple Loosestrife (*Lythrum salicaria*). *New York Fish and Game Journal.* Vol. II. No. 1.

Task Force To Bring Back the Don. August, 1991. *Bringing Back the Don.* Published by City of Toronto.

Tourbier, J. and R. Pierson Jr. 1976. *Biological Control of Water Pollution.* Published by University of Pennsylvania Press, PA.

Turner, M. 1987. *Landscape Heterogeneity and Disturbance. Ecological Studies 64.* Published by Springer - Verlag, New York.

Tyler, M., Ph.D. 1995. Committee Advisor for Muddy Pond Practicum. Personal Communication. Department of City Planning, Faculty of Architecture. University of Manitoba.

Vaughan Engineering Associates Limited. May, 1993. *Shubenacadie Lakes Planning/Pollution Control Study.* File No.1813. Norman Gridley, Manager, Environmental management Division, in Association with Griffiths Muecke Associates.

Waring, R. and W. Schlesinger. 1985. *Forest Ecosystems Concepts and management.* Published by Academic Press, Inc. Orlando, Florida. Pp. 340.

Waverley Village Commission. January, 1990. *Waverley Community Development Plan.* Prepared by Innerspace Planning and Designin association with Brian Deslouges, Landscape Architect.

Weller, M. 1994. *Freshwater Marshes: Ecology and Wildlife management.* Third edition. Published by the University of Minnesota Press. Minneapolis.

Wilson, E. 1995. PBS Network Television Special.

Further Reading

Design with science. By T. La Dell. In *Landscape Design.* October, 1994. pp. 18-20.

Implementing sustainability: the use of natural channel design and artificial wetlands for stormwater management. By L. Smith and T. Carlisle. In *Journal of Environmental Management.* Vol. 37. 1993. pp. 241-257.

Looking good: the use of natural methods to control urban runoff.. By J. Tourbier and R. Westmacott. In *Urban Land.* April, 1989. pp. 32-35.

Making a parking lot into an exhibit. By Agatha Hughes. In *The Public Garden.* January, 1990. pp. 14-17.

Non-point source water pollution management: improving decision-making information through water quality monitoring. By L. Reinelt, R. Horner and R. Castensson. In *Journal of Environmental Management.* Vol. 34. 1992. pp. 15-30.

On Nature: Nature, Landscape, and Natural History. D. Halpern. (Ed.) Published by Antæus. New York, New York. 1986. Pp. 320.

Recharge beds save space, preserve environment. In *Land & Water.* January, 1988. pp. 14-15.

Role of wetlands in the removal of suspended sediments. By K. Boto and W. Patrick, Jr. In *Wetland Functions and values: The State of Our Understanding.* Published by the American Water Resources Association. November, 1978.

Scope of things to come? By A. Steele. In *Landscape Design.* June, 1994. pp. 16-17.

Soil and water conservation in a landscape perspective. By Leslie Sauer. In *Journal of Soil and Water Conservation.* Vol. 46. No. 3. May-June, 1991. pp. 194-196.

Storm water recharge beds replace retention basins. In *Highway & Heavy Construction.* July, 1988. Pp50-52.

Technology aids wetlands mitigation. By J. Astroth, Ph.D. In *Public Works.* March, 1995. pp. 41-42.

The reed bed revolution. By P. Worrall. In *Landscape Design.* March, 1992. pp. 16-18.

Vegetation and habitat conditions in Western Head Bog, a southern Nova Scotia plateau bog. By A. Damman and J. Dowhan. In *Canadian Journal of Botany.* Vol. 59. 1981. pp. 1343-1359.

Watershed Protection Techniques. A quarterly bulletin on urban watershed restoration and protection tools. Published by the Center for Watershed Protection, Silver Spring, Maryland.

We don't 'do' wetlands. By Kathleen McCormick. In *Landscape Architecture.* October, 1991. pp. 88-90.

Wetlands of Europe. By J. O'Sullivan. In *Naturopa.* No. 77. 1995. pp. 19-20.

What ecology can do for environmental management. By K. Shrader-Frechette. In *Journal of Environmental Management.* Vol. 41. 1994. pp. 293-307.