BURNS BOG: A PROPOSAL FOR ECOLOGICAL RESTORATION AND VISITOR CENTRE DESIGN

by

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ABSTRACT

Using Burns Bog as a case study, this project aims to illustrate the environmental and social importance of ecological restoration, to research the physical methods of bog restoration, and to design a simple visitor centre and recreation trail network.

Burns Bog is a raised peat bog with a distinctive chemistry, form, flora, and large size that make it globally unique. The Bog may soon be protected as park or open space by a government purchase of a large portion of its land mass. Burns Bog has been disturbed in the past, primarily by peat extraction, and requires both restoration and management to ensure its long-term viability.

Restoration in this thesis is divided into hydrology and vegetation. The key issue regarding hydrology is the loss of water through drainage ditches. I recommend that all ditches be properly blocked and that a number of sites in the Bog be rewetted using other methods, such as bunding and peat removal, to raise the water table level.

The existing composition of plant communities in Burns Bog is very diverse, due to the results of past disturbances. I propose vegetative restoration for a number of sites in the Bog. I also suggest that the current level of plant community diversity is valuable for wildlife habitat and future tourism, and recommend that managers maintain this diversity within the foreseeable future (50-100 years).

The last portion of this thesis is a proposal for a visitor centre and trail system design, the purpose of which is to allow maximum public access to Burns Bog while minimizing impact on the bog ecosystem.

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INTRODUCTION

1.1 Background information

Burns Bog is a large bog ecosystem located in the Fraser River delta between the south arm of the Fraser River and Boundary Bay (Hebda *et al.*, 2000). Historically, the Bog stretched over 4300 hectares; currently, this wetland covers about 3000 hectares. A numbered company, formerly Western Delta Lands and/or Fraser Delta Properties Partnership, owns approximately 2200 hectares (73%) of the Bog. The City of Vancouver uses about 200 hectares of the Bog as a landfill for about 25% of the garbage collection in the Lower Mainland; due to the extent of physical alteration, this land is no longer considered a part of the bog ecosystem complex. There are seven smaller private landfills along the northern and southwest borders of the Bog (Hebda *et al.*, 2000). The Delta Nature Reserve, which is the largest existing park or protected area in the Bog, covers about 60 hectares of the Bog's land mass. Forty percent of the original bog area has been altered or destroyed by development (Hebda et al., 2000), and the bog is largely isolated from other natural areas by agricultural, residential, and industrial land use. Despite this level of disturbance, Burns Bog retains important ecological processes and continues to support distinct rare biotic communities (McDade, 2000).

Form and Hydrology

Burns Bog is classified as a 'raised' or 'domed' peat bog (Figure 1), meaning that it formed a shallow dome of peat during its development (Hebda *et al.*, 2000; Wheeler and Shaw, 1995). A peat bog differs from other types of wetlands in that it contains an internal mound of water that is acidic and nutrient-poor, a two-layered peat deposit, and plant communities dominated by *Sphagnum* and ericaceous plants. The unique growing conditions of peat bogs allow relatively few specialized plants to thrive. A raised bog is 'ombotrophic', meaning that the primary source of water is precipitation.

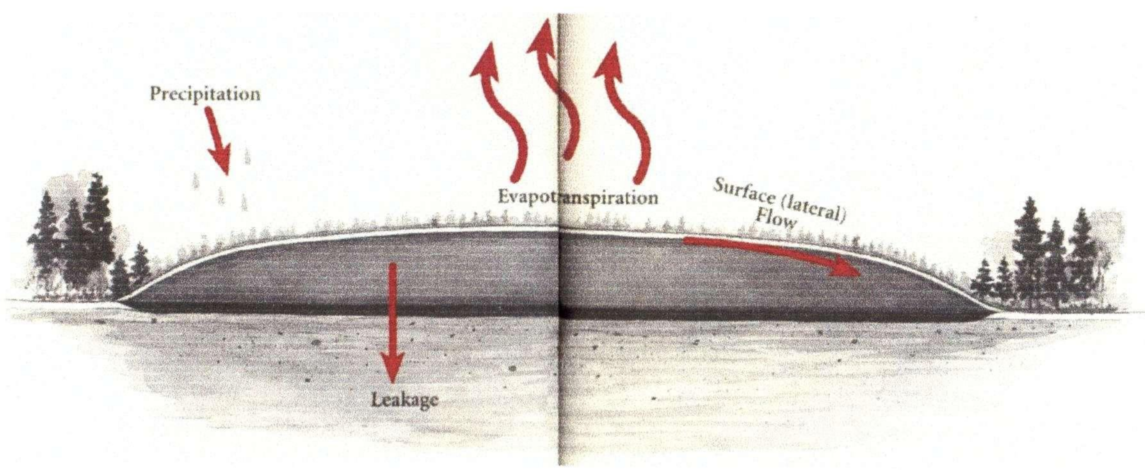


Figure 1: Simplified hydrology and form of a raised bog (McDade, 2000)

The structural and functional requirements of a raised bog can be simplified into three elements:

1. A large, relatively uniform (hydrologically speaking) dome or plateau, which is rain fed and in which peat accumulation occurs (Figure 1)
2. A narrow transition zone called the 'rand', often with a relatively steep slope (Figure 2)

3. A discharge zone called the 'lagg', located at the edge of the transition zone, where the excess of water from the bog collects and drains away (Figure 2)

All of the above must be present for a bog to be viable and maintain its integrity.

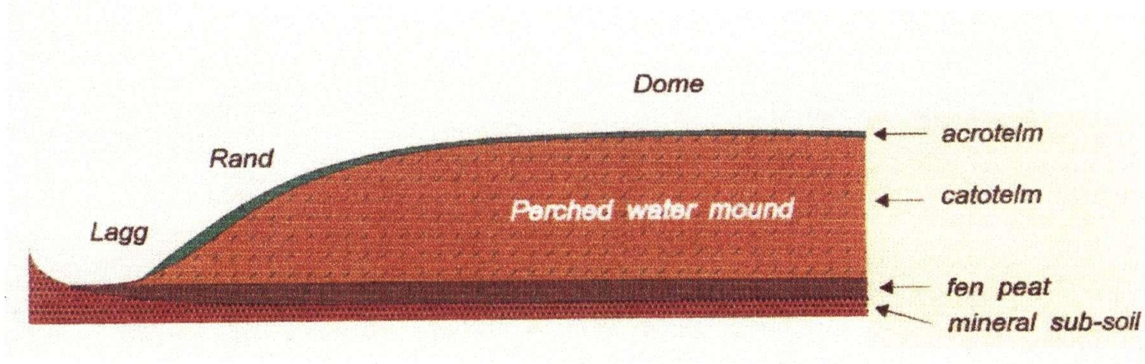


Figure 2: Diagrammatic profile across a raised bog (Wheeler and Shaw, 1995)

Water in a raised bog flows most freely through the 'acrotelm' (freshly decomposing *Sphagnum* peat), where it moves laterally towards the edge of the bog; hence, water flow from a raised bog, as distinct from other bogs, is generally outward and does not generally depend upon water flow from adjacent ecosystems (Hebda et al., 2000). The 'catotelm' is a layer of saturated decomposed *Sphagnum* peat, through which water moves extremely slowly. In the case of Burns Bog, the catotelm lies above a thin layer of highly compacted impermeable sedge peat. Deltaic deposits of gravel, sand, silt and clay form the lowest layer of Burns Bog (Figure 3).

Fauna

Burns Bog is a rare habitat type in the Lower Mainland and has a high diversity of bird, mammal, amphibian, and insect species, some found only rarely elsewhere. Several provincially and nationally listed species occur in Burns Bog. Several studies have reported that the Bog is home for at least part of the year to 41 mammal species, 175 bird species, 11 amphibian species and 6 reptile species (Hebda et al., 2000; Knopp and Larkin, 1999). An estimate of insect biodiversity numbers over 4000 species (McDade, 2000). It is the size and diversity of habitat in Burns Bog, ranging from forests to heathland to open water, which allows such a wide variety of animals to exist in Burns Bog.

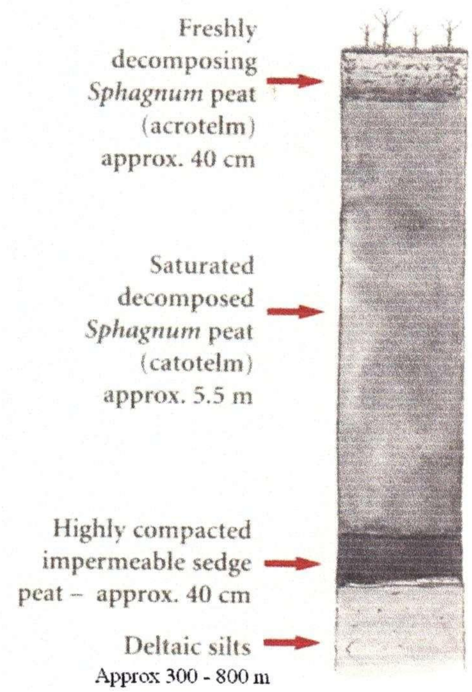


Figure 3: Layers of Burns Bog (McDade, 2000)

Seven specimens of the red-listed Southern Red-Backed Vole (*Clethrionomys gapperi occidentalis*), a species that has not been found in British Columbia since 1947, were captured in 1999 during a mammal survey in the Bog (Hebda et al., 2000). Burns Bog is one of only two sites in the Lower Mainland where the blue-listed Greater Sandhill Crane (*Grus canadensis tabida*) is known to nest.

Flora

The plants of Burns Bog have been studied and documented since the late 1800s. Before the mid-twentieth century, the bog was blanketed by *Sphagnum* moss species and stunted lodgepole pine (*Pinus contorta*). Other dominant species at that time included Labrador tea (*Rhododendron groenlandicum*), bog cranberry (*Oxycoccus palustris*), bog blueberry (*Vaccinium uliginosum*), bog laurel (*Kalmia microphylla* ssp. *occidentalis*), cotton-grass (*Eriophorum chamissonis*), and salal (*Gaultheria shallon*) (Hebda et al., 2000).

The plant communities have changed since the mid-1970s, due to, among other factors, peat mining, highway construction, growth of the City of Vancouver landfill, and cranberry field construction. These activities altered the drainage, area, and nutrient levels in various parts of the bog, and had an impact on plant species composition (Hebda et al., 2000). Today there are more species at the edges of the bog that are common in BC, such as salal and red alder (*Alnus rubra*), and there are many non-native plants present, including species from Europe (e.g. English holly, European birch, blackberry) and cultivated plants (e.g. domestic blueberry and cranberry) in areas of the bog where human activity is common.

Despite the high level of disturbance, the Bog continues to support rare plants and plant associations (Hebda et al., 2000). The Bog currently contains hundreds of plant species, including many lichens and fungi that may be unique to the Bog. Several plant species, including crowberry (*Empetrum nigrum*), cloudberry (*Rubus chamaemorus*), velvet-leaved blueberry (*Vaccinium myrtilloides*), and bog-rosemary (*Andromeda polifolia*) occur near their southern geographical limit in the Bog (Hebda et el., 2000). The Pine-*Sphagnum* plant association (Appendix 2) is provincially red-listed by the BC Conservation Data Centre.

1.2 Historical Use

First Nations

Human use of Burns Bog likely dates back over 4000 years (Washbrook, 1996). Archaeological evidence and information from interviews suggests that six First Nations groups historically used the Bog: the Tsawwassen, the Musqueam, the Semiahmoo, the Squamish, the Sto:lo, and the Katzie Nations (Hebda et al., 2000; Burns, 1997). The Bog was used for hunting (e.g., black bear, black-tailed deer, elk) and gathering (e.g., blackberries, blueberries, cranberries, Labrador tea, salal, *Sphagnum*). There are many myths and legends about Burns Bog that persist today, and the Bog is still considered to be extremely important to several of these groups in terms of cultural, archaeological, traditional, and current uses (Hebda et al., 2000).

Peat Mining

Peat harvesting in Burns Bog began in the 1930s (Burns, 1997). Harvesting was initially unsuccessful and did not gain momentum until the second World War. Magnesium firebombs and flares used by the U.S. Army required peat as the catalyst in magnesium refining, and large bogs such as Burns Bog were an ideal peat source. After the war, harvesting continued and the peat was sold for horticultural purposes. Large-scale peat harvesting activities ceased in Burns Bog in 1984 (Hebda et al., 2000).

Four main methods of peat extraction were used in Burns Bog, each creating a different form on the remaining surface of the peat. Between 1941 and 1948, peat was hand-cut (about 0.5 m deep) using chainsaws and shovels and transported away by railway cars (Hebda et al., 2000). The harvest sites had to be drained by a series of ditches to create suitable conditions for the workers and machinery; higher strips of land were left to allow the peat to dry. The peat-mining trenches and the strips of high ground left a distinct 'ridge and groove' pattern, which can be seen by aerial photograph (Catherine Berris and Associates, 1993).

The Atkins-Durbrow Company utilized a 'hydropeat' method from 1948 to 1981. The sites were cleared of woody vegetation, and then high-pressure water hoses blasted the peat into a slurry, which was pumped in pipes to the processing plant (Hebda et al., 2000). Fewer ditches were dug for this method because it required water. Remnant strips were left between harvested areas, creating a 'narrow trench' pattern (Catherine Berris and Associates, 1993).

From about 1952 to 1980, Western Peat Company used the 'vacuum' method. Most of the peat removed by this method was a part of the acrotelm layer; the drier and more fibric nature of the acrotelm made it ideal for horticultural use (Hebda et al., 2000). Trees were removed and a large number of drainage ditches were dug to further reduce the water content of the upper peat layers. Using special tractors, the peat surface was 'fluffed up' to dry and then gathered by large vacuuming machines. This method left large rectangular field patterns on the Bog surface.

The final harvest method was used by Western Peat Company between 1978 and 1984. This was another hydropeat method, similar to the one used by the Atkins-Durbrow Company. Water was pumped into the harvest sites from the nearby Fraser River, and a hoverbarge with a backhoe crane attachment was used to excavate the peat up to three metres deep (Hebda et al., 2000). The hoverbarge method created a series of scooped depressions that appear more random in form from the air than the previous two methods.

1.3 Current Use

Recreation

Recreational use of the Bog is currently low because most of the land is privately owned. The land north of the Vancouver Landfill, which is owned by the City of Vancouver, is notably exploited by hikers. Hiking is also common in the Delta Nature Reserve, along with bike riding, dog-walking, and bird-watching. Other limited uses throughout the Bog include waterfowl hunting and all-terrain vehicle riding.

Research

The scientific and educational merits of the Bog are countless. The vast diversity of plants and animals, social and political issues, and unexplored terrain allows for a high degree of variety in research topics and educational possibilities.

Agriculture

Most of Burns Bog is too wet, acidic, and nutrient-poor for agriculture, and is therefore not sought after as typical farmland. However, cranberry production requires the high water levels that exist in the Bog, and so the edge of the bog provides excellent, accessible land for cranberry farming. Blueberries and several other agricultural crops are also grown around the edge of the Bog.

Hunting
The central part of the Bog is sometimes used as a waterfowl hunting ground by a local gun club (Burns, 1997). Burns Bog is a vital part of the Pacific Flyway for migratory birds, such as waterfowl. A gunshot noise alone is enough to keep waterfowl from a large area of the bog, and this leaves less land for the tens of thousands of birds to feed and rest during their migration route. The sounds of hunting also frighten other wildlife, such as the black bears, deer, coyotes, and beavers that make Burns Bog their home throughout the year.

1.4 Hydrological Results of Peat Extraction

Parts of the soil profile, namely the acrotelm and the upper layers of the catotelm, were removed or damaged during peat extraction. The acrotelm is a vital element of bog function, because it regulates hydrology, directly contributes to peat formation, and ensures long-term sustainability of the Bog by maintaining hydrological and peat accumulation processes (Hebda et al., 2000). Without a functional acrotelm, the Bog cannot maintain its hydrological or ecological integrity.

Ditches alter the hydrology of the Bog by draining parts of the bog faster than they would drain naturally (Figure 4). Reduction of the water table level usually leads to compaction of the peat and increased decomposition rates. This creates habitat for trees, shrubs, and weedy species which decrease the competitive ability of bog vegetation. The effects of ditch excavation can be summarized as follows:

1) The Bog's storage capacity has decreased and evaporation (due to the open water of ditches and ponds) has increased, causing 27.5% of the Bog to dry out.
2) Ditches affect 38% of the Bog; they tend to remove water more quickly than normal after a precipitation event, thereby reducing the ability of the Bog to delay runoff time.
3) Ditches have lowered the average annual position of the water table by discharging water more quickly than would be the case in a non-ditched bog.

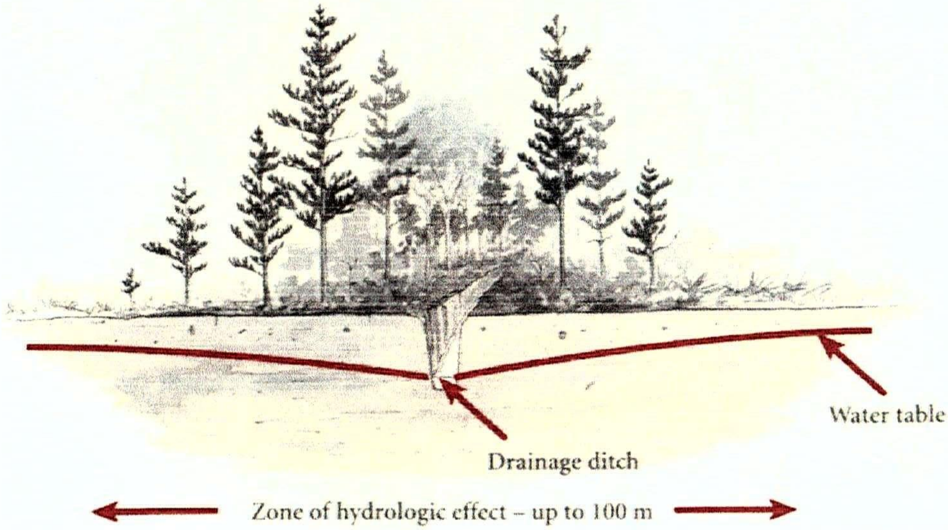


Figure 4: Effect of drainage ditches in Burns Bog (McDade, 2000)

The lagg zone of Burns Bog has been greatly modified or removed. Ditches perform the same drainage function as the lagg would, so a function that should be confined to the perimeter of the Bog now has effects throughout the Bog. According to Hebda et al. (2000), a more natural lagg function must be returned to the Bog, or the peat-forming communities and the bog ecosystem complex will degrade and perish.

In the 1930s, 90-100% of the Bog area (as defined by the current water mound) had a water table above a depth of 50cm. Today, only 52% of the Bog has a water table that high. This means that the water mound in Burns Bog has been shrinking and will continue to shrink, with the associated ecological consequences, if the loss of water is not reversed.

Finally, it has been suggested that an incursion into the middle of a water mound will cause it to split, resulting in two separate and lower water mounds. The Burns Bog ditches constructed south and east of the 80th street extension in 1999 constitute such an incursion. If two smaller water mounds were to form in Burns Bog, the integrity and viability of the bog would be placed at extreme risk (Hebda et al., 2000).

1.5 Ecological Results of Peat Extraction

Changes in the hydrological regime of Burns Bog have brought about accompanying alterations to plant species composition. The results are summarized below:

1) A large portion of the historical vegetative cover was removed (Appendix 3).
2) A permanent decrease of the water table of only 10-15 cm over a few years, which has occurred widely in the bog, strongly favours the growth of woody vascular plants and causes a shift away from peat-forming *Sphagnum* communities (Appendix 4).
3) Undisturbed ridges between peat extractions and undisturbed bog edges close to drainage ditches have dried out due to a lower water table, leading to non-bog vegetation such as birch (Appendix 2 – Birch Forest)
4) The bog is shrinking; only 51% of the Bog area (as defined by the water mound) supports functioning bog vegetation (Appendix 4 – wet bog conditions)
5) There has been an increase in plant community diversity due to disturbance (Appendix 2)
6) Aquatic habitats have developed, creating habitat for waterfowl, amphibians, and aquatic mammals like beaver and muskrat.
7) An increase in forest coverage of the Bog results in more habitat for forest dwelling wildlife such as the red-listed Southern Red-backed Vole.
8) Exotic vegetation has invaded the most disturbed sites (especially European birch, the cultivated high-bush blueberry, and tawny cotton-grass)

1.6 Other Human Disturbances

Road Construction
Highway 91 cuts through the east side of Burns Bog. The highway was constructed to 'float' on the Bog to reduce its impact on bog hydrology. However, the highway is a barrier to animal and plant dispersal, and it creates fragmentation of the bog habitat. In spite of its floating construction, water drains along the highway edges towards the Fraser River; water movement

beneath the highway has been shown to occur (Hebda et al., 2000) but is poorly understood. Runoff from the road pollutes the soil near the highway and filters into the groundwater.

Pollution
Burns Bog acts as a carbon sink, keeping carbon dioxide and methane from the atmosphere (thus reducing global warming). Many other pollutants produced in the Lower Mainland (pulp mills, car emissions, industrial waste) are also somewhat reduced by the sheer amount of vegetation in the Bog. However, the Bog has limits; evidence of pollutants can be found in the water of Burns Bog, particularly around the perimeter. If the carbon-sink capability of the Bog were removed by human activity, such as agriculture or urban expansion, these pollutants would have a much greater impact on the Lower Mainland and Fraser Valley.

Tour Groups
The Delta Nature Reserve, the only part of Burns Bog that is protected from development, is used extensively for walking, bike riding, and school group tours. Boardwalks exist only in the Delta Nature Reserve. Tours in the southwest corner of the Bog occur frequently (once or twice per week) during the drier months, and students often wander off the trails. The trails are subject to extensive widening during the wet season when the water table is at or above the surface, and bog vegetation is slow to regenerate from trampling.

1.7 Summary of Disturbance

The key results of the damage to Burns Bog can be summarized as follows:

1) About 50% of the Bog's acrotelm has been eliminated or seriously damaged
2) Most peat extractions are recovering naturally, but often to a state different than pre-disturbance
3) Increased drainage has lowered the water table (disturbing the bog ecosystem complex)
4) The forest perimeter is expanding towards the centre of the Bog (the Bog is drying)
5) Exotic species have invaded but are confined to sites of major disturbance (roads and filled areas)

1.8 Summary of Key Issues and their Restoration Implications

Below is a summary of the key conclusions from Hebda et al. (2000) as they relate to the ecological restoration of Burns Bog. The implications of these key findings for restoration are discussed under each conclusion.

General:

- Burns Bog is globally unique on the basis of its chemistry, form, flora, and large size.
  - Implication: Restoration and management of Burns Bog as a sustainable ecosystem are of particular ecological importance locally, regionally, and globally.
- The Bog is currently isolated from adjacent natural ecosystems by urban, industrial, and agricultural development.
  - Implication: The lack of connectivity between Burns Bog and other natural ecosystems, particularly for terrestrial wildlife, may be addressed within the goals

and objectives of a restoration proposal, and possible within the context of a regional greenway / open space strategy.

- Peat mining and other activities have disturbed the hydrology and ecosystems of more than half of the remaining bog, and these disturbances continue to affect the Bog today.
  - Implication: Human disturbances have resulted in a diverse mosaic of plant communities; some of this diversity is desirable in terms of increased biodiversity and a wider variety of wildlife habitat, and some of these plant communities have low ecological value and require restoration or enhancement.

Hydrology:

- Precipitation is, and must continue to be, the dominant source of water and nutrients in the bog ecosystem.
  - Implication: The restoration of Burns Bog must aim to retain as much precipitation as possible within the Bog.
- The Bog's ecological viability is directly dependent on the extent and integrity of the water mound and the peat that encloses it; further disruption of the water mound poses high risk to the integrity and viability of Burns Bog.
  - Implication: The Bog cannot persist without its water mound; thus, the priority of any restoration proposal must be to rewet areas of the Bog that have dried or appear to be drying.
- The acrotelm is vital to the persistence of the water mound and peat-forming communities; the existing area of acrotelm must be maintained and a fully functional acrotelm must redevelop over the area of the water mound.
  - Implication: Any existing peat-forming plant communities must be protected and newly restored plant communities should have the capability of forming peat.
- Little of the essential lagg zone remains in an undisturbed state; a fully functioning lagg must occur at the margins of the water mound.
  - Implication: After rewetting the central bog, the second priority is to maintain all existing lagg areas and restore lagg function to a number of other perimeter locations.
- Water from the east side of Highway 91 may play an important role in sustaining shallow pools that support the main water mound.
  - Implication: The forested ecosystem east of Highway 91 is an important part of the Bog ecosystem complex and must not be treated as a separate restoration problem.
  - Implication: Consideration should be given to the connectivity between the central bog and the forest east of Highway 91, particularly in terms of hydrological function; flows between these areas must be maintained.
- Ditches drain water in excess of normal discharge leading to a decrease in water storage; in the critical summer water-table position this threatens the Bog's viability.
  - Implication: If feasible, all drainage ditches must be blocked.

Biota:

- The undisturbed plant communities that occur in the southern third and in the north-west sector of the Bog are vital to its survival.
  - Implication: All undisturbed plant communities should be protected
  - Implication: Undisturbed plant communities provide templates and transplant donor sites for the restoration of damaged areas.

- The Burns Bog area includes several nationally and provincially listed animals and plant communities in both the central core and at the margins.
    - Implication: In the protection and restoration of plant communities, consideration should be given to maintaining and enhancing habitat for red- and blue-listed species.
- Burns Bog is the only known habitat for the Southern Red-backed Vole in the province, and critical habitat for the regional Greater Sandhill Crane population.
    - Implication: Within the task of maintaining habitat for listed species, particular emphasis should be placed on the habitat requirements of the Southern Red-backed Vole and the Greater Sandhill Crane.
- The size and diversity of plant communities in Burns Bog provide habitat for a wide range of wildlife species; the Bog maintains the largest extent of bog ecosystems in the Fraser Lowland and a high level of biodiversity.
    - Implication: It is desirable to maintain a relatively high degree of plant community diversity, instead of attempting to restore Burns Bog to a single historic plant community.
- Burns Bog contains several species at their southern limits of geographic range.
    - Implication: Those areas in the Bog that contain these particular species (bog blueberry, crowberry, cloudberry, bog rosemary) should be protected from any damage or destruction, either by development or by future management techniques.
- Peat extraction has created aquatic habitats for waterfowl, amphibians, and aquatic mammals like beaver and muskrat.
    - Implication: Aquatic habitats enhance biodiversity values; all aquatic habitats should be maintained and more might be created through the restoration process.
- Increasing forest coverage in the Bog results in more habitat for forest dwelling wildlife such as the red-listed Southern Red-backed Vole.
    - Implication: Although forests were not historically present in Burns Bog, at least some of the forested ecosystems in the Bog should be protected as habitat, particularly for raptors and small mammals.

Processes:

- The expansion of forest communities indicates that the Bog has been and is drying because of drainage by ditches
    - Implication: This drying process must not continue; the Bog should largely be rewetted and some forested areas cleared and replanted with peat-forming communities.
- Widespread *Sphagnum* regeneration is occurring in the peat-mined areas of the Bog.
    - Implication: Many areas in the Bog have naturally regenerated and will not require plant restoration; the focus should be on sites that have been heavily or recently damaged and have not yet regenerated through natural processes.
- Connectivity is limited, but must be maintained for the long-term viability of the Bog, especially its wildlife.
    - Implication: Consideration should be given to purchasing and protecting any remaining natural areas that would link the Bog with other natural areas, such as the Fraser River, Boundary Bay, and the creeks originating from Panorama Ridge.
    - Implication: The possibility of a land bridge or a tunnel that connects the main bog with the forested area east of Highway 91 should be explored.

- Exotic species occur on disturbed peat but do not occur in undisturbed vegetation to any extent.
    - Implication: Management of exotic species is not of great concern for the central part of the Bog, and can be confined to moderately disturbed surfaces and the Bog's perimeter.

SITE DESCRIPTION

Location and Context

Burns Bog is located in the Municipality of Delta, British Columbia between the Fraser River and Boundary Bay. The Bog is surrounded on two sides, south and west, by Agricultural Land Reserve (Appendix 1). Industrial land runs along the northern strip between the Bog and the Fraser River, and single-family homes comprise the majority of land use on Panorama Ridge to the east of the Bog. Aside from the Vancouver Landfill and the Delta Nature Reserve, the Bog is currently zoned for agriculture, extractive activity, and park.

Highway 91 cuts the mostly forested eastern edge of the Bog from the rest of the ecosystem. Highway 99 runs through agricultural land to the south of the Bog, much of which used to be a part of the bog landscape. River Road follows the Fraser River through the industrial lands that line the Bog. A number of smaller roads, mainly for industrial and agricultural access, extend a short way into the Bog's perimeter.

Disturbance Regime

Burns Bog has undergone a great deal of disturbance (Appendix 6a), particularly during the past 60 years. Peat extraction comprises the bulk of the disturbance, and includes both the direct impacts of vegetation and peat removal and the indirect consequences of drainage ditches (Appendix 6b). Much of the existing mixed conifer forest between Highway 91 and the slopes of Panorama Ridge is second growth, due to clearcutting and selective logging practices. Patches of cultivated sites and other cleared areas dot the Bog, and a number of landfills, both public and private, operate along the Bog's perimeter. Fire is a natural disturbance that has been intensified by human presence; there is evidence that First Nations groups deliberately set fire to areas of the Bog to stimulate the growth of fruit-producing shrubs. The last major fire occurred in 1996, and is believed to have been caused by a discarded cigarette.

Hydrology and Ecology

The Bog exhibits the typical characteristics of a raised bog ecosystem. These characteristics include a peat mound that reaches a high point of about five metres in the centre of the bog, acidic nutrient-poor water derived directly from precipitation, and an internal water mound. Three types of water are contained within the hydrological boundary of the Bog: bog water (pH 3.5-5.5), transitional water (pH 4.5-6.0), and non-bog water (5.0-8.0) (Hebda et al., 2000). Historically, Burns Bog displayed a radial drainage pattern, flowing from the center of the dome to the edge. This pattern still exists today, but has been altered due to high levels of drainage; the water mound has shifted towards the southwest corner of the Bog (Appendix 6c).

Twenty-four different plant communities were mapped in Burns Bog (Appendix 2), including seven forested communities, nine-shrub or herb-dominated communities, and six sparsely to non-vegetated communities (Hebda et al., 2000). A number of these ecosystems are of natural origin, such as the mixed forests and pine-*Sphagnum* types, and represent moderate to high quality wildlife habitat, particularly for birds and small mammals. Some of the vegetation types have developed due to the drying effects of the drainage ditches, such as the birch and pine-salal forests. Much of the peat-mined area has naturally recolonized with white beak-rush ecosystems, which are important peat-forming communities. Some cleared areas have been slow to recover and have been colonized by herbaceous and weedy vegetation.

Studies were conducted during the Burns Bog Ecosystem Review (2000) to determine habitat suitability for a variety of wildlife, including raptors, rare and endangered bird species, rare and endangered small mammals, and amphibians. Almost all of the Burns Bog plant communities provide at least moderate habitat values for these species, but those of particular value included the mixed conifer and birch forests, Open Water, Pine-salal Forest, and Pine-*Sphagnum* Woodland (Appendix 7).

From the extensive studies and subsequent analysis carried out in the Burns Bog Ecosystem Review, the authors (Hebda et al., 2000) determined a zone of ecological viability that is required in order to preserve the viability of Burns Bog (Appendix 5). It is with the consideration of the importance of preserving this area from further disturbance that the four levels of government have made their proposal to purchase and protect over 2000 hectares of the Bog.

GOALS AND OBJECTIVES

Project Goal: The goal of this project is to demonstrate the environmental and societal importance of the ecological restoration of wetlands within the field of landscape architecture.

Project Objectives:

1) ***Ecological*:** To develop an ecological restoration proposal for Burns Bog, focusing on water management, plant community restoration with the goal to maintain habitat for rare and endangered wildlife, and monitoring of invasive species; the objective is to restore the Bog to a sustainable state, thus it will be framed by a systems approach (meaning that the focus will not only be on restoring the physical structure of the site, but also restoring the functional processes to a self-sustaining condition).

2) ***Functional*:** To locate and design a visitor centre and trail system to allow maximum access to diverse Burns Bog plant communities while minimizing physical damage to the bog ecosystem.

3) ***Experiential*:** To ensure that the recreational and educational design component of the Burns Bog restoration project fosters a public understanding of the ecology of the Bog, exposes visitors to the Bog's visual and ecological variety, and creates an environment in which individuals can explore and discover the fragility and beauty of a bog ecosystem.

Ecological Restoration Defined:
In order to realize the stated objectives, it is essential to define what ecological restoration means in the context of this thesis. We will define ecological restoration as an attempt to shift the ecosystem back toward a greater value that it currently has (Hunter, 1996), where 'greater value' is defined as:

- The return of hydrological function and vegetative communities appropriate to a raised bog ecosystem (not necessarily a single plant community)
- The protection of habitat for rare and endangered species, both plants and animals
- A relatively high diversity of plant communities for the next 50-100 years, both for diversity of wildlife habitat and as an intriguing educational tool for visitors

3.1 Rationale for Restoration

The authors of the Burns Bog Ecosystem Review (2000) determined from extensive consideration of a variety of topics, including wildlife, vegetation, and hydrology reports, that about 2,450 hectares of Burns Bog should be preserved in order for this unique ecosystem to remain ecologically viable (McDade, 2000) (Appendix 5). In February of 2001, the federal, provincial, regional, and municipal governments pooled resources and offered Western Delta Lands a rumoured $70 million, plus tax credits, for over 2000 hectares of the Bog. This offer was rejected by the landowners. In December of 2003, another deal for $78 million was offered. This time, the sale of 2,170 hectares was court-ordered, due to the financial and legal difficulties faced by the current owners (Guylas, 2003). The offer was thrown out of court due to sales of small parcels of the property by the landowner; a final offer of $73 million was accepted in early February of 2004, and the government purchase of just over 2100 hectares of Burns Bog became official at the end of March (Appendix 8). It appears as though the timing of this restoration proposal fits with the impending preservation of the Bog.

If the area required to preserve the ecological viability of Burns Bog is protected by this government purchase, the Bog will require restoration in order to reduce the impact of the past extractive activities and to speed the recovery of the bog ecosystem (Hebda *et al.*, 2000). The most pressing issue, as seen above, is the hydrological viability of the Bog. Steps have already been taken to remedy the major problem of water loss; the engineering department of the Municipality of Delta has installed ditch-blocking devices at key locations. Unfortunately, the hydrological results of the ditch blockages do not appear to have been documented.

If and when the hydrological integrity of the Bog can be restored and maintained in perpetuity, the next priority is vegetative recolonization of a number of disturbed sites that have not naturally regenerated to 'desirable' bog plant communities. Although it is very likely that natural, spontaneous vegetative colonization of some sort will occur, it is desirable to optimize conditions such that colonization and establishment of bog species is encouraged (Wheeler and Shaw, 1995). In establishing new plant communities on damaged surfaces, consideration will be given to creating habitat for red- and blue-listed species, and to maintaining a representative diversity of habitat types.

A Systems Approach

Wheeler and Shaw (1995) suggest that there are three possible approaches to restoration of raised bogs:

- Maintenance or recreation of wildlife interest not pertaining to bogs
- Maintenance or re-establishment of viable populations of typical bog species
- Maintenance or re-establishment of a regenerating, self-sustaining bog ecosystem

The last of the three approaches represents an ecosystem approach, as opposed to a species-centered one.

The restoration of Burns Bog will be framed by a systems approach, meaning that the focus is not only on restoring the physical structure of the site, but also on restoring the functional processes to a self-sustaining condition. This concept as it relates to Burns Bog is summarized in the following three key points (Hebda et al., 2000):

1) Efforts to maintain ecosystem integrity should include strategies to maintain biodiversity, particularly the species that are vital to the development of a bog ecosystem complex
2) Ecosystems are inherently dynamic; the sustainable condition is a dynamic one
3) Due to the dynamic nature of ecosystems, the focus should not be on the preservation of a particular species, a particular plant community, or a particular ecological end state, but instead on ensuring the circumstances that allow the elements and processes of an ecosystem to naturally persist or change are present.

Favourable Conditions for Restoration

Compared to bogs of Eastern Canada and Europe, Burns Bog is in a favourable condition for restoration. The reasons for this can be summarized as follows:

1) A large amount of natural bog vegetation remains within the Bog (a large zone of bog vegetation surrounds the disturbed zone and many patches exist within the disturbed zone); this amount of natural vegetation favours regrowth via existing seed banks (Appendix 3)

2) Most of the peat extraction occurred in the centre of the Bog (Appendix 6), resulting in naturally wet conditions being maintained in large areas of the Bog; therefore, surface rewetting and raising of the water table is less necessary in Burns Bog than in other bog restorations.
3) The hydrological area of the Bog covers almost 3500 hectares; there is more internal site diversity and a larger buffer from outside impacts than in most other bog restoration circumstances.

3.2 Rationale for a Visitor Centre

With the amount of media coverage that Burns Bog has received in recent years, it seems likely that there will be a great public demand to visit this place that so many have fought to protect. However, the sensitive nature of the Bog ecosystem requires a certain degree of restraint regarding public access. The vital peat-forming communities of Burns Bog are extremely fragile; even foot-traffic can damage the delicate micro-systems of the Bog (McDade, 2000). A number of the wildlife species, particularly the Greater Sandhill Crane, are wary of human contact. Because the Bog clearly cannot support the level of human use that is common to other GVRD parks and natural areas, McDade (2000) suggests that much of the Bog be protected from unrestrained public use as ecological reserve.

A well-programmed educational visitor centre and trail system can aid in the protection of the Bog. Interpretive displays and tours will educate the public about the importance of keeping part of the Bog as an ecological reserve. Raised boardwalks will allow foot access into the more intriguing areas of the Bog, while protecting the sensitive plants from trampling and reducing the likelihood of visitors roaming off the trails. A place that is destined to become both a regional and international tourist attraction requires good management; otherwise, in spite of our efforts, that which we have worked so hard to preserve could be lost.

DESIGNATION OF THE DONOR SITE

Since Burns Bog is unique in the Lower Mainland, it seems logical to use the undisturbed and naturally revegetated plant communities of the Bog as a reference model for the restoration. For the vegetative recolonization elements of the Burns Bog restoration project, it is necessary to locate and describe sites within the Bog that could potentially be utilized for plant collection (donor sites), such as large areas that contain a healthy *Sphagnum* population and are relatively easy to access. This search for donor sites would involve:

1) Determining which plant community each of the restoration sites will be restored to
2) Measuring the area of land that needs to be restored (e.g. the disturbed surfaces that have no redeeming vegetation); the donor area should be about 1/15 of that size (Quinty and Rochefort, 1997)
3) Selecting the donor sites; *Sphagnum* plants should be collected from areas considered least 'sensitive' to ensure that damage is minimized (Wheeler and Shaw, 1995)

Donor site selection is discussed in further detail in 'Restoration Recommendations'.

RESTORING THE HYDROLOGY OF BURNS BOG

5.1 Key Questions

After conducting a site analysis and a review of the relevant literature, I developed a number of 'Key Questions' that seemed to be central to my thesis. These Key Questions are answered below:

1) How do I determine whether blocking the ditches will be sufficient to maintain hydrological integrity? ***I can't. This is something that must be determined by years of water level monitoring.***

2) Relating to question 1, the crucial ditches have largely already been blocked by the Municipality of Delta Engineering Department; how do I determine if this has made a difference in the water table? ***I have water table data from the year 2000 for eleven dipwells. I could measure the water depth of these dipwells and compare it to the data from 4 years ago. This would not be an accurate comparison, but a rough idea for use in a discussion.***

3) Does the original east-west ridge form of the water mound have to be restored or can it be left at its current south-west point position? ***Although there is no certain answer to this question, Wheeler and Shaw (1995), Quinty and Rochefort (1997), and Hebda et al. (2000) do not mention that the historic shape of the water mound must be restored. It seems that the water table just needs to be raised such that it is sufficiently close to the surface throughout the year, in order to allow Sphagnum growth to reform the acrotelm. Also, to restore the water mound to its former position would require a restoration of the peat to its historic elevations; thus the restoration of the water mound form might follow the restoration of the peat accumulation process in the acrotelm.***

4) Is it possible to remove part of the catotelm from a raised bog and then replace the acrotelm, thereby lowering the water table level? ***Yes, it would be possible, as long as the acrotelm was replaced and remained functional after the process. Wheeler and Shaw (1995) do suggest removing the top layers of peat to lower the peat elevation towards the water table, but these recommendations are for recently-damaged bogs without a functioning acrotelm layer present. There are better researched and tested ways to raise the water table, such as bunding and ditch-blocking (see below).***

5) Relating to Question 4:
   - Would removing part of the catotelm be more damaging to the bog ecosystem than leaving it alone? ***Yes, because the process of natural regeneration has already begun in most damaged sites and the acrotelm would preferably be left alone to continue to produce peat. There are other less invasive and cheaper methods of raising the water table, as mentioned in the answer to Question 4.***
   - Has stripping of the acrotelm, removal of part of the catotelm, and subsequent replacement of the acrotelm ever been attempted in bog restoration? ***Not to my knowledge, although in some British cases the acrotelm has been stripped off, stored until a peat mining operation is completed, and then replaced (Wheeler and Shaw, 1995).***
   - Would it be easier to construct bunds around the affected areas to raise the water table? ***Probably.***

- If acrotelm removal and replacement was a feasible option, would it only have to occur in areas that are drying out? ***Yes, because most of the Bog has begun the process of natural regeneration into bog plant communities on its own.***

5.2 Rationale for Restoring the Hydrology of Burns Bog

Little damaged bogs have a consistently high water table, so the successful regeneration of a raised bog requires permanently wet conditions (Wheeler and Shaw, 1995). The lower water levels that are currently pervading throughout Burns Bog are undesirable because they are unsuitable for the growth of many bog plants and they may further oxidative decomposition of the peat.

Wheeler and Shaw (1995) identify five major aims of water management for raised bog restoration:

1) Identify the causes of the dry conditions
2) Increase the retention of nutrient-poor precipitation input
3) Elevate the level of permanent saturation as far as possible
4) Reduce water-level fluctuations
5) Prevent or reduce water inputs from other sources (e.g. mineral / nutrient enriched or polluted water sources)

As mentioned in the introduction, the key hydrological problem with Burns Bog is the loss of water through drainage ditches. Although many of the ditches have been blocked since the Burns Bog Ecosystem Review (2000) pointed out drainage ditches as a major concern to hydrological integrity, it is unknown whether this action has had any positive effect on the water table in the Bog, where positive effects would include a higher overall annual water level and a decrease in water level fluctuation throughout the year. Several consecutive years of water level measurements are required for comparison with pre-ditch-blocking levels.

5.3 Rewetting Options for Burns Bog

There are two types of rewetting options for a raised bog: to rewet a remnant of upstanding peat (a 'massif'), and to provide appropriately wet conditions in extensive cut-over surfaces ('depressions') (Figure 5). A massif may comprise an entire bog, an uncut remnant, or upstanding blocks within peat extraction complexes (Wheeler and Shaw, 1995). A depression may include an entire bog, a natural pond in an uncut area, or a pool formed by deep peat extraction. In the case of Burns Bog, the entire bog is a massif, there are a number of uncut and upstanding massif remnants, and there are a number of ponds that have resulted from the peat extraction processes.

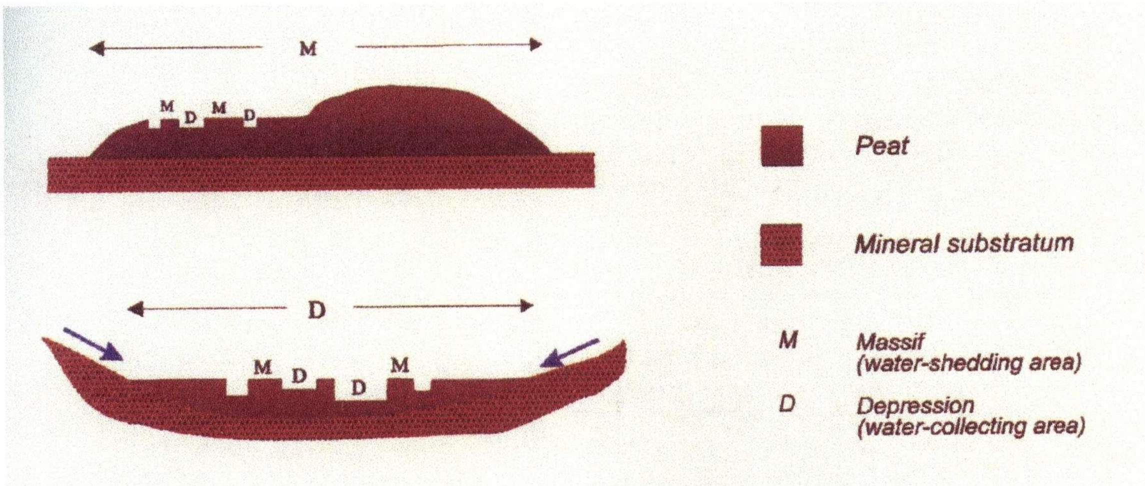


Figure 5: Illustrating massifs and depressions in a raised bog (Wheeler and Shaw, 1995).

Wheeler and Shaw (1995) describe a variety of rewetting options, all of which include ditch-blocking as the first step. Those that appear to be relevant to the topographic forms and hydrology of Burns Bog are discussed below:

1) ***Sculpting of the peat surface to the position of the water mound***
This is the idea that was brought up in Key Question #4, although in this case the top layer of the peat is simply removed. Problems with this option are that it may be difficult to predict the ultimate position of the water table and to sculpt the peat mound with the exactitude required (Wheeler and Shaw, 1995). This approach has been little-tried and appears to be relevant to Burns Bog only in areas where the acrotelm is absent and natural revegetation has not yet begun.

2) ***Elevation of the water level by containment within wall bunds***
A bund is defined as an embankment used to pond backwater to a greater extent than a dam (dams are generally used to block linear water courses) (Wheeler and Shaw, 1995). This method involves constructing wall bunds made of low-permeability peat or plastic, which effectively raises the impermeable base of the bog and elevates the water table level. Bund construction and maintenance is relatively expensive and potentially unstable, and the water table may not be sufficiently stable close to the peat surface, particularly on badly-damaged surfaces. This option is applicable for maintaining good quality bog vegetation where lateral water loss threatens survival, and may be less effective for renaturation of badly-damaged massifs (Wheeler and Shaw, 1995)

3) ***Inundation using parapet bunds***
This is a form of the bunding approach described above; the difference with this method is that parapet bunds extend above the level of the adjoining peat massif, to form a long, low surface dam against which water may be impounded, such that water might accumulate on the top of the peat massif (Wheeler and Shaw, 1995). In comparison, wall bunds only soak the peat and do not bring the water table above the surface. Parapet bunding may reduce the amplitude of water-level fluctuations, which is beneficial for the regrowth of vegetation. Though expensive, this method is more suited to the renaturation of badly-damaged surfaces than wall-bunding.

4) ***Inundation by reduction of the level of the peat surface to form lagoons***
This approach differs from option #1 (sculpting the peat mound) in that it aims to produce a series of hollows that can store water (Wheeler and Shaw, 1995). Inundated areas can act as *growth lagoons* for direct plant colonization, or as *feeder tanks* to help soak adjoining peat. This method leads to larger flooded areas than using parapet bund, and is more of a mire-centred approach as opposed to a species-centred one (Wheeler and Shaw, 1995). Unfortunately, this option may involve substantial peat extraction, which has obvious disadvantages. This method might be applicable in Burns Bog in small areas that have been colonized by birch and other weedy species.

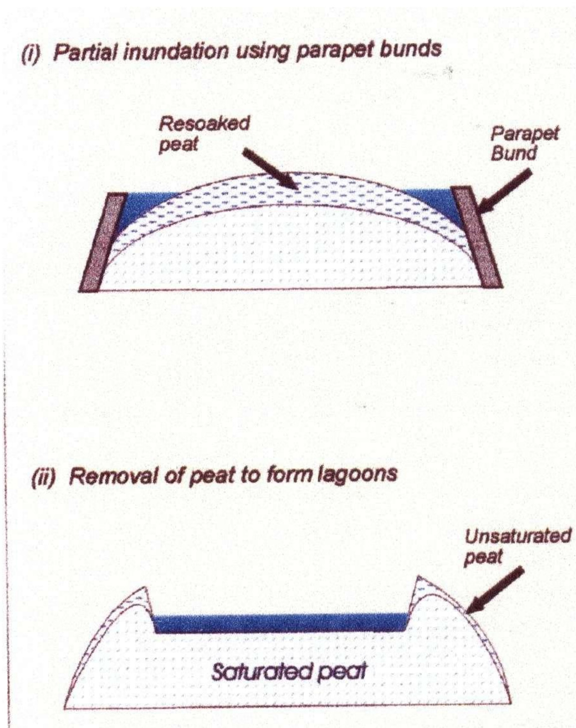


Figure 6: Illustrating inundation using parapet bunds and removal of peat to form lagoons

RESTORING THE VEGETATION OF BURNS BOG

6.1 Key Questions

After conducting a site analysis and a review of the relevant literature, I developed a number of 'Key Questions' that seemed to be central to my thesis. These Key Questions are answered below:

1) Do I want to maintain the current level of plant community diversity or allow the Bog to return to its historic configuration? ***I want to maintain a relatively high level of diversity for at least the next 50-100 years, although not necessarily retaining all of the current plant communities; some of the heavily disturbed or invasive communities will need to be restored.***

2) Is it feasible to maintain a certain level of plant community diversity, as opposed to allowing all of the plant communities to grow into a single low-shrub community? ***If there is money available, it would be physically possible to maintain a certain level of diversity by reverting some plant communities to earlier successional stages. Answering this question through a literature review is not possible, because the results would be site specific to Burns Bog. Small test plots should be set up throughout the Bog to determine rates of successional change.***

3) How long might each of the current plant communities take to return to the historic one (Pine-*Sphagnum* Low Shrub), if ever? (note: the answers below were determined by examining a time-since-disturbance map; the peat accumulation rate estimate comes from Mitsch and Gosselink, 2000)
    i. ***Bare surface = less than 60 years***
    ii. ***Herbaceous Vegetation on Disturbed Peat = more than 45 years***
    iii. ***White Beakrush communities = more than 30-40 years, in some areas this community will naturally remain indefinitely***
    iv. ***Open Water = more than 60 years, probably at least 100 years (assuming a vertical peat accumulation rate of 1m/100yrs)***
    v. ***Yellow Water-lily = more than 30-40 years, probably at least 100 years (assuming a vertical peat accumulation rate of 1m/100yrs)***

4) If natural regeneration of plant communities (those that don't currently require physical restoration) will take over 100 years, is it acceptable to allow that process to take place and let wildlife deal with it naturally? ***Yes.***

6.2 Rationale for Restoring the Vegetation of Burns Bog

When humans have altered or damaged any ecosystem, we have a responsibility to see that that ecosystem is left in a functional state. If we just leave the damaged ecosystem to its own devices, assuming that nature will eventually fix itself, we are being irresponsible. Any undesirable results of leaving a damaged ecosystem alone, such as the invasion of exotic species, will be the fault of those who damaged the ecosystem and then abandoned it, even if they had the best of intentions (Will Marsh, 2004 – personal communication).

It is evident that just such an occurrence of 'undesirable' events is currently taking place in Burns Bog. Many areas of the Bog, particularly those under the influence of drainage ditches, have dried out due to low water levels and high water table fluctuations during the year. The result of this drying is the growth of 'weedy' species such as birch (*Betula* spp.) and the subsequent reduction in *Sphagnum* growth due to shading, nutrient enrichment, and increased water loss due to evapotranspiration. As managers of an extremely rare ecosystem, we have a responsibility to ensure that it continues to function as a bog and not allow it to become a forested landscape (at least not at such an unnatural rate of succession). Options to ensure ecological integrity of Burns Bog include removal of weedy species, rewetting of dry areas, and replanting with appropriate bog vegetation, particularly *Sphagnum*.

6.3 Plant Communities of Little-Damaged Raised Bogs

The key plant type in a raised bog is moss, primarily *Sphagnum* spp., which grow in cushion-like spongy mats (hummocks), pools, and lawns (Mitsch and Gosselink, 2000; Wheeler and Shaw, 1995). *Sphagnum* is often associated with cotton-grass (*Eriophorum* spp.), various sedges (*Carex* spp.), and certain ericaceous shrubs such as cranberry and blueberry (*Vaccinium* spp.) and Labrador tea (*Rhododendron groenlandicum*) (Mitsch and Gosselink, 2000). Trees (usually shore pine [*Pinus contorta* spp. *contorta*] in the Fraser Lowland) in raised bogs are often found as stunted individuals that may be scarcely 1m high yet several hundred years old (Hebda et al., 2000; Mitsch and Gosselink, 2000).

According to Wheeler and Shaw (1995), vegetation types in raised bogs may include:

- *Sphagnum* and heath (ericaceous plants and possibly stunted conifers)
- *Sphagnum* pools (floating mats)
- Cotton-grass wet meadows and pools
- Rushes / sedges and wet heath

We can also add hardhack meadows to this, because historic bogs of the Fraser Lowland often contained hardhack communities in their lagg zones.

6.4 Plant Community Templates (the 'Reference Ecosystems')

Although Hebda et al. (2000) identified fourteen different plant communities in Burns Bog, simplified from twenty-four ecosystem types, only five of those plant communities will be considered as templates for restoration. Three of the identified plant communities (Cultivated Field, Disturbed Surface, and Herbaceous Vegetation on Disturbed Peat) are highly disturbed and not acceptable as bog plant communities (see section 6.3). Three of the forested communities (Birch Forest, Pine-salal Forest, and Pine-*Sphagnum* Woodland) are indicative of drying conditions and thus are not desirable as restoration templates; the final forested community (Mixed Conifer Forest) was historically only present at some of the edges of the Bog and does not grow in highly wet and acidic bog conditions. Although these forested communities are valuable in terms of wildlife habitat, they require relatively dry growing conditions and thus are not hydrologically compatible with the restoration of a raised bog ecosystem.

Two water-based communities (Open Water and Yellow Water-lily – Watershield) are valuable as habitat and as water sources for adjacent areas; it may be necessary to create more of these aquatic environments in the Bog. The remaining five plant communities (White Beakrush – *Sphagnum*, White Beakrush – Three-way Sedge, Hardhack Thicket, Pine-*Sphagnum* Low Shrub, Pine-*Sphagnum* Tall Shrub) are those that are commonly associated with raised bog ecosystems and may be chosen from for vegetative restoration of highly disturbed areas.

Hebda et al. (2000) note that White-Beakrush – Three-way Sedge is not a peat-forming community; the peat-forming White Beakrush – *Sphagnum* community is a superior choice as a restoration template. Hebda et al. (2000) identified the Pine-*Sphagnum* Tall Shrub community as a transitional community between wet bog conditions and dry bog conditions, meaning that the tall shrub form of the pine-*Sphagnum* community indicates a transition from Pine-*Sphagnum* Low Shrub to Pine-*Sphagnum* Woodland due to drying.

This leaves us with five choices for plant communities as templates for restoration:

- Open Water
- Yellow Water-lily - Watershield
- White Beakrush – *Sphagnum*
- Pine-*Sphagnum* Low Shrub
- Hardhack (only in the lagg zone)

Interestingly, this condensed list of acceptable template plant communities corresponds closely with the description of a typical raised bog plant community (above): *Sphagnum*, heath, rushes and sedges, and hardhack in marginal areas.

6.5 Environmental Gradients for Template Communities

In order to determine which of the above 'template' plant communities would be appropriate for any particular restoration site in Burns Bog, it was necessary to establish the environmental gradients for each plant community. The following five elements were tested for their correlation with each plant community (Appendix 11):

- Time since disturbance (peat mining)
- Peat mining method
- Depth to water table
- Depth of peat removal
- Underlying soil type

To test this correlation, I developed GIS maps for all of the above elements (Appendix 9). For each mapped element, I counted the number of polygons that each plant community fit into, in order to determine which environmental gradients might result in a particular plant community. Many of the potential environmental gradients could only be mapped for the areas that had been peat mined, because much of the remaining Bog is relatively intact and, for example, has no time since disturbance or peat mining method to record. A more detailed description of this method follows below:

Time Since Disturbance:

GIS data from the Environmental Assessment Office were available that showed rough estimates of peat mining dates. Some of these date estimates had ranges of more than 30 years (e.g. 1952-1980), so it was necessary to fill in the gaps by examining aerial photographs from UBC's Geographic Information Centre. I developed a final map with years-since-disturbance intervals of five years or less: 20-25, 25-30, 30-35, 35-40, 40-45, 45-50, 50-55, 55-60. For each plant community, I counted the number of times the plant community showed up in each date interval (by counting plant community polygons). From this data, I was able to create graphs that show how long it has been since each plant community was disturbed (Appendix 11). For example, 94% of the Pine-*Sphagnum* Low Shrub communities were disturbed 55-60 years ago.

Peat Mining Method:
The Environmental Assessment Office GIS data included peat mining method information for the entire Bog. There were four different methods used to mine the peat from Burns Bog. For each plant community, I counted the number of polygons within each of the mining method categories, and then graphed that information to show what peat mining method(s) correlated with that plant community.

Depth to Water Table:
To determine the depth of the water table throughout the Bog, it was necessary to compare GIS maps that showed the estimated contours of the current water table levels with the current estimated topography. To do this, I subtracted the water table level from the surface elevation for each plant community polygon. This method produced a map that shows the depth to the water table, in the following metre intervals: 0.0, 0.2, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0. If the current water table appeared higher than the current ground level, but there was no standing water recorded at that location, then the depth to water table was given a value of 0.2. From this map, I produced graphs showing how each plant community correlated with depth to water table (e.g. 100% of the open water polygons had a depth to water table value of 0.0).

Depth of Peat Removal:
I established the depth of peat removed during peat mining by comparing GIS maps showing the estimated historic elevation contours with the current estimated topography. I subtracted the current elevation from the historic elevation for each plant community polygon, and then graphed the results to see how depth of peat cut correlated with each plant community.

Underlying Soil Type:
The Environmental Assessment Office GIS data included a detailed soils map of the Burns Bog area. Using this map, I was able to correspond each plant community polygon with a particular soil type, and then graph that information to show how the plant communities correlated with soil type.

6.6 Correlation Between Plant Communities and Environmental Gradients

After developing the graphs described above for each potential environmental gradient (Appendix 11), I was able to see which elements more closely corresponded with plant community development. As might be expected, the plant communities correlated the most strongly with peat mining method and time since disturbance. This indicates that the majority of the plant communities that were mined are likely to be in various successional stages. Depth to water table graphs produced bell curves for most plant communities, indicating that each plant community has a range of water table levels that it tolerates; thus, this is a relatively important environmental gradient to understand when planning to establish new plant communities in Burns Bog. Most plant communities existed on a relatively small number of soil types, suggesting that soil type is another important environmental gradient to consider. Depth of peat removed had variable results and did not correlate strongly enough with any plant community to use this as an environmental element.

From the above assessment, we can list the environmental gradients for each plant template plant community:

Open Water:
Most Common Depth to Water Table: 0.0m
Most Common Soil Types: LUMBUM Series Fibric Mesisol (forest peat)

Yellow Waterlily – Watershield:
Most Common Depth to Water Table: 0.0m
Most Common Soil Types: LUMBUM Series Fibric Mesisol (forest peat) and Typic Mesisol (*Sphagnum* peat), TRIGGS Series Mesic Fibrisol (*Sphagnum* peat)

White Beakrush – Sphagnum:
Most Common Depth to Water Table: 0.2-0.5m
Most Common Soil Types: LUMBUM Series Fibric Mesisol (forest peat) and Typic Mesisol (*Sphagnum* peat), TRIGGS Series Mesic Fibrisol (*Sphagnum* peat)

Pine-Sphagnum Low Shrub:
Most Common Depth to Water Table: 0.5-1.5m
Most Common Soil Types: LUMBUM Series Fibric Mesisol (forest peat) and Typic Mesisol (*Sphagnum* peat), TRIGGS Series Mesic Fibrisol (*Sphagnum* peat) and Typic Fibrisol (*Sphagnum* peat)

Hardhack:
Most Common Depth to Water Table: varies (most common = 0.2, 0.5, 1.5m)
Most Common Soil Types: LUMBUM Series Fibric Mesisol (*Sphagnum* peat), LULU Series Terris Mesisol (*Sphagnum* peat)

The above information allows us to determine which template plant communities can be established at any particular site, given the soil type and the depth to the water table.

SPECIES OF CONCERN IN THIS RESTORATION

7.1 Wildlife

Within the Goals and Objectives of this thesis is the mandate to protect and enhance habitat for rare and endangered species. Thus, consideration must be given to species–habitat relationships when deciding how to restore and maintain the vegetative communities of Burns Bog. Table 1 (below) contains the red- and blue-listed wildlife species that were confirmed by Summers and Gebauer (1999a and 1999b), Fraker et al., (1999), and Gebauer (1999). The absence of amphibians and reptiles in this list is due to lack of substantiated sightings; four red- and blue-listed amphibians and reptiles were searched for intensively during the 1999 surveys and were not located within the Burns Bog study area (Knopp and Larkin, 1999). In this thesis, the focus will be on habitat for confirmed red-and blue-listed species, and within those, only those species of either high or moderate management concern with be considered.

Table 1 shows that only seven of the fourteen provincially listed species confirmed in Burns Bog are of high or moderate management concern. Those species of low management concern are listed as such because of lack of nesting or foraging habitat in Burns Bog, lack of on-the-ground observation (vs. flying over), or species that are relatively common within the Lower Mainland.

In general, there are three major habitat types used by red- and blue-listed species in Burns Bog: forested, open water, and open heath communities. Small mammals, including the Southern Red-backed Vole, Pacific Water Shrew (*Sorex bendirii*), and Trowbridge's Shrew (*Sorex trowbridgii*) were found in forested habitats (Fraker et al., 1999). The Barn Owl (*Tyto alba*) and the Great Blue Heron (*Ardea herodias*) also inhabit the forested plant communities of Burns Bog (Summers and Gebauer, 1999). The American Bittern (*Botaurus lentiginosus*) prefers open ponds and also likely frequents the common rush-dominated areas in the south-western areas of the Bog (Summers and Gebauer, 1999). The Greater Sandhill Crane was found most often in the open heath areas, including the White Beak-rush communities, the Pine-*Sphagnum* – Low-Shrub community, and nearby agricultural fields (Gebauer, 1999). The Greater Sandhill Crane (Georgia Depression population) and the Southern Red-backed Vole are of particular management concern in Burns Bog because of their very limited or lack of occurrence elsewhere in the Lower Mainland and in British Columbia.

The open water and open heath plant communities that provide habitat for these rare and endangered species will be given priority in the vegetative restoration. Forested plant communities will not be recommended for planting, due to their damaging effects to bog ecosystems, but existing perimeter forested areas will be protected wherever possible.

Wildlife Species of Concern	Provincial Listing	Management Concern	Plant Community (Habitat)	Notes
Southern Red-backed Vole (*Clethrionomys gapperi occidentalis*)	Red	High	Pine-Sphagnum – Woodland Pine-Salal Forest Mixed Conifer Forest	Found only in Burns Bog (nowhere else in the province)
Pacific Water Shrew (*Sorex bendirii*)	Red	High	Mixed Conifer Forest	
Greater Sandhill Crane - Georgia Depression population (*Grus canadensis* pop. 1)	Red	High	White Beak-rush – Sphagnum White Beak-rush – Three-way Sedge Pine-Sphagnum – Low Shrub Cultivated Fields Herbaceous Vegetation on Disturbed Peat	
Barn Owl (*Tyto alba*)	Blue	High	Mixed Conifer Forest Pine-Salal Forest Birch Forest Pine-Sphagnum – Woodland Cultivated Fields	Roosts in perimeter forests of the Bog
Trowbridge's Shrew (*Sorex trowbridgii*)	Blue	Moderate	Birch Forest Mixed Conifer Forest Pine-Salal Forest Pine-Sphagnum – Woodland	Relatively common in the Lower Mainland but habitat is decreasing and becoming fragmented
American Bittern (*Botaurus lentiginosus*)	Blue	Moderate	Open Water Herbaceous Vegetation on Disturbed Peat	
Great Blue Heron (*Ardea herodias*)	Blue	Moderate	Birch Forest Mixed Conifer Forest	Uses the Bog for foraging

			Pine-Salal Forest Pine-Sphagnum – Woodland	
Green Heron (*Butorides virescens)*	Blue	Low	Open Water	At the northern end of its range in the Lower Mainland
California Gull (*Larus californicus*)	Blue	Low	Unknown / Limited Habitat in Burns Bog	Common in the Lower Mainland
Caspian Tern (*Sterna caspia*)	Blue	Low	Unknown / Limited Habitat in Burns Bog	Never observed on the ground and not expected to nest in the Bog
Peregrine Falcon (*Falco peregrinus pealei*) and (*Falco peregrinus anatum*)	Blue (F.p. *pealei*) and Red (F. p. *anatum*)	Low	Unknown / Limited Habitat in Burns Bog	Suitable nesting habitat not available; forages in foreshore areas such as Boundary Bay
Short-billed Dowitcher (*Limnodromus griseus*)	Blue	Low	Unknown / Limited Habitat in Burns Bog	A common migrant in the Lower Mainland
Short-eared Owl (*Asio flammeus*)	Blue	Low	Unknown / Limited Habitat in Burns Bog	Suitable nesting habitat is limited in the Bog and widespread dense thickets may hinder hunting of prey
Purple Martin (*Progne subis*)	Red	Low	Unknown / Limited Habitat in Burns Bog	Not expected to nest within the Bog

Table 1: Matrix illustrating wildlife species of management concern in Burns Bog and their use of Burns Bog plant communities. Those species with low management concern are not included in the habitat management discussion of this thesis. References for the above information include: Summers and Gebauer (1999a), Summers and Gebauer (1999b), Fraker et al. (1999), Andrusiak (1992), Gebauer (1999), and Hebda et al. (2000).

7.2 Plants

Only one provincially listed plant species was found during the 1999 survey in Burns Bog: Rice cutgrass (*Leersia oryziodes*). Rice cutgrass was found in a cranberry field and adjacent drainage ditches in the western part of the Bog (Madrone Consultants, 1999).
Four plant species are at their southern geographic limits in Burns Bog: velvet-leaved blueberry (*Vaccinium myrtilliodes*), crowberry (*Empetrum nigrum*), cloudberry (*Rubus chamaemorus*), and bog-rosemary (*Andromeda polifolia*) (Hebda et al., 2000). The plant communities each of these species is associated with are listed below (Madrone Consultants, 1999):

Velvet-leaved blueberry:

- Pine-*Sphagnum* – Low Shrub
- Pine-*Sphagnum* – Tall Shrub
- Pine-*Sphagnum* –Woodland
- Pine-Salal Forest

Crowberry:

- Pine-*Sphagnum* – Low Shrub (only undisturbed areas)

Cloudberry:

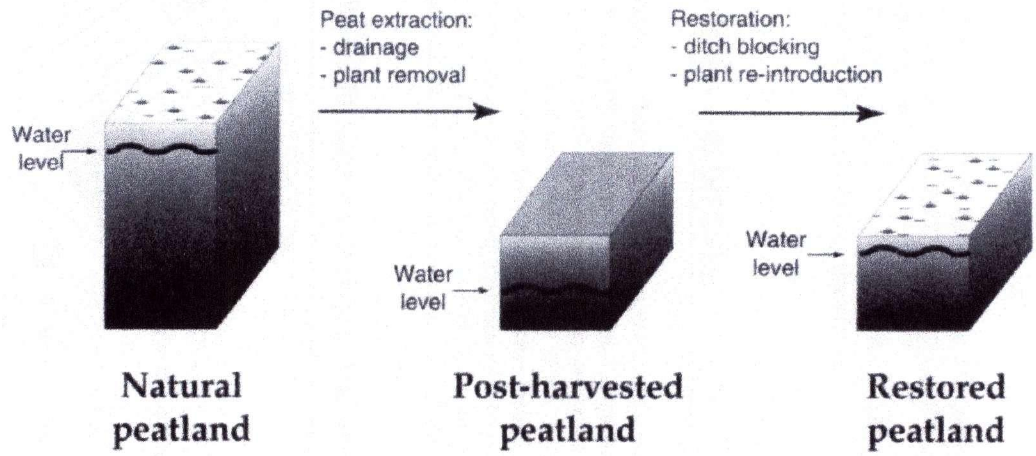
- Pine-*Sphagnum* – Low Shrub (only undisturbed areas)
- White Beak-rush – *Sphagnum* (only undisturbed areas)

Bog-rosemary:

- Pine-*Sphagnum* – Low Shrub (only undisturbed areas)
- White Beak-rush – *Sphagnum*

Protection of the remaining undisturbed plant communities of Burns Bog is clearly important for the maintenance of the above plant species, and particularly the Pine-*Sphagnum* – Low Shrub and White Beak-rush – *Sphagnum* communities. Protection of the western agricultural field that contains the rice cutgrass population is also an important consideration.

RESTORATION SCENARIOS



Source: Quinty and Rochefort (1997)

To illustrate the potential effects of a number of management scenarios for Burns Bog, I list and describe below a number of alternative actions, ranging from non-interference to extensive management and maintenance. This description will only consider the hydrology, vegetation, and potential impacts to wildlife habitat; impacts by human visitors will be considered in Chapter 13, and monitoring/maintenance will be considered in Chapters 11 and 12.

Option 1: Protect the Bog

Purchase and protection of the Bog as an ecological reserve must be the first step in any restoration scenario. This action will stop further direct degradation to the bog ecosystem. However, without taking any further action to counteract the current drying trends and the invasion of exotic species, indirect damage from peat mining and drainage ditches will continue to occur and the bog will continue to degrade until it no longer functions as a viable raised bog ecosystem (Hebda et al., 2000).

Option 2: Block the Ditches

There are three main concerns in rewetting peat-mined sites:

- Maintaining a consistently high water level in the peat
- Providing adequate water storage
- Preventing lateral water loss (Wheeler and Shaw, 1995)

Blocking or damming the drainage ditches is the fundamental step that must be taken in order to rewet the bog ecosystem, because rewetting of an ombotrophic bog can only be achieved by retaining the incoming precipitation (Wheeler and Shaw, 1995). This is a relatively simple step, often only requiring dams of peat, plastic, wood, or sheet metal every 100 metres along the length of the ditch (Quinty and Rochefort, 1997). In fact, most of the dams that run out of Burns Bog have already been blocked, either by the Municipality of Delta Engineering Department or by beavers.

In this scenario, managers will need to examine the current extent of the ditch-blocking in the Bog and record which ditches have not been blocked and which require more thorough damming. In the case of those ditches that still require blocking, the following principles apply (Wheeler and Shaw, 1995):

- Clear vegetation where dams are built to ensure a good seal
- It is particularly important to block deep ditches that cut into mineral soil
- Peat dams will often be adequate, but may require an impermeable core of plastic wood, or metal sheeting
- Number and spacing of dams depends on the size, fall, and orientation of the drainage ditch
- Pay careful attention to the impacts on adjacent properties
- On-going maintenance of dams is essential
- Adequate provision must be made for overflow precipitation

The last point in the list above is meant to bring attention to the fact that even in undisturbed bogs, high run-off occurs from autumn to spring when precipitation surpasses evaporation (Wheeler and Shaw, 1995). Therefore, any measures used for reduction in outflow from the Bog, such as blocking drainage ditches, must have the capacity to deliver peak discharges out of the Bog (Wheeler and Shaw, 1995). If adequate provision is not made for overflow water, the following may occur (Wheeler and Shaw, 1995):

- Erosion of the regenerating peat surface
- Damage to the dam network and bunds
- Damage to the recolonist vegetation

Quinty and Rochefort (1997) include the following ditch-blocking techniques in their "Peatland Restoration Guide":

- Fill the ditch with peat for a distance of 2-3 metres, then compact the peat with heavy machinery
- Block the ditches at an interval of about 100 metres
- Use well-decomposed peat for ditch-blocking (e.g. not peat from the acrotelm), but ensure that the machinery used to remove the peat does not cut into the underlying mineral layer (this would lead to nutrient enrichment and the possible growth of undesirable plants)
- A backhoe or clamshell can be used to extract the decomposed peat and compact it in the ditch to block the flow of water (bulldozers can also be used, but they are less efficient)
- Do not completely fill in the ditches (this allows for topographical variety)

<u>Option 3: Block the Ditches; Remove Weedy Vegetation</u>

Most of the key drainage ditches in the Bog have been blocked, and yet birch and other weedy species continue to thrive in some areas. This suggests that removing scrub vegetation from dry areas without any additional rewetting action would simply result in a regrowth of the same weedy vegetation the following spring. Therefore, this option alone would likely be a waste of time and resources.

However, vegetation management is a necessary step to reduce the invasion and spread of undesirable species. Scrub vegetation, such as birch, damages a bog in the following ways (Wheeler and Shaw, 1995):

- Shading, through living leaves and leaf litter
- Increased water loss through evapotranspiration
- Reduction of water input through interception of rainfall
- Nutrient enrichment through leaf fall
- Provision of roosting posts for birds (droppings cause nutrient enrichment)
- A positive feedback through the production of seeds

Birch and other undesirable species may be removed by hand or with machinery. Fire is a dangerous control measure because the fire spreads into the peat layer and burns uncontrollably. Herbicides may be required in highly damaged areas, but are not recommended for their obvious environmental impacts. Since Birch Forest cover has spread over the driest areas of the Bog, it may be possible to bring in some types of machinery and not be concerned about machines becoming mired in the Bog.

Option 4: Block the Ditches; Remove Weedy Vegetation; Construct Bunds around Dry Areas

Bunds may be constructed from peat, clay, or plastic membranes. Wall and parapet bunds can be used to:

- Seal the edges of upstanding bog remnants
- Reduce run-off from remnants
- Impound water within existing peat cuttings
- Create new lagoons

Wheeler and Shaw (1995) stress that bunds should be kept as wet as possible, and recommended the construction of a trench on the remnant side of the bund to ensure a supply of water.

With respect to the wet season overflow problem brought up in Option #2 above, Wheeler and Shaw (1995) suggest the following techniques to provide wet season overflow control on bunds:

- Lay an adjustable collar-overflow pipe system throughout the bund
- Use a sluice
- Maintain a marginal ditch to act as a lagg and carry the surplus water away (must ensure that the water level in the ditch remains high)

This option would likely result in an effective rewetting of Burns Bog, therefore allowing peat-forming communities, and particularly *Sphagnum* mosses, to colonize and reproduce. The only disadvantage with this method is the uncertainty regarding the time it would take for peat-forming communities to regenerate naturally, and whether these desired communities would form at all, particularly in the sites where weedy species were growing.

Option 5: Block the Ditches; Rewet Dry Areas by Bunding or Cutting Peat

This option is simply a more economical version of Option #4. In some areas of the Bog, weedy vegetation may not require removal. The act of rewetting alone may cause the undesirable species to die off because they are generally less tolerant of very wet soil conditions than typical bog species; this would then leave the ground open for recolonization by desirable bog species, such as *Sphagnum*.

As seen in Chapter 5, bunding is just one of several options for rewetting dry areas of the Bog. Another rewetting option involves cutting the surface of the peat down to the existing water table, effectively raising the water table level in the chosen area. This option would be feasible in areas of the Bog where the acrotelm has been removed by peat-mining and other disturbances; the absence of the sensitive peat-forming acrotelm allows the freedom to remove peat without fear of interrupting existing peat-forming processes. Once the peat was contoured close enough to the water table, conditions would be suitable for the natural recolonization of *Sphagnum* and other bog vegetation.

Option 6: Block the Ditches; Remove Weedy Vegetation; Construct Bunds around Dry Areas; Replant Damaged and Cleared Areas

With respect to the timing of plant restoration, the drainage ditches should be blocked (and any bunds constructed) during the fall preceding plant re-introduction because this allows storage of snow melt water and high winter precipitation levels during the spring (Quinty and Rochefort, 1997).

One of the most important considerations in restoring a damaged bog is how to regain the *Sphagnum* cover, because *Sphagnum* is required to reinstate a functioning acrotelm (Wheeler and Shaw, 1995). There are two basic ways to facilitate the regrowth of *Sphagnum*:

- *Sphagnum* collection (this should only be done for small sites)
- *Sphagnum* farming (preferable for large sites)

***Sphagnum* Collection**:

The first step in plant collection is to choose the collection site(s). Donor sites should be the 'least sensitive' areas of the donor ecosystem, and should preferably be in the same geographic area (Wheeler and Shaw, 1995). In the case of Burns Bog, the donor sites will simply be those areas of Burns Bog that have remained intact or that have naturally reformed healthy peat-forming communities. Treeless areas occupied by *Sphagnum* are ideal for collection sites, and within those sites, areas dominated by *Sphagnum* forming hummocks and flats should be given priority (Quinty and Rochefort, 1997). The reason for collecting the more drought-tolerant *Sphagnum* species, as opposed to those that grow in hollows and pools, is that the more flood-tolerant species will have difficulty re-establishing on open fields where conditions are dry (Quinty and Rochefort, 1997).

The size of the collection surface is determined by the size of the areas requiring revegetation. Quinty and Rochefort (1997) suggest that the borrowing site be 1/15 of the size of the area to be restored; this ratio minimizes the impacts of plant collection in the donor site while ensuring sufficient plant material for revegetation. The preferable shape of the collection site would be a long and narrow strip (Quinty and Rochefort, 1997), presumably to maximize the ability of the surrounding vegetation to recolonize the donor site after plant removal.

Sphagnum collection can be accomplished using a rotivator, which should pass only once and only to a depth of about 10cm over the donor area to shred the living plants (Quinty and Rochefort, 1997). A front end loader can then be used to load a truck with the shredded plant material for transportation to the restoration sites. The *Sphagnum* should be piled at the restoration site the same day as it is removed from the donor site; in cool temperatures, the shredded *Sphagnum* can sit for a few days at the restoration site without drying out.

The *Sphagnum* can be scattered using a manure spreader, completely covering the bare peat to a depth of 1-2 cm. It is also recommended to cover the shredded plants with a straw mulch to maintain the humidity of the plants; without this protection, the *Sphagnum* can dry very rapidly and die (Quinty and Rochefort, 1997). The mulch may need to be spread by hand because driving a tractor over the newly spread *Sphagnum* might damage the plants.

One must keep in mind that these machinery recommendations come from Quinty and Rochefort's "Peatland Restoration Guide" (1997), which is based on the restoration of peatlands in eastern Canada. They suggest that the machinery be used in early spring, when the ground is still mostly frozen, so that the machinery doesn't sink and become mired in the bog. The climate in the Lower Mainland is much milder and the ground is unlikely to be frozen in early spring, if ever. Thus, it might be necessary to undertake the above *Sphagnum* collection and spreading actions by hand, with much lighter machinery, or with machinery that has been specially adapted to the soggy ground conditions in Burns Bog.

***Sphagnum* Farming**:
All *Sphagnum* species can reproduce vegetatively. One can increase the amount of *Sphagnum* plants available for restoration projects by propagating *Sphagnum* in 'nursery' pools. It is best to use a mix of aquatic and terrestrial *Sphagnum* species, to increase the chances of plant survival and growth (Ferland and Rochefort, 1997). In *Sphagnum* farming, fragments of *Sphagnum* are 'broadcast' into pools of water. The *Sphagnum* grown in these 'nursery' pools can be used on large restoration areas in place of *Sphagnum* collected from donor sites. *Sphagnum* species that might prove best suited to farming conditions, due to their range of moisture requirements and their existing widespread growth in the Bog, include: *Sphagnum capillifolium, S. fimbriatum, S. fuscum, S. pacificum, S. papillosum*, and *S. tenellum.*

Vascular Plants:
It is also beneficial to transplant vascular bog species into restoration sites, particularly because it has been shown that species such as *Eriophorum* spp. and *Juncus* spp. afford protection against wind and wave action in flooded areas, and provide a more suitable microclimate for *Sphagnum* (Wheeler and Shaw, 1995). If vascular plants are used, it is important to ensure a balance between vascular and *Sphagnum* plants, such that the nurse vascular plants do not outcompete the *Sphagnum* and create an undesirable, non-peat-forming plant community. Test plots are always recommended.

Wheeler and Shaw (1995) note the following considerations for transplanting vascular bog plants:

- Carry out the transplant in autumn or early spring, to allow vegetation to establish before summer drought
- Transplant material as soon as possible after collection, to avoid drying
- It is crucial to maintain high and stable water levels
- It should be apparent after one growing season whether the transplants have been successful; any reasons for failed transplants should be noted before replacement
- Use phosphorus fertilization with caution: it is still experimental, it may favour growth of 'undesirable' species, and it may stimulate the microbiota, leading to increased peat decomposition

Option 7: Block the Ditches; Remove Weedy Vegetation; Construct Bunds around Dry Areas; Replant Damaged and Cleared Areas; Manage for Long-term Plant Community Diversity

As mentioned in the rationale for vegetative restoration, Burns Bog is a heavily disturbed site and we have a responsibility to see that it continues to function. John Lyle (1985) defines a place that combines human activity with natural areas as a 'human ecosystem'. What Lyle means by this is that although humans like to think of themselves as somehow separate from nature, we are integral, interacting components of ecosystems at every level. In fact, Lyle (1985, p. 80) argues that the "network of human control has come to encompass all living things, and the responsibility is clearly ours". The small natural areas remaining throughout the world, such as Burns Bog, are dependent for their survival on human foresight and intelligence; without our conscious control, ecosystems created or heavily altered by human activities "usually do not work very well" (Lyle, 1985, p. 16). We have an ethical obligation to manage Burns Bog and ensure its continued survival; even though we lack enough information to make certain that the restoration of Burns Bog is a success, we must "recognize at the same time that we will have to do it anyway" (Lyle, 1985, p. 16).

We are responsible for ensuring that the Bog remains in a functional state, and because it is a human ecosystem, we are also responsible for ensuring that human values are respected. As stated in the Goals and Objectives, the purpose of this particular ecological restoration is to shift the ecosystem back toward a greater value that it currently has, where 'greater value' is defined as:

- The return of hydrological function and vegetative communities appropriate to a raised bog ecosystem (not necessarily a single plant community)
- The protection of habitat for rare and endangered species, particularly small mammals, amphibians and reptiles, and the Greater Sandhill Crane
- A relatively high diversity of plant communities for the next 50-100 years, both for diversity of wildlife habitat and as an intriguing educational tool for visitors

Thus, in this restoration scenario, I proposed to maintain a relatively high level of plant community diversity for at least the next 50-100 years, although not necessarily retaining all of the current plant communities; some of the heavily disturbed or invasive communities will need to be restored. It would be possible to maintain a certain level of diversity by reverting some plant communities to earlier successional stages. To determine whether this is possible in Burns Bog, a literature review will not suffice; small test plots should be set up throughout the Bog to determine rates of successional change. This procedure might not be an expensive one; a few hours spent clearing a small patch of vegetation with a backhoe might suffice.

RESTORATION RECOMMENDATIONS

The recommendations described below are based on the information presented earlier in this paper, particularly Chapters 5, 6, 7, and 8. The literature review information on hydrology, vegetation, and wildlife provided criteria with which I was able to make decisions regarding restoration actions. The Restoration Scenarios were meant to summarize all possible options for the restoration of Burns Bog; elements from most of these scenarios have been incorporated into the recommendations below, based on their specific ecological and economic value for each area requiring restoration.

9.1 Hydrology

Although it appears that the restoration recommendations described in this chapter only focus on plant community restoration, the rewetting and thus the hydrological restoration of Burns Bog will largely be accomplished within these actions. For example, a number of the areas that are recommended for restoration will have their water levels raised by either removing a top layer of peat or by using a bunding approach.

However, it is critical that three actions involving the drainage ditches in Burns Bog be carried out before any vegetative restoration takes place:

1) All remaining open ditches must be blocked
2) The condition of ditches that were blocked in the past must be assessed to ensure a proper seal
3) Provision must be made for wet season overflow

As mentioned in Chapter 12, water table levels will have to be assessed for a number of years to determine whether blocking the ditches indeed brings about the desired effect of rewetting Burns Bog.

9.2 Restoration Polygons

This chapter is meant to be read in conjunction with Table 2 and Appendix 10. Appendix 10 illustrates the locations of the nineteen plant community polygons chosen for restoration, and Table 2 (below) describes the recommended restoration actions for each polygon and the criteria on which those actions are based.

The existing plant community polygons chosen for restoration are mostly either Disturbed Surface or Herbaceous Vegetation on Disturbed Peat. There are also two Birch Forest polygons. The target communities are generally those listed in section 6.4, and include White Beak-rush – *Sphagnum*, Pine-*Sphagnum* – Low Shrub, Hardhack, and Open Water.

Recommended actions are described for each plant community polygon, and include:

- Field-testing to ensure that the soil, water table depth, and water chemistry GIS maps are accurate for each of the sites in question; existing and target plant community environmental gradients appear to match on these GIS maps, but this information must be tested on the ground to verify its accuracy
- Clearing weedy or existing vegetation

Table 2: Recommended restoration actions for Burns Bog. This table is meant to be read in conjunction with Appendix 10 (Restoration Polygons).

Polygon Number	Existing Plant Community	Target Plant Community	Recommended Action(s)	Decision Criteria
1	Disturbed Surface	White Beak-rush - *Sphagnum*	▪ Field test for soil and water depth compatibility ▪ Clear any weedy plants ▪ Replant with: ➢ *Sphagnum tellenum* ➢ White Beak-rush	▪ Will increase the abundance of peat-forming communities (aiding acrotelm formation) ▪ Will provide habitat for: ➢ Greater Sandhill Crane
2, 3, 6	Disturbed Surface	Hardhack	▪ Field test for soil and water chemistry compatibility ▪ Replant with: ➢ Hardhack (majority) ➢ Sweet gale ➢ Labrador tea ➢ Cascara ➢ Pacific crab apple	▪ Will re-establish lagg vegetation in perimeter areas (part of hydrological restoration)
4, 5	Disturbed Surface	Non-bog or none	▪ Ensure that land uses in these two polygons do not impact the Bog adversely (e.g. nutrient inputs, pollution, exotic species)	▪ These polygons fall outside the zone of ecological viability and are already developed ▪ Restoration is neither necessary nor desired in non-bog areas
7	Disturbed Surface	Plant production site for restoration purposes ("Restoration Centre")	▪ Purchase land from owner ▪ Rezone to agricultural use ▪ Clear concrete and other construction debris down to exposed peat / soil ▪ If soil is productive, use this site as a production area for bog restoration plants	▪ Site is currently zoned for industrial extraction; the mixed conifer forest surround this site is extremely important habitat and disturbance in this area should be minimized ▪ Site is close to a residential area and is this ideal for school and community tours of a restoration

				project (community interaction and promotion) ▪ Site is close to restoration sites, so plant transport and storage costs will be minimized
8	Disturbed Surface	Hardhack	▪ Field test for soil and water chemistry compatibility ▪ Connect site with adjacent Burns Bog Ditch (an existing lagg zone) by digging site to same depth as Burns Bog Ditch (no more than 1 metre deep) ▪ Replant with: ➢ Hardhack (majority) ➢ Sweet gale ➢ Labrador tea ➢ Cascara ➢ Pacific crab apple	▪ Will re-establish lagg vegetation in perimeter areas (part of hydrological restoration)
9	Disturbed Surface	Open Water	▪ Cut peat to 1 metre below water table and leave as open water	▪ Will provide more open water habitat on the east side of the Bog, particularly for the American Bittern, other waterbirds, small mammals, and amphibians and reptiles ▪ Will create more wet conditions on this drier side of the Bog
10	Disturbed Surface	Hardhack	▪ Field test for soil and water chemistry compatibility ▪ Clear concrete and other construction debris down to exposed peat / soil ▪ Cut peat down to depth of adjacent hardhack areas	▪ Will add to existing adjacent hardhack complex ▪ Will re-establish lagg vegetation in perimeter areas (part of hydrological restoration)

			▪ Replant with: ➢ Hardhack (majority) ➢ Sweet gale ➢ Labrador tea ➢ Cascara ➢ Pacific crab apple	
11, 12	Disturbed Surface	Pine-*Sphagnum* – Low Shrub	▪ Field test for soil compatibility ▪ Bund perimeter of these two sites to raise water table to within 0.5 metres of surface ▪ Replant with: ➢ *Sphagnum capillifolium* ➢ Labrador tea ➢ Bog blueberry	▪ Will increase the abundance of peat-forming communities (aiding acrotelm formation) ▪ Adjacent plant communities match with target community ▪ Will provide habitat for: ➢ Greater Sandhill Crane
13	Disturbed Surface	Pine-*Sphagnum* – Low Shrub	▪ Field test for soil compatibility ▪ If adjacent farmers will allow, remove this road and cut down to adjacent peat levels ▪ Replant with: ➢ *Sphagnum capillifolium* ➢ Labrador tea ➢ Bog blueberry	▪ Will increase the abundance of peat-forming communities (aiding acrotelm formation) ▪ Adjacent plant communities match with target community ▪ Will provide habitat for: ➢ Greater Sandhill Crane
14, 15	Birch Forest	Hardhack	▪ Bund to raise water table to within 0.5 metres of surface ▪ Birch trees and other woody vegetation should die from over-wet conditions ▪ When forest has been rewetted sufficiently, plant hardhack in clearings (should spread quickly because hardhack is a thicket-forming species)	▪ Will re-establish lagg vegetation in perimeter areas (part of hydrological restoration) ▪ This is a cheaper way of restoring this large area than clearing the site and removing peat to raise the water table level

16, 17	Herbaceous Vegetation on Disturbed Peat	Pine-*Sphagnum* – Low Shrub	▪ Field test for soil and water depth compatibility ▪ Clear existing vegetation ▪ Replant with: ➢ *Sphagnum capillifolium* ➢ Labrador tea ➢ Bog blueberry	▪ Site is adjacent to other Pine-*Sphagnum* – Low Shrub communities ▪ Site too dry for White Beak-rush communities; thus, it is cheaper and more logical to plant Pine-*Sphagnum* (no rewetting required)
18	Herbaceous Vegetation on Disturbed Peat	Pine-*Sphagnum* – Low Shrub	▪ Field test for soil and water depth compatibility with adjacent Pine-*Sphagnum* – Low Shrub sites ▪ Clear existing vegetation ▪ Replant with: ➢ *Sphagnum capillifolium* ➢ Labrador tea ➢ Bog blueberry	▪ Existing plant community has low habitat value ▪ Provides habitat for: ➢ Greater Sandhill Crane
19	Herbaceous Vegetation on Disturbed Peat	White Beak-rush - *Sphagnum*	▪ Field test for soil and water depth compatibility ▪ Clear existing vegetation ▪ Replant with: ➢ *Sphagnum tellenum* ➢ White Beak-rush	▪ Site too wet for Pine-*Sphagnum* – Low Shrub community ▪ Provides habitat for: ➢ Greater Sandhill Crane

Note: Weedy plants, as referred to in this table, include birch, highbush blueberry, and any other exotic species.

Note: Peat removal is used instead of bunding in several "Disturbed Surface" plant communities to raise the water table level because the acrotelm has already been badly damaged or completely removed in these areas. The polygons from which peat will be cut are also relatively small compared to other restoration polygons.

Note: The undisturbed Pine-*Sphagnum* – Low Shrub community contains several more species than those listed in the "Recommended Actions, replant with…" cells above; only the most common species are listed in order to save on planting costs.

- Clearing concrete, building foundations, and other foreign materials
- Raising the water table level by removing peat or by adding bunding
- Replanting with native bog vegetation

Not all of the above actions are recommended for each plant community polygon; the recommended actions are specific to the location, environmental conditions, land ownership, adjacent plant communities, and former uses of each polygon.

9.3 Unique Polygons

There are three sites in which typical restoration actions are not recommended. Polygons 4 and 5 are located at the southeast corner of the Bog and are not situated within the zone of ecological viability (Appendix 5) as shown in Hebda et al. (2000). These two polygons are already developed and restoration of these sites would be expensive and not necessary for maintenance of bog ecosystem function. I have recommended that these two polygons remain developed, and that they are placed under management restrictions such that they do not impact the Bog adversely in the future (e.g. nutrient inputs, pollution, invasion of exotic species). Left in this condition, these polygons will likely contain habitat for small mammals, raptors, and songbirds.

Polygon 7 is located at the far east end of Burns Bog, near Watershed Park. The site is currently zoned for industrial extraction, although it has already been cleared of vegetation. As seen in section 7.1, the forested areas of Burns Bog are important habitat, particularly the Mixed Conifer Forest that surrounds Polygon 7. Further industrial disturbance should be minimized in this location. I have recommended that this site be utilized as a plant production facility for restoration of the other plant community polygons. This site, termed the Restoration Centre, is ideal for community education about the restoration of Burns Bog, due to its proximity to a residential area. This polygon is also ideal for a plant production site; its proximity to Burns Bog will reduce plant transportation and storage costs.

9.4 Missing Polygons

A number of plant community polygons that one might expect to see restoration recommendations for, based on the information presented earlier in this paper, have not been included in Table 2. These include the majority of the Birch Forest communities, all of the Cultivated Fields, and two large polygons of Herbaceous Vegetation on Disturbed Peat in the southwest area of the Bog. The reasons for these apparent omissions are explained below.

Birch Forest: A great deal of emphasis was placed on the damaging effects to bogs of birch forests and other woody vegetation in the Introduction and in Option 3 of the Restoration Scenarios. However, Birch Forest also provides important habitat for red- and blue-listed species, including the Barn Owl, Trowbridge's Shrew, and the Great Blue Heron. It has also been suggested that the Bronze Birch Borer (*Agrilus anxius*), a small beetle, may in the near future take a toll on the two birch species in Burns Bog (*Betula pendula* and *B. papyrifera*), thereby reducing the vigour and spread of birch (McLean, 2004). Therefore, I suggest that the current extent of Birch Forest is acceptable, and I recommend in Chapter 12 that any further spread of Birch Forest should be monitored closely and curtailed where possible.

Cultivated Fields: Only one of the four Cultivated Field polygons in Burns Bog falls within the zone of ecological viability (Hebda et al., 2000). This field at the far west edge of the Bog is used for growing highbush blueberries and is relatively small in area (150 m x 380 m). Although highbush blueberries are considered an invasive species in Burns Bog, they only appear to have spread to disturbed areas such as the adjacent roadway and have not spread into the Bog itself. This is also an ideal site for tour groups to see first-hand the impacts that agriculture has on a bog ecosystem. In addition, this land would have to be purchased from the owner before any restoration could take place. This field does, however, fall within the water mound boundaries of the Bog, and I recommend in Chapter 12 that the effects of this agricultural field on bog water chemistry, water table levels, soils, and adjacent vegetation be studied in greater detail to determine if environmental restrictions need to be placed on farming activities in the area.

Herbaceous Vegetation on Disturbed Peat: According to Hebda et al. (2000), the two large polygons of Herbaceous Vegetation on Disturbed Peat that occur in the southwest area of the Bog consist of common rush (*Juncus communis*) growing amongst a carpet of *Sphagnum pacificum*. These two polygons clearly already contain a good growth of *Sphagnum*, so do not require new *Sphagnum* transplants. These sites also contain common rush, which appears to be habitat for the blue-listed American Bittern in Burns Bog (Gebauer, 1999). In addition, rush-dominated plant communities are included in the list of typical raised bog vegetation types (Wheeler and Shaw, 1995). It is neither necessary nor economical to attempt restoration of these two polygons.

9.5 Priorities and Phasing

It is unlikely that funding will be available to complete all of the restoration actions recommended in Table 2 in the immediate future. The polygons are ranked below in order of importance:

1) Polygons 4 and 5

Although I do not recommend any restoration actions for these two polygons, it is important to assess early on whether the current land uses within these polygons have any adverse impacts on the Bog ecosystem, and that changes or improvements to these land use be made accordingly.

2) Polygons 1 and 7

Polygon 1 is the first priority for restoration. This is the largest of the nineteen polygons slated for restoration and is an ideal site for interpretation and public education. Beginning the restoration at this location will help to explain the restoration process to the public and will cover a large area at one time.

Polygon 7 would ideally be developed into the Restoration Centre at the same time as Polygon 1 is restored. This would enable the production of any plants that cannot be collected from donor sites (especially *Sphagnum*) for beginning the vegetation restoration of Polygon 1, and would help present a good face to the public at the beginning of the restoration. The Restoration Centre would differ from the Visitor Centre in that is would provide the facilities for plant production; restoration volunteer headquarters; storage space for tools, machinery, and other equipment; and an interpretive program for local residents and tourists specifically geared towards the restoration program.

3) Polygons 2, 3, 6, 8, 10, 14, and 15

The polygons listed above are all slated to be restored to a Hardhack community. This part of the vegetative restoration is closely connected with the hydrological restoration of the perimeter lagg function. The natural lagg areas of the Bog are represented vegetatively by the Hardhack plant community. Hebda et al. (2000) suggested that the lagg of the Bog should be restored wherever possible, so Polygons 2, 3, 6, 8, 10, 14, and 15 are meant to "fill in the gaps" between existing natural lagg areas.

4) Polygons 11, 12, and 13
These three polygons create a complex of adjacent disturbed surfaces on the west side of the Bog. After polygons 1 and 7, this is the next largest area of Disturbed Surface. Due to the lack of vegetation in the Disturbed Surface areas, I recommend that these sites take priority over the remaining Herbaceous Vegetation on Disturbed Peat polygons (below).

5) Polygon 18
This polygon is the largest area of Herbaceous Vegetation on Disturbed Peat slated for restoration. Polygon 18 will be planted with Pine-*Sphagnum* Low Shrub, which will take longer to grow in than the White Beak-rush – *Sphagnum* Community recommended for Polygon 19.

6) Polygon 19
This is the next largest area of Herbaceous Vegetation on Disturbed Peat, after Polygon 18.

7) Polygons 16 and 17
These two polygons at the south edge of the Bog are need to be accomplished near the end of the restoration program because the adjacent Polygon 15 will be rewetted to a Hardhack community and the water levels in Polygons 16 and 17 will likely change. The new water levels in this area need to be stable before any restoration in Polygons 16 and 17 should be attempted.

8) Polygon 9
This is a small Disturbed Surface polygon near the Delta Nature Reserve on the east side of the Bog. The small size and the location of this polygon within a large area of Pine-*Sphagnum* – Low Shrub gives it a low priority for restoration.

9.6 Donor Sites

As mentioned in Designation of the Donor Site, Burns Bog itself is the most appropriate location in the Lower Mainland from which donor plants might be collected. Preferred sites for *Sphagnum* and other bog plant collection would be those areas with the appropriate vegetation that are relatively easy to access, preferably by vehicle, and which are considered least sensitive to damage (Wheeler and Shaw, 1995).

The areas to be restored have been discussed above. The total area that these restoration sites cover, grouped by target plant community, are listed below. The area required for donated plant collection, estimated at 1/15 of the area requiring restoration, is included:

Target Plant Community	Area	Donor Area
White Beak-rush – *Sphagnum*	33.5 ha	2.2 ha
Hardhack	20.7 ha	1.4 ha
Pine-*Sphagnum* – Low Shrub	30.9 ha	2.1 ha

As seen in Option 6 of the Restoration Scenarios, Quinty and Rochefort (1997) note that the ideal sites for *Sphagnum* collection are treeless areas occupied by *Sphagnum*, particularly those areas dominated by *Sphagnum* forming hummocks and flats. Of the fourteen plant communities present in Burns Bog, White Beakrush – *Sphagnum* and Pine-*Sphagnum* Low Shrub are the only two that contain the conditions required for a donor site. The Hardhack community is also required for providing plant material because the purpose of restoring the hardhack areas is not to promote peat-forming activities but to regain the historic lagg function of the Bog's perimeter.

The approximate total area that each of the donor plant communities currently occupies in Burns Bog is listed below, as well as the percentage that would have to be removed from each of these plant communities to collect enough material to cover 1/15 of the restoration area. This list is written with the assumption that all donor plant material would be taken from Burns Bog and not grown in nurseries (which is not necessarily the case), and that the plant material removed from the donor site would be used in a restoration site of the same target plant community (e.g. hardhack would be transplanted into a Hardhack restoration site).

Donor Plant Community	Total Area	Donor Area (from above)	Percentage to be Removed
White Beakrush – *Sphagnum*	400 ha	2.2 ha	0.55%
Hardhack	130 ha	1.4 ha	1.08%
Pine-*Sphagnum* – Low Shrub	742 ha	2.1 ha	0.28%

Considering that the amount of plant material required for removal would involve one percent or less of all three donor plant communities, I suggest that plant collection would be an acceptable impact on the Bog. As noted earlier, even this amount of vegetation removal is likely to be reduced by *Sphagnum* farming and by growing other bog plants in nurseries such as the Restoration Centre. The specific sites for donor plant removal will have to be determined through more detailed field study, particularly focusing on which areas contain important wildlife habitat (these sites would be considered too 'sensitive' for vegetation removal) and which areas are easily accessible by vehicle (for easier plant and volunteer transportation). Consideration should also be given to whether the donor sites can be seen from the proposed trail system; donor sites might be interesting features for an interpretive tour or they might be considered unsightly.

9.7 Representativeness

Aside from the objective of preserving and enhancing habitat for red- and blue-listed species, it is also important to consider those species, both plant and animal, which make up the representative raised bog ecosystem. Representative species are those within the normal range of ecological variability for a given ecosystem; in other words, representative species are the most common species one would expect to find in Burns Bog. One cannot neglect the protection of these species and their habitats, for the representative species make up the bulk of the biota.

Below is a list of the most common species found in Burns Bog, and the plant communities in which they are most frequently observed:

Birds (Summers and Gebauer, 1999a; Summers and Gebauer, 1999b)

Canada Goose (*Branta canadensis*)	Permanent deep pools (ponds); persistently flooding areas; seasonally flooding areas
Mallards (*Anas platyrhyncos*)	Permanent deep pools (ponds); persistently flooding areas; seasonally flooding areas
Other dabbling ducks	Permanent deep pools (ponds); persistently flooding areas; seasonally flooding areas
Northern Harrier (*Circus cyaneus*)	Open ponds
Red-tailed Hawk (*Buteo jamaicensis*)	Mixed perimeter forests; farm fields; ditches
Rough-legged Hawk (*Buteo lagopus*)	Mixed forests; farm fields
Bald Eagle (*Haliaeetus leucocephalus*)	Ditches; mixed forests

Mammals (Gebauer, 1999)

Coyote (*Canis latrans*)	All
Black-tailed Deer (*Odocoileus hemionus columbianus*)	Perimeter mixed forests
Douglas' Squirrel (*Tamiasciurus douglasii*)	Coniferous trees
Gray Squirrel (*Sciurus carolinensis*)	Mixed conifer and birch forests
Eastern Cottontail (*Sylvilagus floridanus*)	Peripheral areas
Beaver (*Castor canadensis*)	Ponds, ditches, deciduous forests
Raccoon (*Procyon lotor*)	Pine forest; all
Shrew-mole (*Neurotrichus gibbsii*)	All
Deer Mouse (*Peromyscus maniculatus*)	All
Muskrat (*Ondatra zibethicus*)	Ponds and ditches

Amphibians and Reptiles (Gebauer, 1999)

Pacific Tree Frog (*Hyla regilla*)	All
Green Frog (*Rana clamitans*)	Open *Sphagnum* heathland; ponds and ditches
American Bullfrog (*Rana catesbeiana*)	Open *Sphagnum* heathland; ponds and ditches
Northwestern Salamander (*Ambystoma gracile*)	Ponds and ditches; deciduous forests; mixed conifer forests
Common Garter Snake (*Thamnophis sirtalis*)	All
Northwestern Garter Snake (*Thamnophis ordinoides*)	All

Plants (Hebda et al., 2000)

Sphagnum spp.	Pine-*Sphagnum*, White Beakrush-*Sphagnum*
Labrador tea	Pine-*Sphagnum*
Salal	Mixed Conifer Forest, Birch Forest, Pine-salal Forest

Blueberries (*Vaccinium* spp.)	Pine-*Sphagnum*
Lodgepole pine	Mixed Conifer Forest, Birch Forest, Pine-salal Forest, Pine-*Sphagnum*

The representative plant communities in Burns Bog include Pine-*Sphagnum* (low shrub, tall shrub, and woodland forms) at 45% of the land area, and White Beakrush (*Sphagnum* and Three-way Sedge forms) at 25% of the Bog. These most common plant communities provide habitat for over 50% of the representative species listed above, while the perimeter forests and open water areas (including ditches) comprise the remainder of important habitat for these common species.

The protection of the Bog as an ecological reserve will ensure that habitat for representative species will be maintained. Indeed, the relatively stable nature of forested, open heath, and open water communities (as opposed to the successional communities of more disturbed sites) suggests a likelihood that habitat for representative species can be maintained in perpetuity with little management or maintenance required.

SUMMARY OF RESTORATION RECOMMENDATIONS

Below is a summary of the Restoration Recommendations for Burns Bog:

1) Protect Burns Bog as an ecological reserve
2) Block any remaining ditches and assess blocked ditches for proper function
3) Remove weedy scrub vegetation from affected areas
4) Construct bunds around dry areas or remove peat to raise the water table
5) Replant *Sphagnum* and other bog vegetation on cleared and sufficiently rewetted surfaces
6) Maintain a certain level of plant community diversity (see Long-term Maintenance)

These recommendations for the restoration of Burns Bog are designed to fulfill the first objective (Ecological) of this thesis, namely:

- To return hydrological function
- To restore plant communities appropriate to a raised bog ecosystem
- To maintain and enhance habitat for rare and endangered wildlife
- To maintain a relatively high plant community diversity for the next 50-100 years

Table 3 summarizes the information presented above and describes the costs, benefits, and potential application associated with each restoration approach.

Option Number	Summary of Restoration Recommendations	Benefits	Costs	Application
1	▪ Protect Burns Bog as an ecological reserve	▪ Ensures that Burns Bog is protected for future generations	▪ About $70 million, shared between the Federal, Provincial, Regional, and Municipal governments	▪ Restoration cannot take place unless the Bog is purchased from current owners and protected from future development
2	▪ Block open ditches ▪ Assess existing blocked ditches for proper seal and function ▪ Provide for wet season overflows	▪ Blocking the outflow of precipitation through ditches is fundamental to the viability of the Bog	▪ Reassessment of all existing blocked ditches ▪ Installation of new ditch-blocking devices ▪ Ongoing maintenance of ditch-blocking devices	▪ Ditch-blocking must take place throughout the Bog; it is the first step in any restoration scenario
3	▪ Remove weedy scrub vegetation from affected dry areas ▪ No other rewetting actions aside from ditch-blocking	▪ Clears the site for natural recolonization of bog vegetation ▪ Temporarily removes the problems that weedy vegetation create, such as shading and increased evapotranspiration	▪ Vegetation removal ▪ If cleared areas are not rewetted and remain dry, weedy vegetation will grow back and will have to be cleared annually ▪ Short-term results	▪ Not applicable (a waste of time and resources) unless ditch-blocking alone is sufficient to rewet dry areas
4	▪ Construct bunds around dry areas	▪ Raises the water table in dry areas permanently ▪ Long-term results	▪ Ongoing monitoring and maintenance of bunds	▪ Applicable in areas that have dried (e.g. Birch Forest) but have not been mined because the acrotelm layer may still be present and functioning ▪ Applicable for relatively large sites
5	▪ Remove peat from dry areas	▪ Raises the water table in dry areas permanently ▪ Long-term results	▪ Peat removal ▪ Clearance of concrete and any other construction	▪ Applicable in Disturbed Surface sites where acrotelm has been badly damaged or

		▪ No maintenance required ▪ Creates opportunity to research a rare method	materials ▪ Method has been little-tried in raised bogs	removed ▪ Applicable for relatively small sites
6	▪ Replant *Sphagnum* and other bog vegetation on cleared and rewetted surfaces	▪ Faster than natural recolonization ▪ Promotes growth of peat-forming communities ▪ Creates educational and volunteer opportunities for public ▪ Creates opportunity for research on revegetation of raised bogs	▪ Farming, purchase, or collection of *Sphagnum* and other bog plants ▪ Planting bog vegetation ▪ Monitoring and maintenance of donor sites and restoration sites	▪ Applicable to disturbed sites with appropriate growing conditions that have not yet naturally regenerated with appropriate bog vegetation ▪ Applicable to sites currently devoid of vegetation (e.g. Disturbed Surface)
7	▪ Maintain plant community diversity by reverting some areas to early successional stages	▪ Maintenance and possible enhancement of current level of biodiversity ▪ Creates educational and volunteer opportunities for public ▪ Creates opportunity for research on plant community succession in raised bogs	▪ Vegetation removal ▪ Farming, purchase, or collection of *Sphagnum* and other bog plants ▪ Planting bog vegetation ▪ Monitoring and maintenance of cleared and replanted sites	▪ Applicable in Pine-*Sphagnum* Low-shrub communities (see 'Long-term Maintenance')

Table 3: Matrix showing costs, benefits, and applicability of each restoration option as listed in the 'Summary of Restoration Recommendations'.

Note: Except for Option 1, all options include ditch-blocking.

PERFORMANCE STANDARDS AND MONITORING PROTOCOLS

11.1 Monitoring

Monitoring can be approached at two levels:

1) Provision of hard and detailed evidence of change
2) Provision of casual data to give a broad indication of change

Wheeler and Shaw (1995) recommend that a **monitoring program** for the raised bog restoration include the following:

1) Base-line data on flora, fauna, and water levels
   - Much of this information is already available through the Burns Bog Ecosystem Review (Hebda et al., 2000) and the technical reports from which the Review was written)
   - More detailed base-line data should be collected from specific sites of interest
2) Selected species or priority areas should be identified for regular monitoring
   - I recommend annual species counts of wildlife of interest and measurement of *Sphagnum* growth rates in selected areas
3) The hydrological and biological response within a representative selection of cut-over areas
   - See recommendations for #2 and #4
4) Dipwells or staff gauges inserted at key points for monitoring water levels
   - I recommend continued weekly or biweekly monitoring of the water table with the eleven existing dipwells and possibly other dipwells in new locations of interest
5) Photographic record (before and after; dam and bund construction)
6) Regular checks on any water control structures and remedial action taken as necessary
7) Records of uncontrollable events (e.g. heavy storms, fires, vandalism) that may influence future interpretation of project success
8) Annual review of results and adaptive management

Vegetation Monitoring

Techniques for monitoring colonization and growth rates of newly vegetated areas include permanent quadrats, random quadrats, and photographic records (fixed point photography) (Wheeler and Shaw, 1995). Researchers should record plant species occurrence and abundance, and the rates of recolonization. After initial base-line data is recorded, Wheeler and Shaw (1995) suggest monitoring vegetation at intervals of 3-5 years. Quinty and Rochefort (1997) suggest the first visit should occur in the fall following the springtime planting, between mid-September and the end of October.

Adaptive Management

In any project, one must plan for the possibility of unexpected problems. For example, in the case of the hydrological restoration, blocking the ditches might not bring the water loss rate all the way back to pre-disturbance conditions, the water levels might not rise as high as expected in the bunded or cut away areas, and annual water level fluctuations might not stabilize as expected. Regarding vegetative restoration, the target plant communities might not establish as quickly as expected, or an entirely different plant community may take its place. Such mid-course difficulties are to be expected during any restoration project and are correctable if the restoration manager is flexible and is able to keep the big picture of the restoration effort in mind.

11.2 Assessment of Success

Using the monitoring program as described above, Wheeler and Shaw (1995) list the following standards as a measurement of success:

Hydrology:

- Are water levels maintained at the levels required by the objectives?
- Have water levels stabilized and fluctuations been reduced sufficiently?
- Are water levels consistently higher in the ditches than previously?
- Are the dams and bunds damaged or leaking?

Vegetation:

- Have durable communities formed? (durable = stable for more than 10 years)
- Is transplanted plant material spreading? (vegetative expansion, flowering, seeding)

Wildlife:

- Has a bird community typical of little-damaged bogs reestablished?

LONG-TERM MAINTENANCE

Ditch Maintenance

I have recommended that all open drainage ditches in Burns Bog be blocked, and that those which have been blocked in the past, either by the Municipality of Delta or by beavers, should be assessed to ensure a proper seal. Some of these existing ditch-blocking devises will likely require replacement or enhancement. As mentioned in Performance Standards and Monitoring Protocols, blocked ditches require regular monitoring. I recommend checking all blocked ditches for general damage and leakage once a year. I also suggest that managers investigate each ditch after major winter storm events to check for erosion and to ensure that the provisions made for high water overflows are effective.

Maintenance of Restored Polygons

Managers should ensure that those polygons slated for restoration in Chapter 9 are indeed on the proper trajectory to their target plant community. I recommend conducting vegetation surveys every 3-5 years. Alterations to restoration sites, or changes in the target plant community, may be necessary depending on the status of each restoration site.

Maintenance of Plant Community Diversity

As suggested in Option 7 of the Restoration Scenarios, I propose to maintain a certain level of plant community diversity in Burns Bog. This action will maintain or enhance biodiversity in the Bog and ensure that a diversity of habitat types is available for red- and blue-listed species. Maintenance of a diversity of plant communities can be accomplished by occasionally clearing small areas and allowing them to regenerate naturally, effectively reverting these areas to earlier successional stages. Ecological succession is defined as:

> "The process by which a series of different plant communities and associated animals and microbes successively occupy and replace each other over time in a particular ecosystem or landscape location following a disturbance to that ecosystem." (Kimmins, 1997, p. 525)

Dr. Richard Hebda (2004), bog expert and one of four authors of the Burns Bog Ecosystem Review (Hebda et al., 2000), states that many of the plant communities of Burns Bog are successional. Ideally, to determine the required timing of the clearing activities described above, one would develop a table similar to the information presented in Table 4, which lists the plant communities in Burns Bog that are likely to be successional stages, the earliest stage after disturbance being White Beak-rush – Three-way Sedge, and the oldest stage being Pine-*Sphagnum* – Woodland.

Plant Community / Successional Stage	Time Since Disturbance: Most Common Dates
White Beak-rush – Three-way Sedge	25-30 years
White Beak-rush – *Sphagnum*	35-40 years
Pine-*Sphagnum* – Low Shrub	55-60 years
Pine-*Sphagnum* – Tall Shrub	55-60 years
Pine-*Sphagnum* - Woodland	55-60 years

Table 4: Burns Bog plant communities that are most likely to be successional stages and an estimate of the possible time span that each stage might take to develop from the time of disturbance, estimated from the time-since-disturbance graphs in Appendix 11. These estimates are unlikely to be accurate, due to lack of data.

Unfortunately, it is difficult to determine a generalized rate of succession for any particular plant community because the environmental variables, such as soil type, depth to water table, microclimate, etc. will alter the rate of succession at any given time or for any particular location. In addition, the historic vegetation of Burns Bog resembled the Pine-*Sphagnum* – Low Shrub and the White Beak-rush – *Sphagnum* plant communities and appears to have been stable at those particular "successional" stages of development, meaning that the restored plant communities are likely to remain stable (i.e. at the same plant community) within our 50-100 year management time frame (Appendix 10) The tall shrub and woodland forms of the Pine-*Sphagnum* ecosystem appear to have developed due to unnaturally dry conditions in the Bog.

Until more detailed data can be collected on the location and rates of change for any successional plant communities in Burns Bog, it seems reasonable to suggest a general scheme for the long-term (50-100 years) maintenance of plant community diversity in Burns Bog, based on the habitat values of each plant community for red- and blue-listed species. After determining the habitat value of each plant community from the wildlife surveys conducted in Burns Bog in 1999 (Table 1), the following conclusions can be made:

1. **Forest and woodland communities** should not be cleared for long-term diversity because they contain important habitat for the majority of wildlife species of concern in Burns Bog, including the Southern Red-backed Vole, Pacific Water Shrew, Barn Owl, Trowbridge's Shrew, and the Great Blue Heron.
2. I have recommended that all of the **Disturbed Surfaces** be restored, so none of these sites would be appropriate for clearing activities.
3. I have recommended that most of the **Herbaceous Vegetation on Disturbed Peat** areas be restored, and those that I have not recommended for restoration are habitat for the American Bittern, so none of these sites would be appropriate for clearing activities.
4. The two **White Beak-rush** communities and the **Pine-*Sphagnum* – Low Shrub** community are important habitat for the Greater Sandhill Crane, and should not be considered for clearing.
5. **Cultivated Field** areas are privately owned and largely outside of the zone of ecological viability, so it would be of little use to consider these areas for replanting with early seral stage bog plant communities.
6. **Hardhack Thicket** areas are only located at the perimeter of the Bog and are closely linked to the maintenance of lagg function, so are not appropriate for clearing activities.
7. It would be irrational to attempt clearing and replanting of **Open Water** and **Yellow Water-lily – Watershield** areas because water levels in these sites are generally above ground throughout the year.
8. **The Pine-*Sphagnum* – Tall Shrub** community appears to have little habitat value for any of the plant or wildlife species of concern in Burns Bog and is the only plant community without other restrictions on clearing and replanting.

The above conclusions suggest that areas containing the Pine-*Sphagnum* – Tall Shrub plant community are the preferred sites for clearing and replanting with early successional species in an attempt to maintain plant community diversity in Burns Bog. Appendix 12 illustrates possible locations and timing for these long-term maintenance activities. The information presented in Appendix 12 is merely meant to illustrate a possible maintenance scenario and would in reality be dependent on further research and adaptive management during the restoration process itself.

Agricultural Fields

As mentioned in the Restoration Recommendations, one of the four agricultural fields that falls within the boundaries of Burns Bog is also located within the zone of ecological viability. This agricultural field may pose a threat to the Bog, in terms of pollution, nutrient inputs, a source of the invasive highbush blueberry, and changes in water table levels and pH. To ensure that the operation of this farm does not damage the bog ecosystem, I recommend that this issue be studied in greater detail.

If conventional cultivation of this site does appear to impact the Bog in a negative way, it might be possible to modify the farming practices to adopt an organic method. Instead of reprimanding the farmer for environmental damage or forcing him to sell his farm in the name of restoration, a more economic and amiable approach would be to use this farm as a showcase for organic farming practices. This blueberry farm would be an ideal stop on an interpretive tour that focuses on sustainable practices, and the farmer might be given the opportunity to advertise his wares.

Exotic Species Invasion

It is unlikely that most invasive species in the Lower Mainland would be able to spread into the harsh growing conditions of Burns Bog. However, it is clear that two birch species (paper birch and European birch) have spread through much of the perimeter of the Bog, particularly in areas where drainage ditches have lowered the water table. Although the current level of birch coverage in the Bog can be considered acceptable, due to the wildlife habitat that this plant community provides, any further spread of the Birch Forest plant community should be monitored closely. If Birch Forest continues to spread in the future, this is an indication that the Bog is continuing to dry out, and that further rewetting measures need to be taken.

VISITOR CENTRE AND TRAIL SYSTEM

13.1 Regional Greenway System

Burns Bog, as a protected area, now provides a large and central open space in Delta. A regional greenway system would allow local residents to travel by foot or bicycle throughout Delta. The proposed trail system in the Bog can create connections at several points along its perimeter, from which trails may be made to connect with other important local open spaces, including the Fraser River, Boundary Bay, the Reifel Bird Sanctuary, and Deas Island Regional Park (Appendix 13).

13.2 Visitor Centre

The proposed program for the Visitor Centre is an international centre for research and education on the estuarine raised bog ecosystem. This site is the start and end point to all of the trails in the Bog (excepting those in the Delta Nature Reserve). To access the Visitor Centre, you enter through the existing Vancouver Landfill entrance road. The location of the Visitor Centre was determined using a decision matrix that considered a variety of factors, including cost, access, feasibility, environmental impact, and plant community diversity (Table 5). The road to the Visitor Centre diverts northwards about halfway across the landfill. After passing through a restored Mixed Conifer Forest, a perimeter forest type that existed at the edge of the Bog pre-disturbance, you arrive at a gravel parking lot (Appendix 14a). At the entrance to the parking lot, the forest parts and you are able to look across fields of red huckleberry (*Vaccinium parvifolium*), snowberry (*Symphoricarpus albus*), and salal. You notice that this building has the 'saltbox' roof form found in many historic barns in Delta (Appendix 14b).

As you enter the parking lot the forest closes back in, making room in some spots to allow you to park your car. To reach the Visitor Centre, you walk past a thicket of oval-leaved blueberry (*Vaccinium ovalifolium*) and vine maple (*Acer circinatum*) and back into the conifer forest. Halfway through, you pass by a grove of native ferns and red elderberry (*Sambucus racemosa*), before emerging from the forest through another patch of blueberry and maple. A boardwalk has been constructed here to carry you across the parallel ditch system used to clean water from the landfill.

Upon entering the visitor centre (Appendix 14c), you are struck by its open, airy feeling, created by the large opening on the second floor and the light that is shining down from the skylights in the roof. To your left is a café, and to your right are a staircase and elevator leading upstairs, and a door leading to the covered outdoor patio. There is also a large display area on this floor where you can learn all about Burns Bog. When you ascend the stairs to the second floor, you see three staff offices and a staff meeting room. You notice that one of the park staff is teaching a group of young students in the classroom. They are being instructed to use the small library behind them to answer a list of research questions about wetlands.

You head back downstairs, this time taking the elevator for a change of pace. As you leave the building by way of the back door, towards the boardwalk trails, you pass washrooms and a gift shop. You make a mental note to buy a Sandhill Crane postcard upon your return. With a map in hand, you start out into the Bog.

Location	Access	Feasibility	Cost	Environmental Impact	Number of Plant Communities Within 1 km	Adjacencies
Landfill	Burns Drive	Landfill likely to be restored as parkland and visitor centre	Purchase of land from City of Vancouver	Negligible (a park would be an improvement over a landfill)	6	- Farmland - Possibly remaining landfill operation
80th Street	80th Street (currently a farm road)	Road through the bog ecosystem would require expansion	Purchase of land from owner (if not already in whole bog purchase deal)	Conventional construction of roads, parking lots, and buildings would impact the bog ecosystem	9	- Farmland
Delta Nature Reserve	Great Pacific Forum (hockey multiplex)	Would require land purchase from GPF or clearing of some DNR forest; very difficult to find	Land purchase or clearing	Minimal on GPR land; high on DNR land	4 (no access across highway)	- Hockey arena - Industrial land - DNR - Residential land - Highway 91
Watershed Park	72nd Avenue	Land would require purchase and rezoning	Land purchase	Minimal (already disturbed)	3 (no access across highway)	- Residential land - Watershed Park - Highway 91
104th Street	104th Street	Would require farmland purchase or bog land clearing	Purchase of farmland or clearing of bog land	Loss of farmland or bog vegetation	8	- Sunshine Hills Golf Course - Farmland
96th Street	96th Street	Would require farmland purchase or bog land clearing	Purchase of farmland or clearing of bog land	Loss of farmland or bog vegetation	7	- Farmland

Table 5: Visitor Centre location decision matrix. The highlighted areas are those which are considered as unacceptable for a visitor centre (due to environmental impact, lack of scenic interest, and access difficulties); using these criteria, the landfill location appears to be the best alternative.

You find yourself on the second-longest boardwalk loop trail, called the Restoration Loop (Appendix 15). After climbing an observation tower so you can watch the volunteers at work restoring Polygon 1, you encounter a sunken structure further along the trail. This structure is called the 'Bogarium' and it brings you about 1.5 metres down a set of steps, allowing you to see the Bog close-up in section (Appendix 14d). A wooden frame supports sheets of clear Plexiglas, through which you can see the depths of a pond and the two-layered peat deposit of the Bog. There is a marker that someone has placed on the glass to show how high the *Sphagnum* grows each year. You wonder how many decades will pass before the moss overtakes this structure.

Soon enough, you have explored the Bog to your satisfaction. You decide to leave the 14 km Burns Bog Day Hike for a more energetic day, and head back to the Visitor Centre for a calming cup of Labrador tea.

13.3 Restoration Centre

The key program for the Restoration Centre is as a plant production site for use in the restoration projects. It is also the proposed location for volunteer training and restoration equipment storage. Visitors are invited to take tours here to learn about the restoration process and how they can become involved in it themselves. The access Road to the Restoration Centre is south off 72nd Avenue, close to the intersection with Highway 91. Visitors can also reach this site by foot. It is a 20-minute walk from the parking lot of the Great Pacific Forum hockey arena, and directly adjacent to the upland residential area on Panorama Ridge.

The site is surrounded by a restored Mixed Conifer Forest, which is what grew at this site historically (Appendix 14e). Passing through this forest upon entering the site, you briefly emerge into an open area, planted with species from the Pine-*Sphagnum* – Low Shrub and White Beakrush – *Sphagnum* communities. You remember that this area is being used as a plant production site for the restoration effort. The forest closes back in as you continue along the road, and you catch a brief glimpse of open water through the trees before ascending a hill covered with a deciduous forest. There are several hills like this one on the site, which are remnant fill piles from previous industrial activity.

When you reach the top of the hill, you see a building that resembles the 'monitor' roof style barn historically found in Delta (Appendix 14f). The centre of this building is open, allowing you to look through to see a pond on the other side. You know that this pond was excavated when the restoration centre was built and the fill was added to the existing fill piles, making them more prominent features in the landscape. Part of the pond is used for *Sphagnum* farming, which is an important component of the restoration projects.

As you walk up to the building, you pass several patches of native plantings (Appendix 14g). These plantings start low near the building (ferns, red huckleberry, salal, snowberry) and then increase in height further away (oval-leaved blueberry, Oregon grape [*Mahonia* spp.], Pacific ninebark [*Physocarpus capitatus*], red elderberry, twinflower [*Linnaea borealis*], salmonberry [*Rubus spectabilis*]). You walk through the building to the end of the deck and look out toward the pond. Below you are native roses (Nootka rose [*Rosa nutkana*], baldhip rose [*Rosa gymnocarpa*], clustered wild rose [*Rosa pisocarpa*]) and a thicket of exotic blackberries (Himalayan and evergreen blackberry). The exotic blackberries are a remnant of this disturbed site, and so is the 'concrete patio' below them. This section of concrete is left as a reminder that this site was once entirely paved.

Inside the building, you see a large display area, two offices, and a meeting room. The gentleman behind the reception desk mentions that the other side of the building contains washrooms and a large reception hall. This hall is used for volunteer training and is also rented out to raise funds for the restoration projects and ongoing maintenance. The receptionist suggests that you take a walk around the site.

On your walk, you discover that most of this place is forested. You particularly enjoy seeing the pond from the Lookout Point; a great number of birds are singing and moving about the bulrushes and cattails on the east side of the pond. Halfway along the trail, you encounter the Ethnobotany Island, where interpretive signs teach you how local First Nations used the plants of the Bog in their daily lives (Appendix 14h). This is a fascinating place, and you make a mental note to return here to see the Labrador tea in bloom.

COMMUNITY CONNECTION

Although this thesis, at least the restoration portion, is largely scientific in nature, one must keep in mind that none of the recommendations presented here can be realized without the political and financial support of key stakeholders and the local community. A brief discussion follows regarding some of the potential stakeholders in this project and the role they might play in the restoration of Burns Bog.

Local First Nations Groups

As mentioned in the Introduction, six First Nations groups used Burns Bog historically. Some elders may possess unique and undocumented knowledge of the pre-disturbance character of the Bog and the ways in which the Bog was used to sustain human life. Such information would prove invaluable for tours, interpretive displays, and special design elements such as the Ethnobotany Island. Education developers might invite all six local First Nations groups to participate in the development of a comprehensive interpretive program. An opportunity also exists for archaeological research; the Tsawwassen First Nation have indicated their interest in a thorough archaeological assessment of the Bog (Hebda et al., 2000).

Government

The Corporation of Delta, the Greater Vancouver Regional District, and the Province of British Columbia now own the majority of Burns Bog (Appendix 8). As such, all three groups should be consulted with regard to the implementation of the restoration plan. Technical expertise and financial support for restoration projects may be sought from the government sector.

Local Citizens

Educators, volunteers, and concerned members of the public will all be interested in participating in the restoration process and the creation of education programs. Educators will be needed to develop interesting and practical tours and interpretive displays. Volunteers will be required for conducting tours and for providing labour in the restoration effort. Political support from local citizens will determine how quickly the restoration of Burns Bog can progress, or indeed, whether it will occur at all.

Local Farmers and Other Businesses

It might be possible, and it is certainly advisable, to obtain corporate funding for the restoration projects and the visitor centres from local businesses. The most visible businesses in the area, and perhaps the most profitable as well, include several cranberry farms, the Lafarge concrete factory (visible from much of the Bog's interior), and the Great Pacific Forum hockey arena (located at one entrance to the Delta Nature Reserve). Corporate sponsorship would ease the financial burden on the government and allow local businesses to promote themselves in a positive light.

An invitation to participate in the master planning process for Burns Bog, possibly using the design recommendations presented in this thesis as a starting point, would allow all of the above stakeholders to be involved in the future of the Bog.

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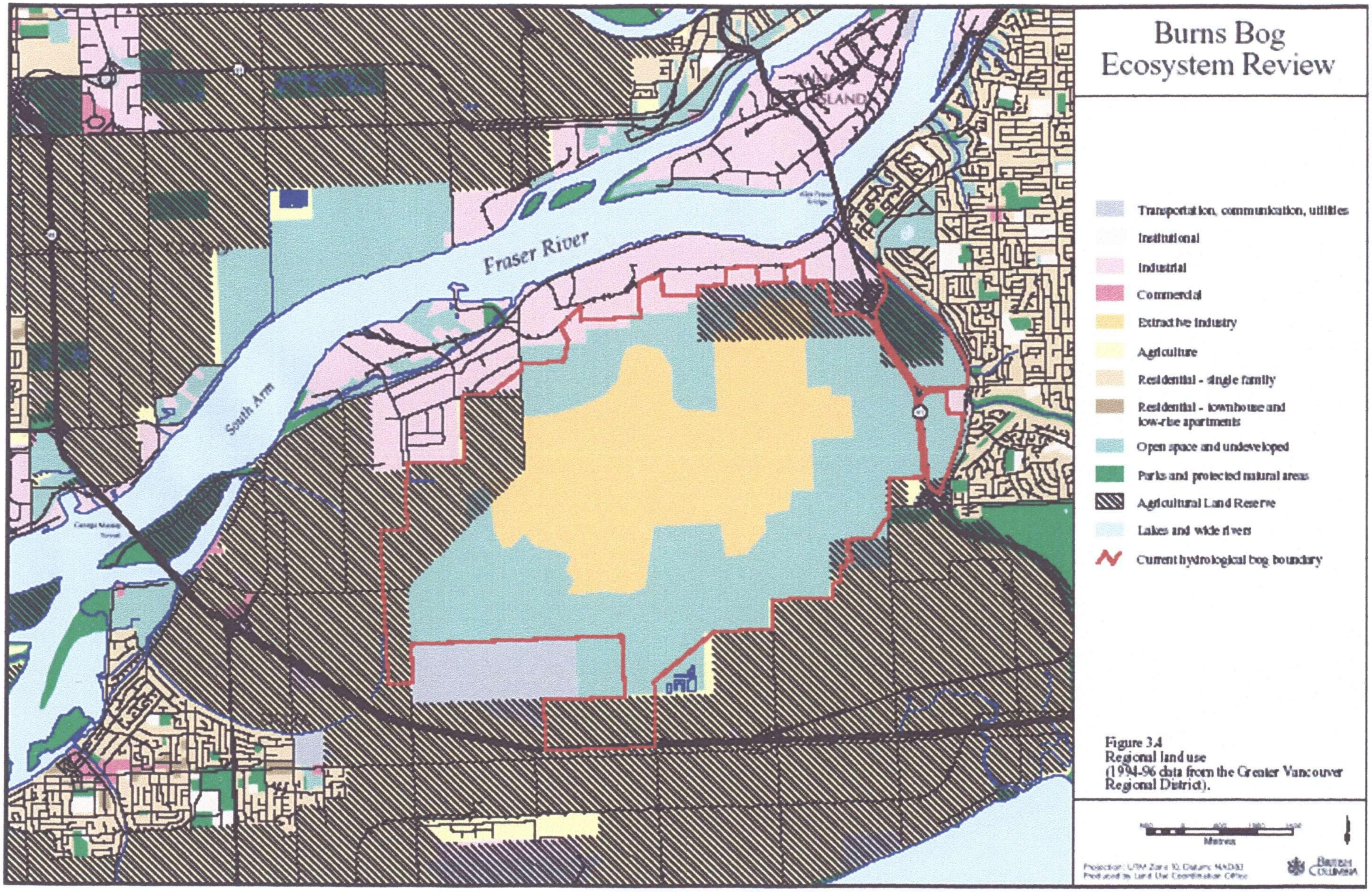
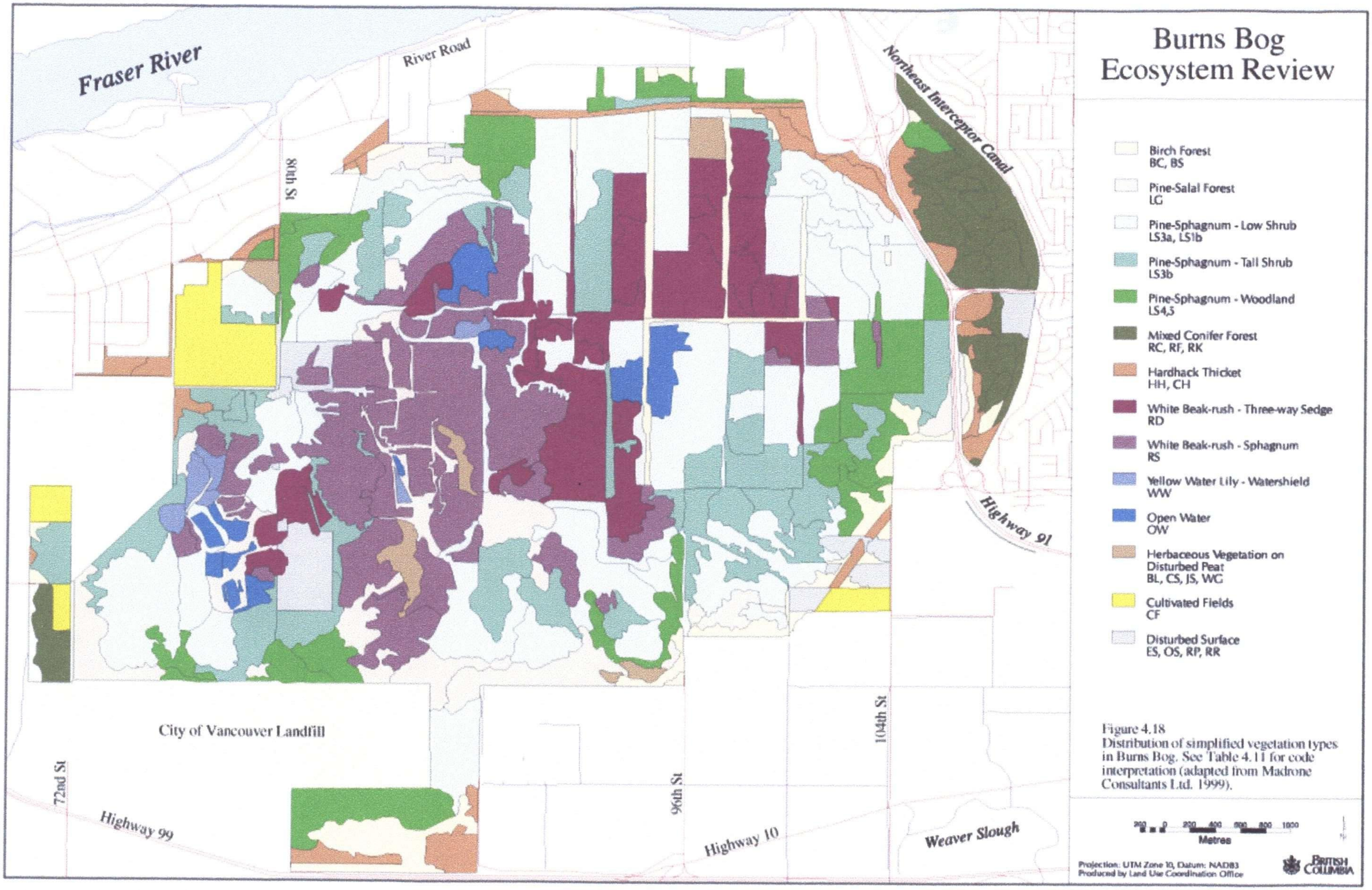
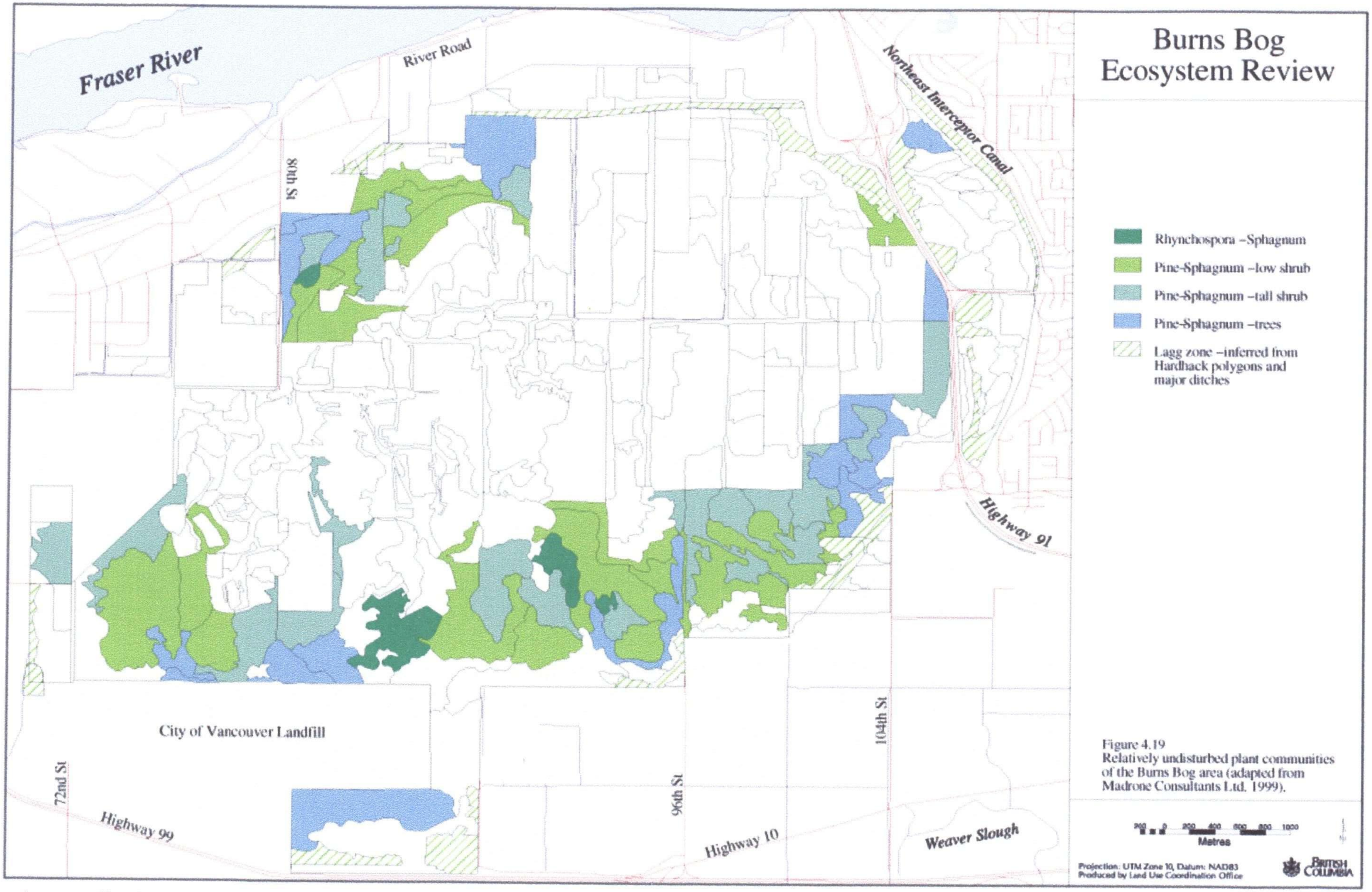


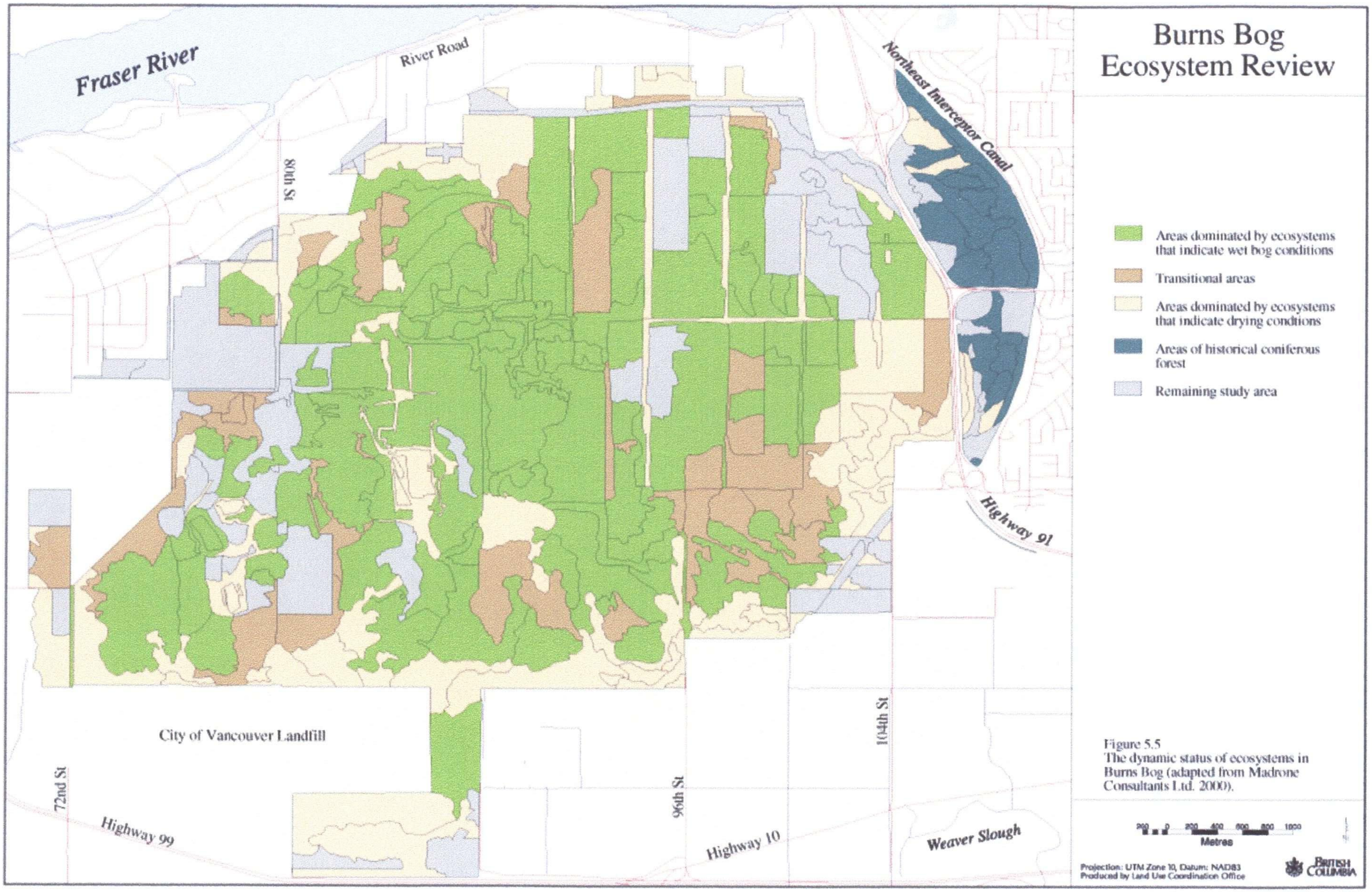
Appendix 1: Regional Land Use (Source: Hebda et al., 2000)



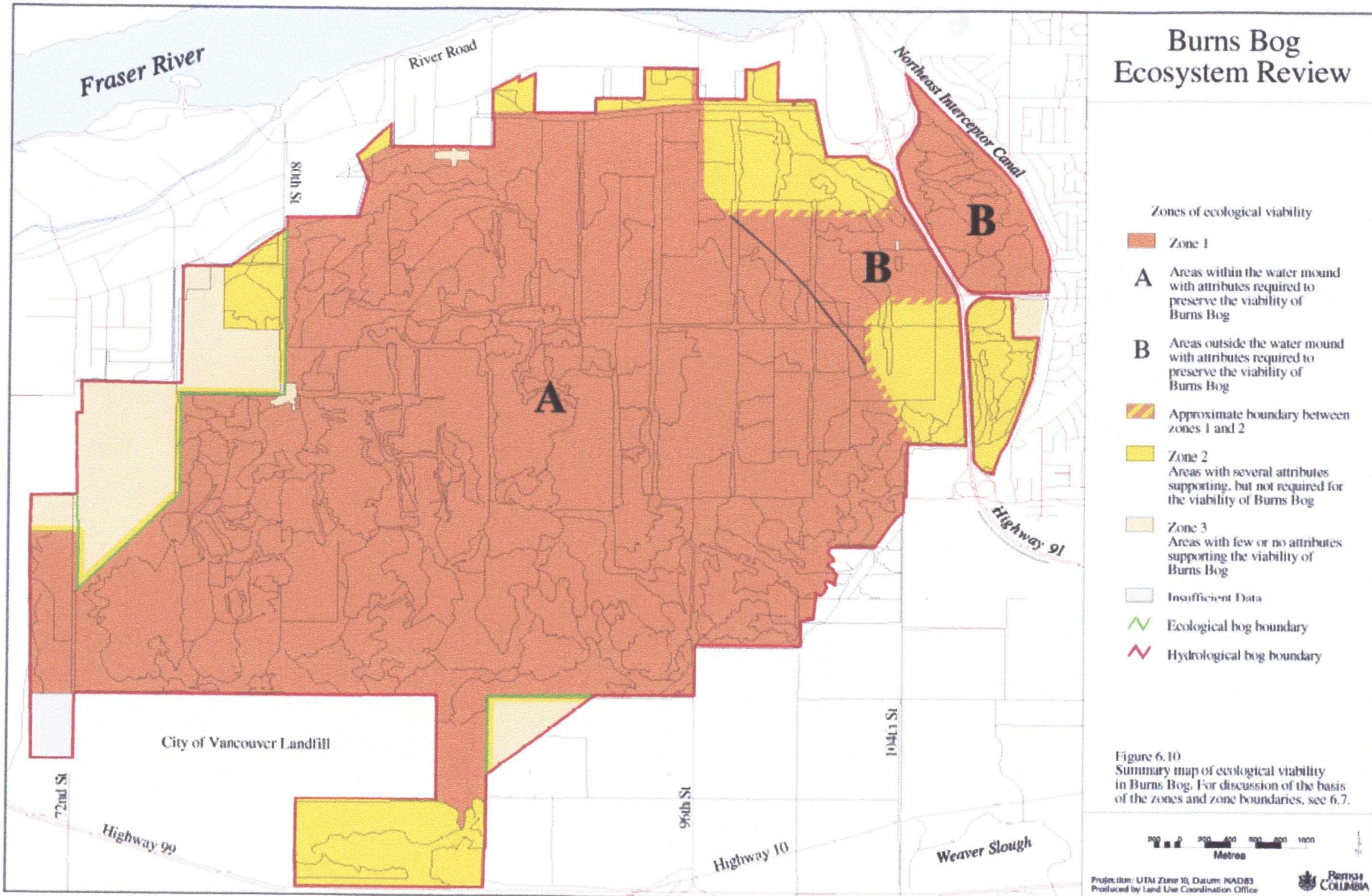
Appendix 2: Distribution of Simplified Vegetation Types in Burns Bog (Source: Hebda et al., 2000)



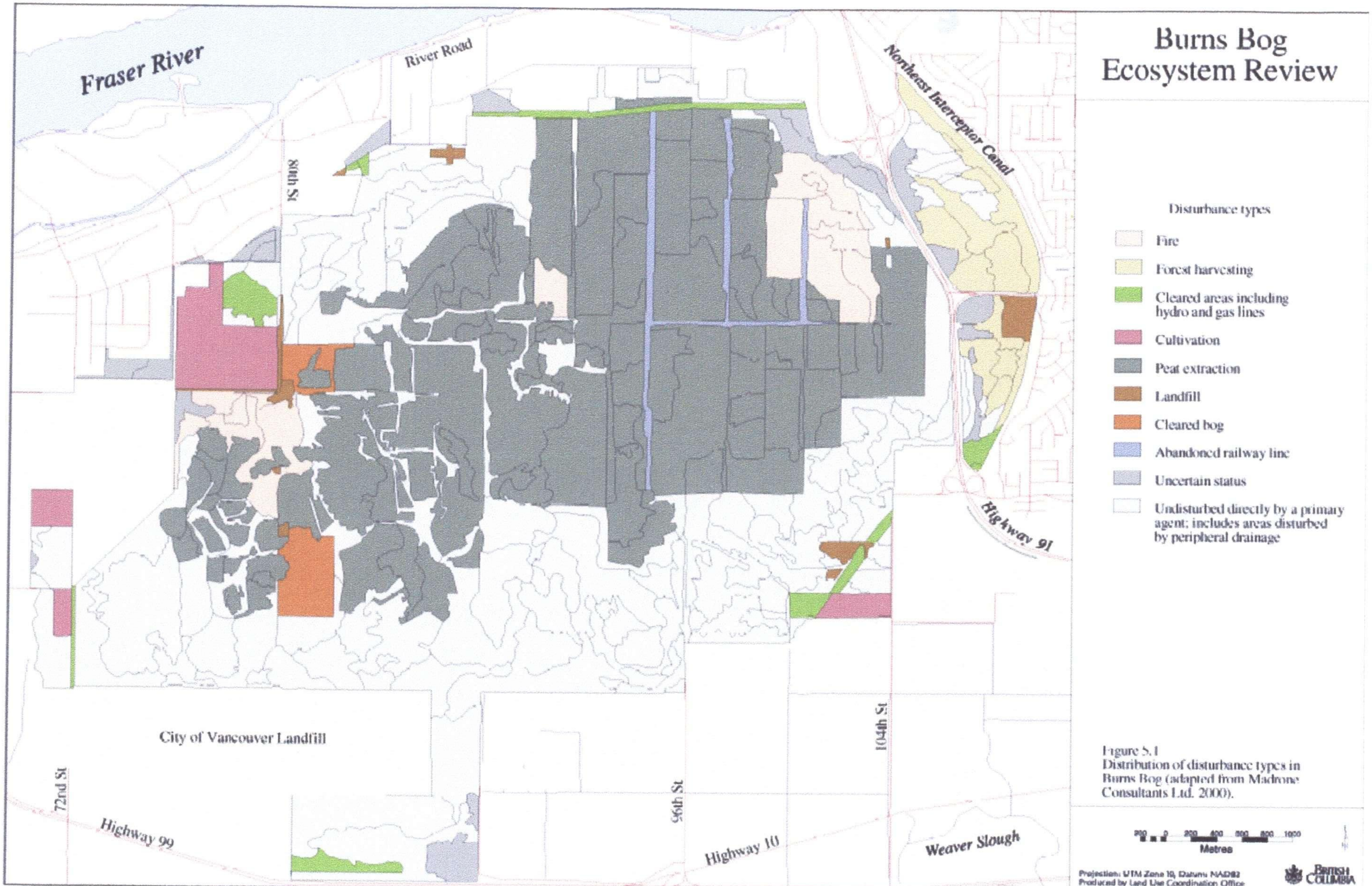
Appendix 3: Undisturbed Vegetation and *Sphagnum* Cover in Burns Bog (Source: Hebda et al., 2000)



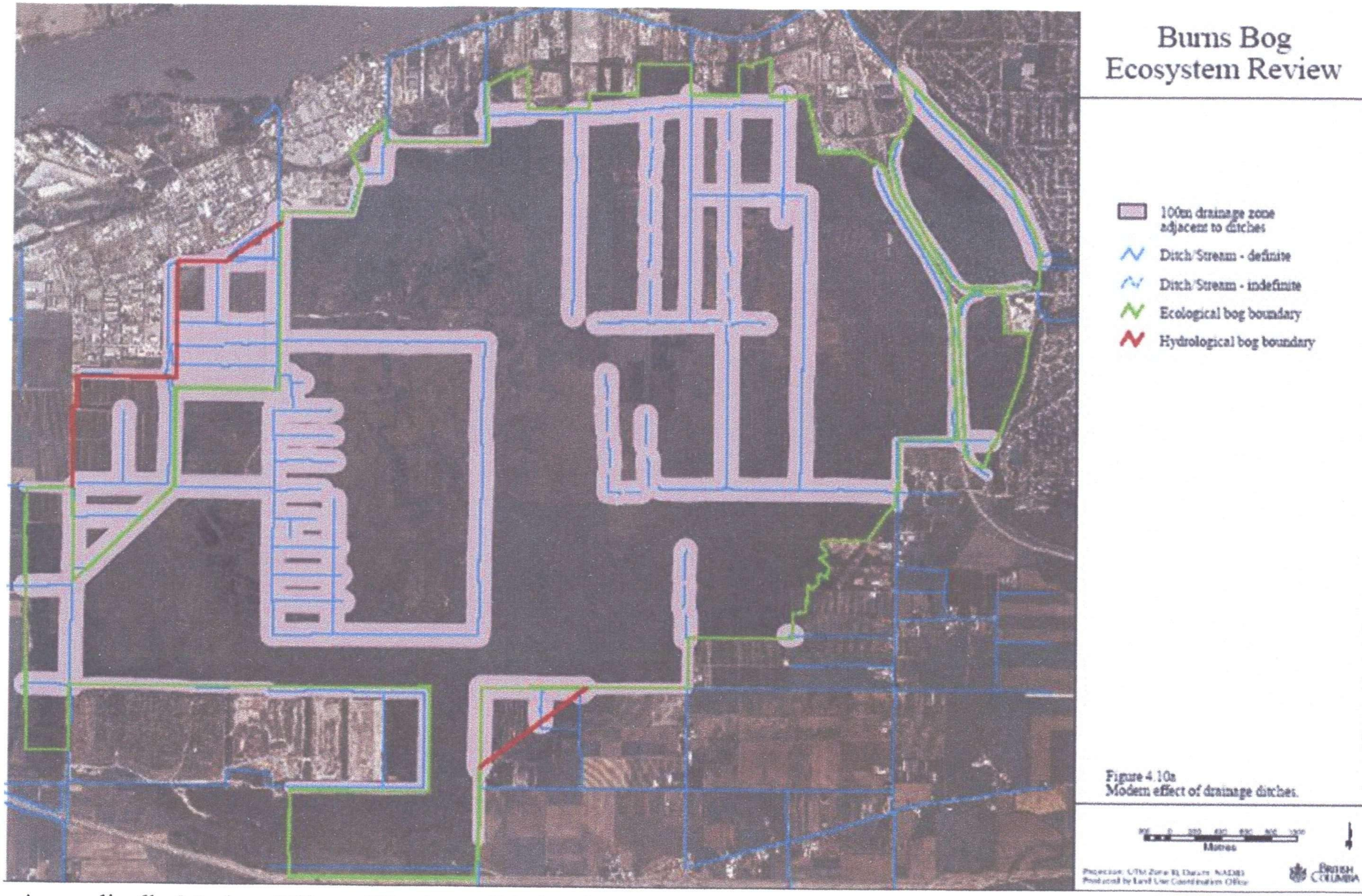
Appendix 4: The Dynamic Status of Ecosystems in Burns Bog (Source: Hebda et al., 2000)



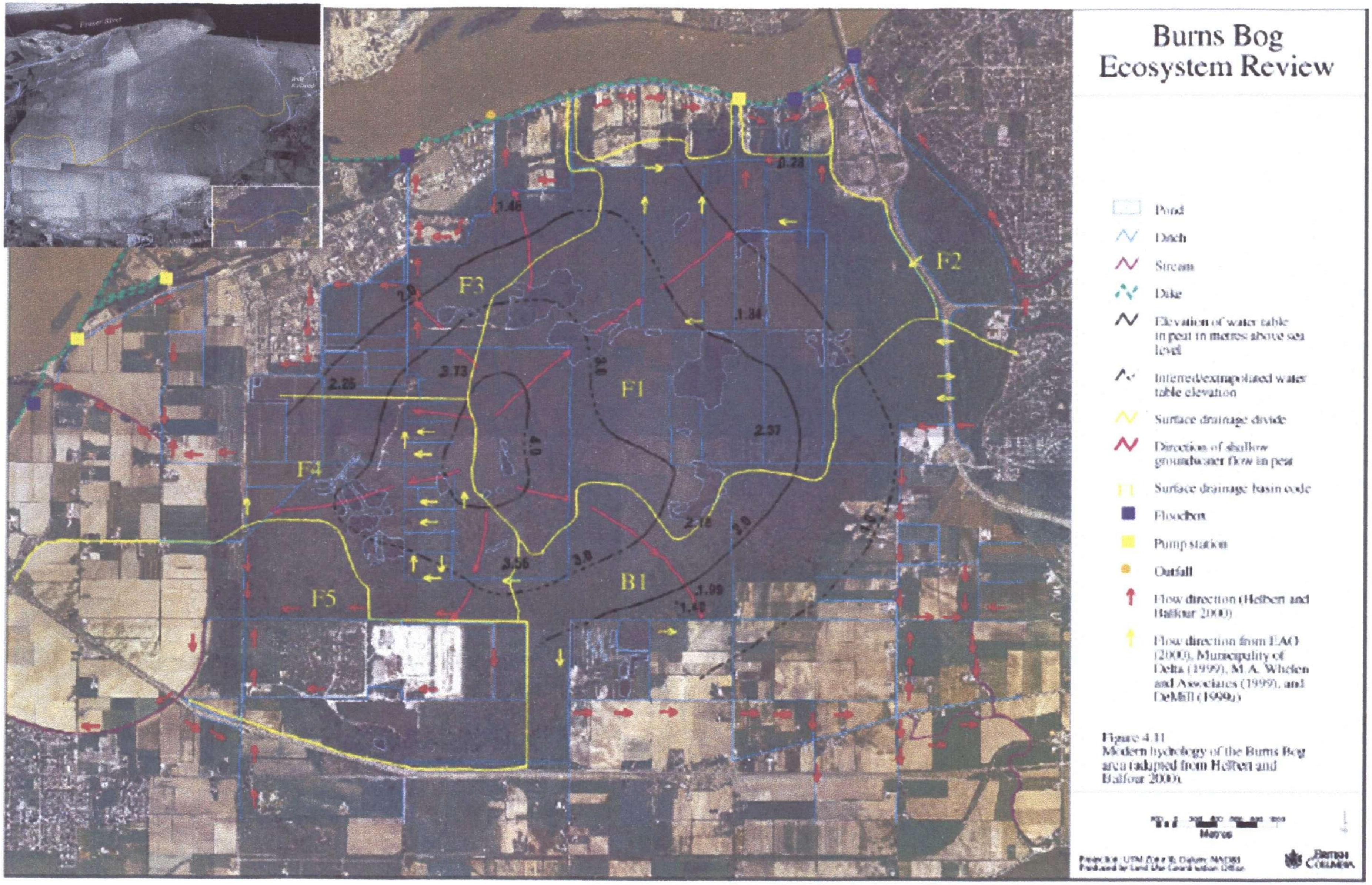
Appendix 5: Summary Map of Ecological Viability in Burns Bog (Source: Hebda et al., 2000)



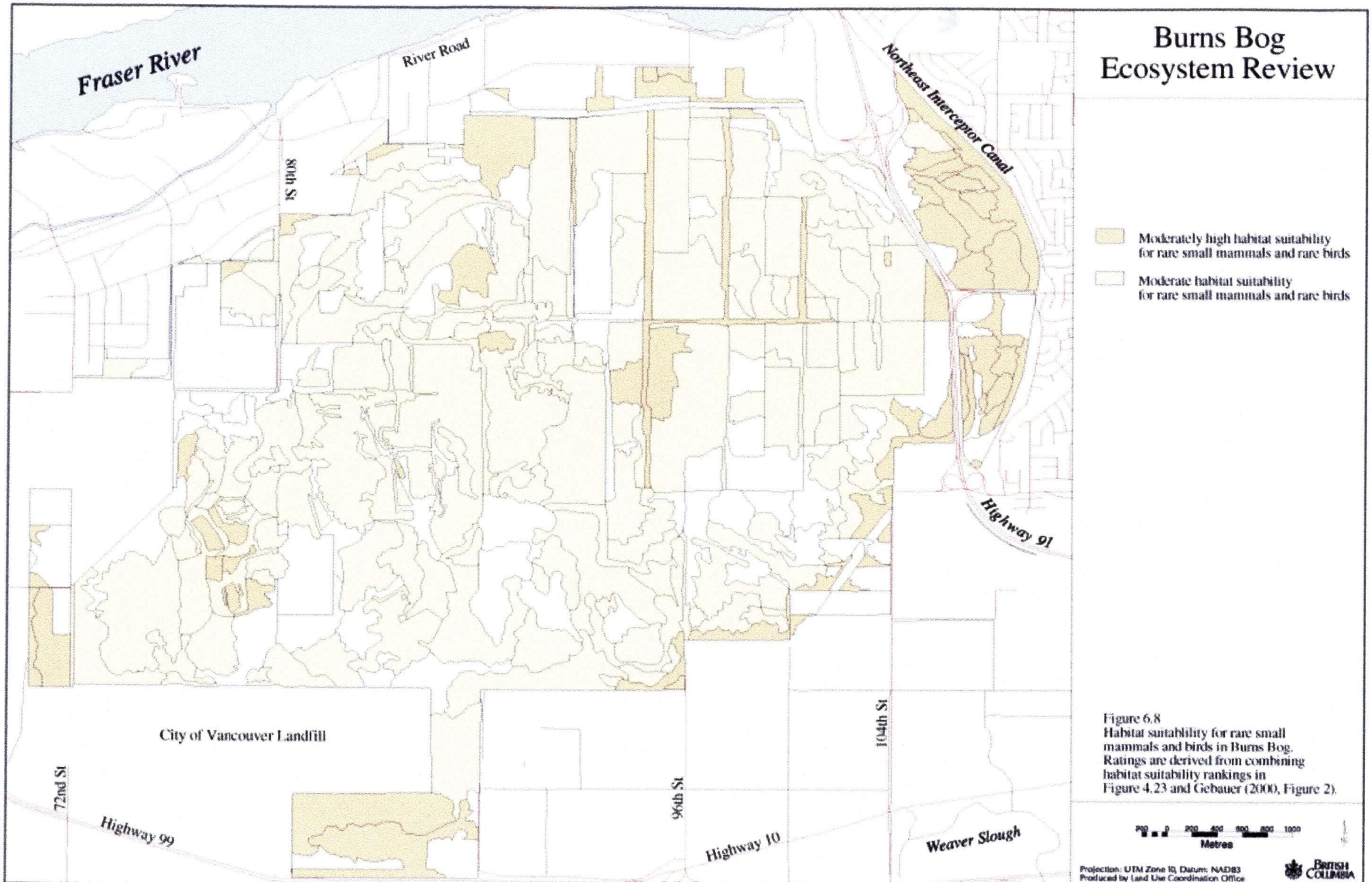
Appendix 6a: Distribution of Disturbance Types in Burns Bog (Source: Hebda et al., 2000)



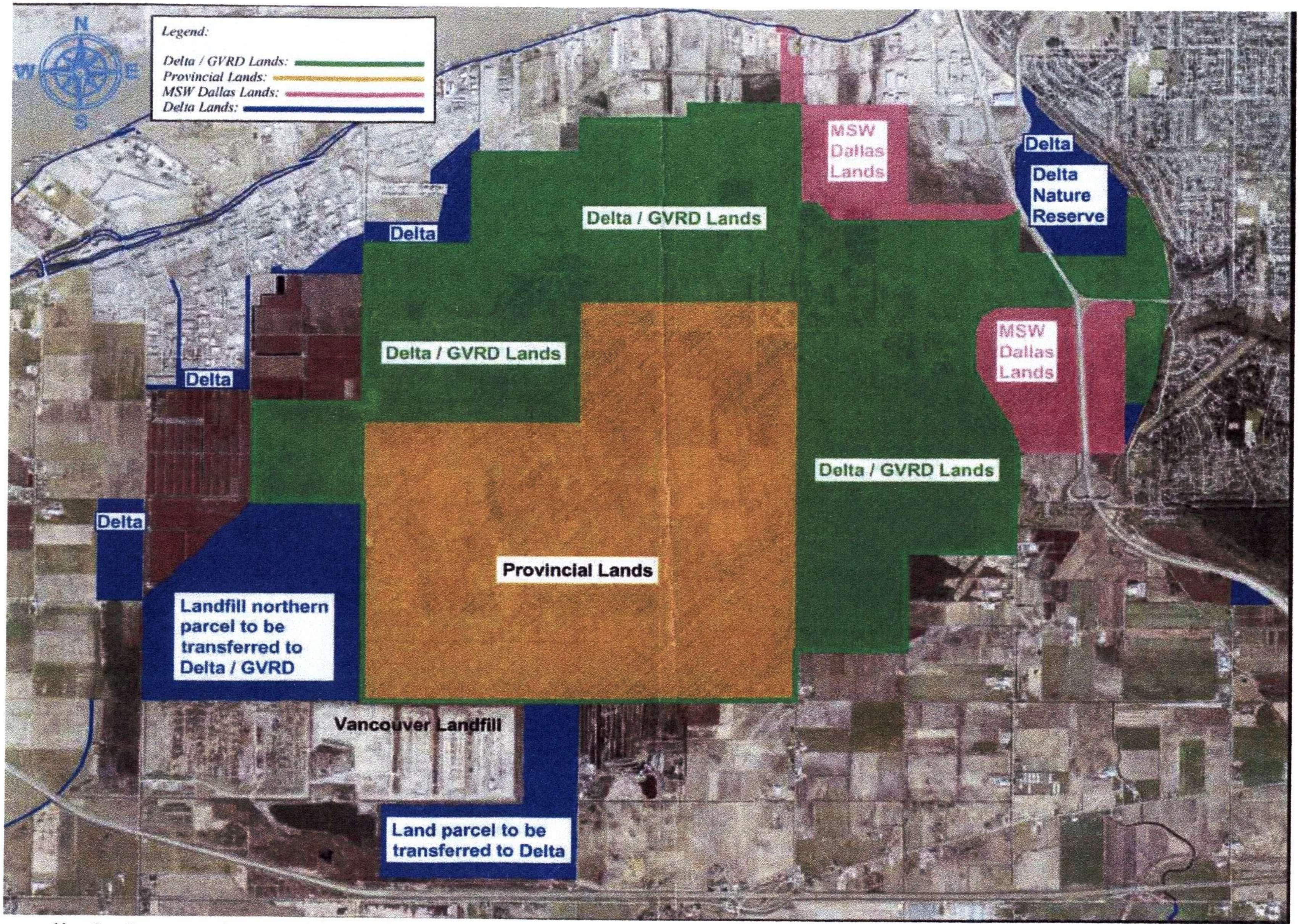
Appendix 6b: Modern Effect of Drainage Ditches in Burns Bog (Source: Hebda et al., 2000)



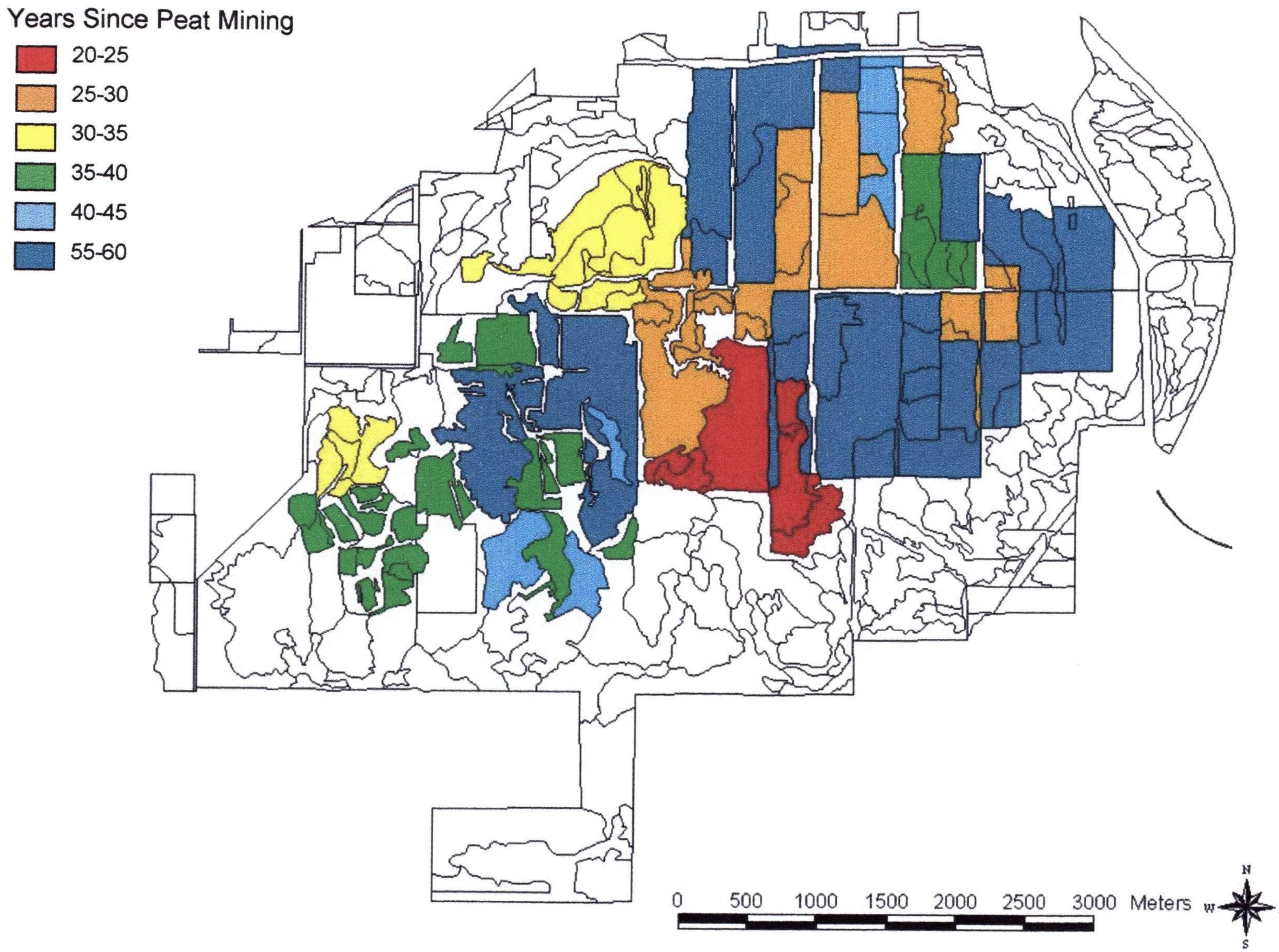
Appendix 6c: Modern Hydrology of Burns Bog (Inset: Historic Drainage Divide) (Source: Hebda et al., 2000)



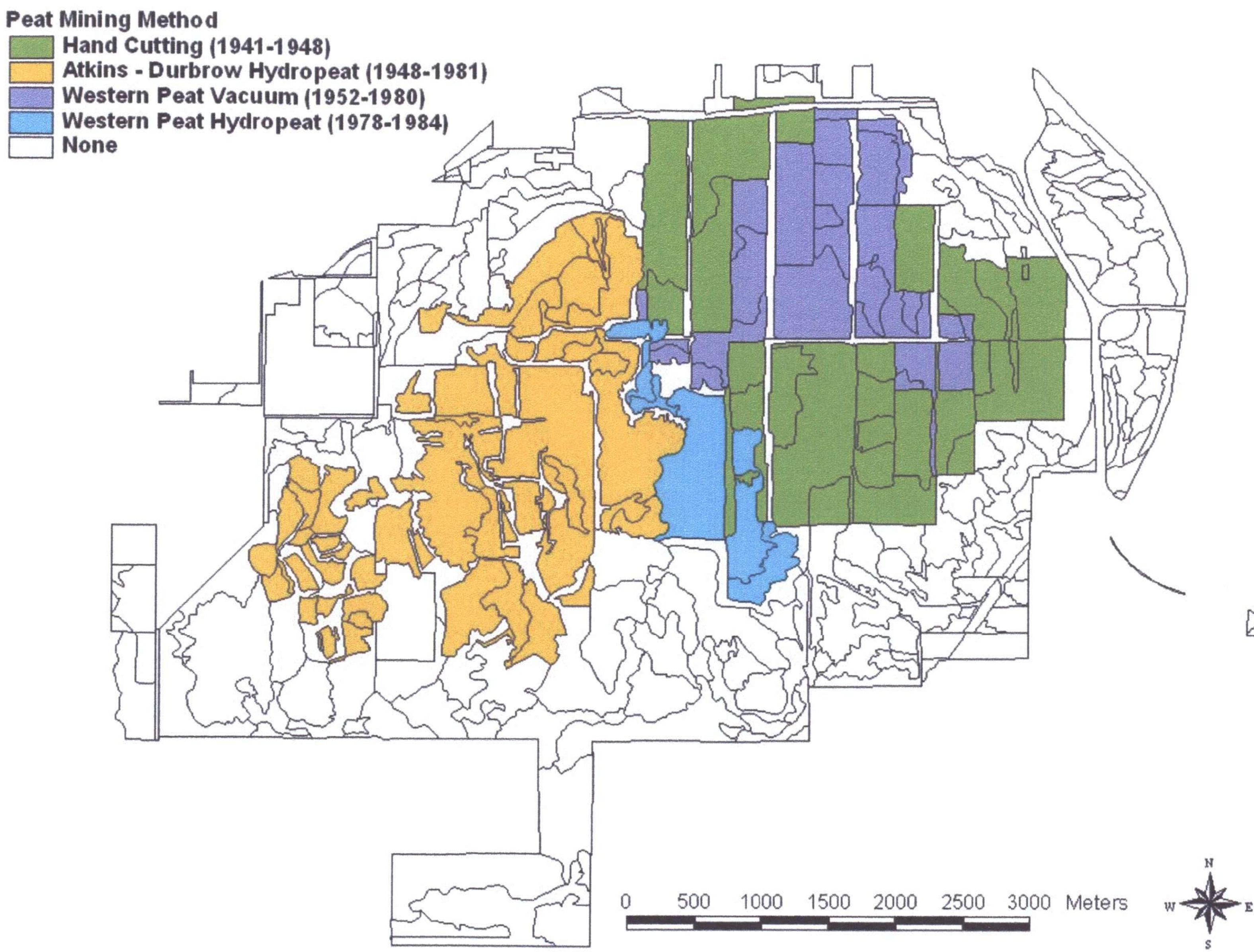
Appendix 7: Habitat Suitability for Rare Small Mammals and Birds in Burns Bog (Source: Hebda et al., 2000)



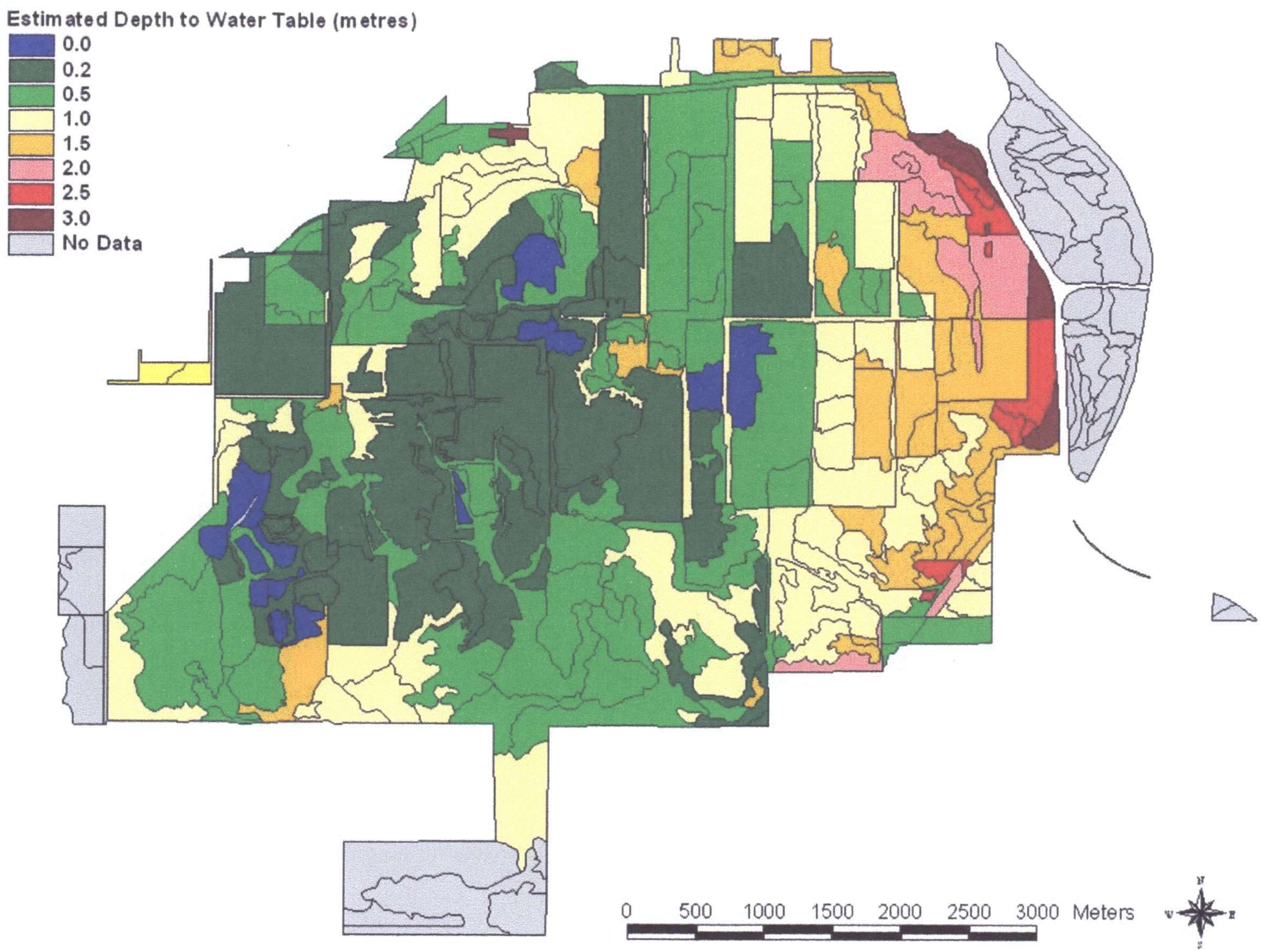
Appendix 8: Current Ownership of Burns Bog (Source: Corporation of Delta, 2004)



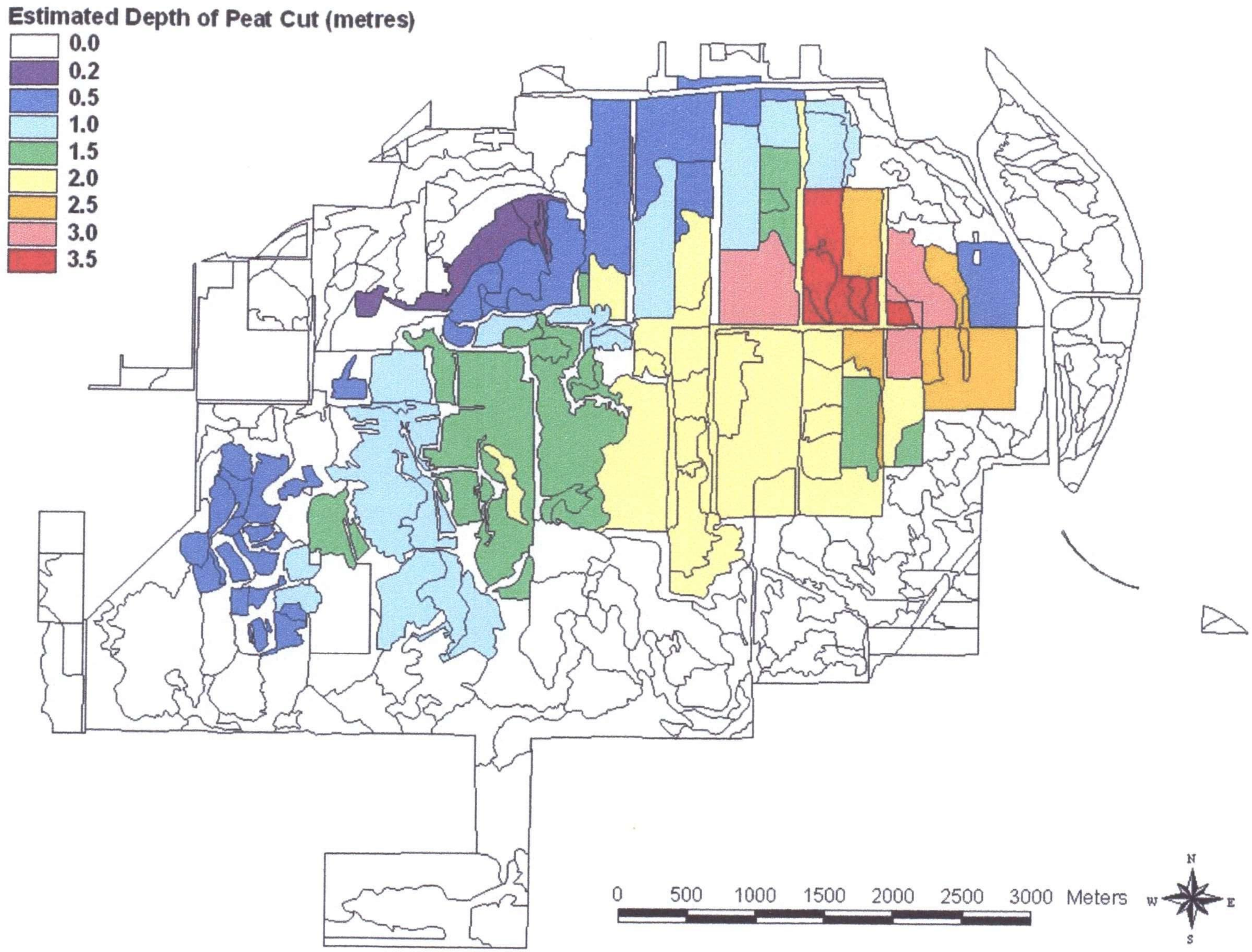
Appendix 9a: Years Since Peat Mining (Source: Burns Bog Ecosystem Review GIS Data, 2000)



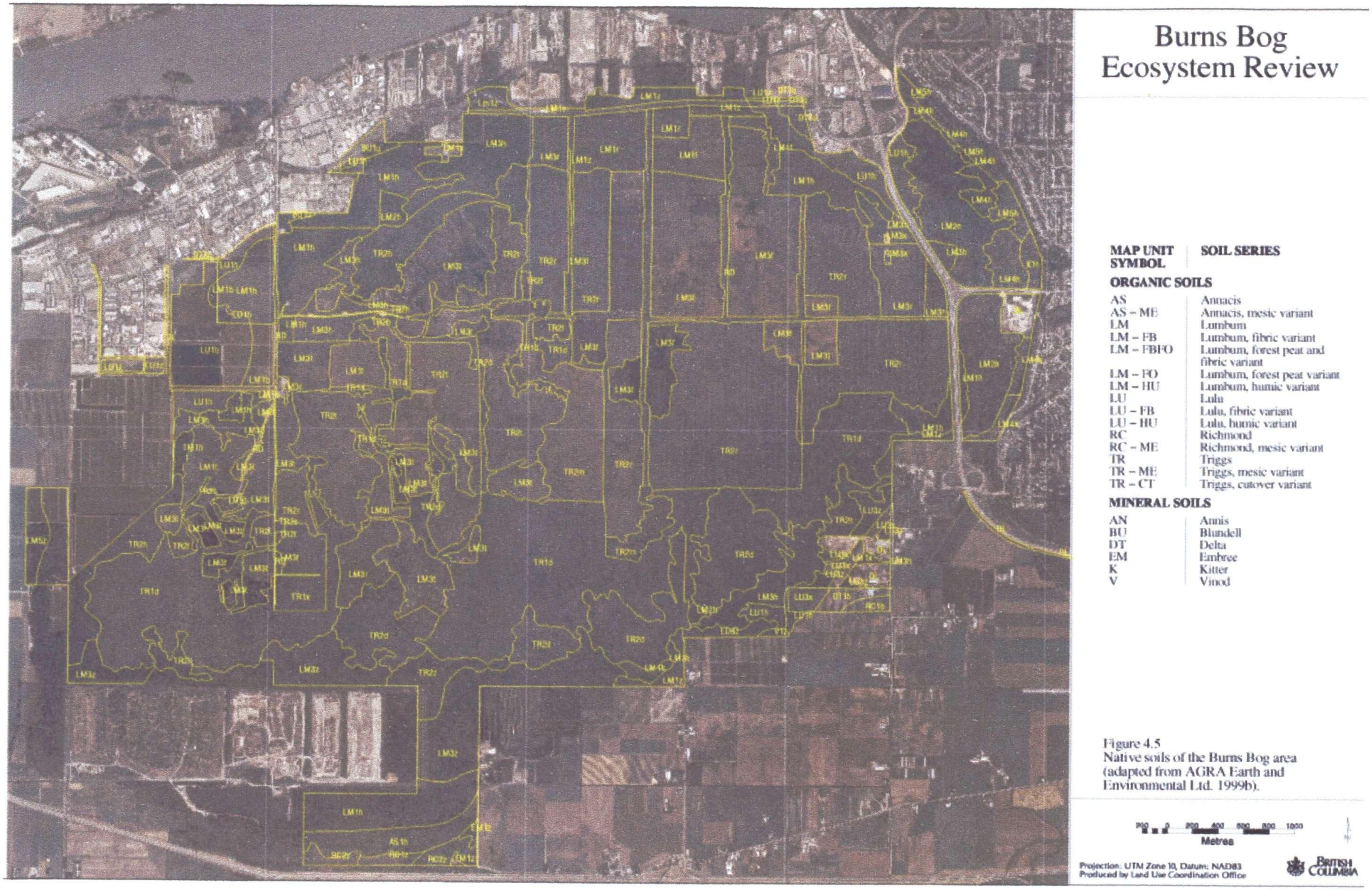
Appendix 9b: Peat Mining Method (Source: Burns Bog Ecosystem Review GIS Data, 2000)



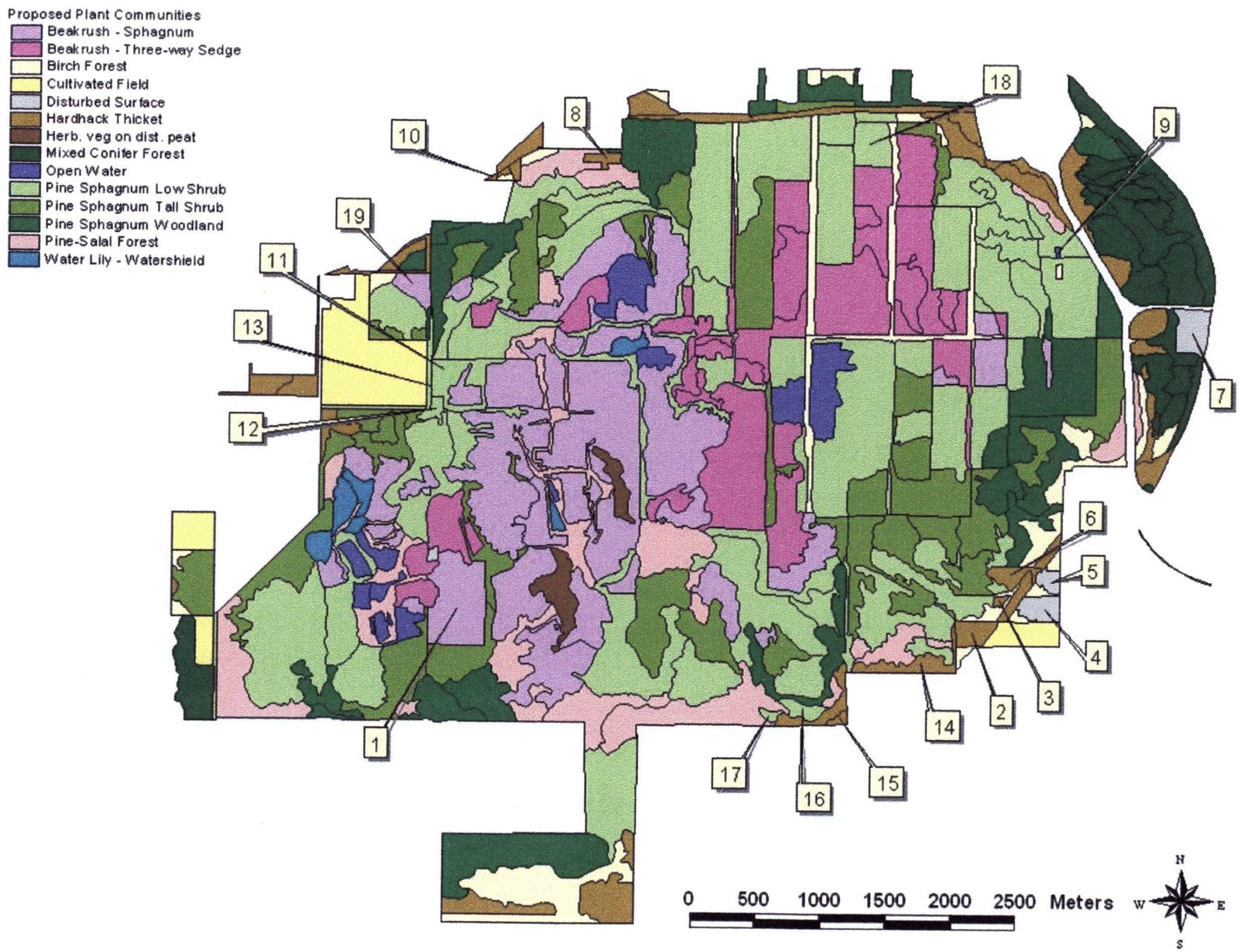
Appendix 9c: Estimated Depth to Water Table



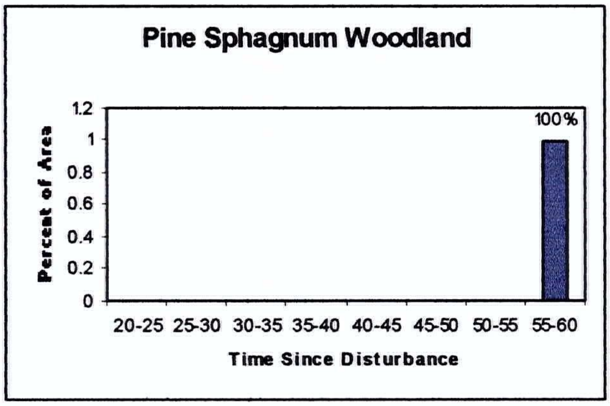
Appendix 9d: Estimated Depth of Peat Cut from Peat Mining

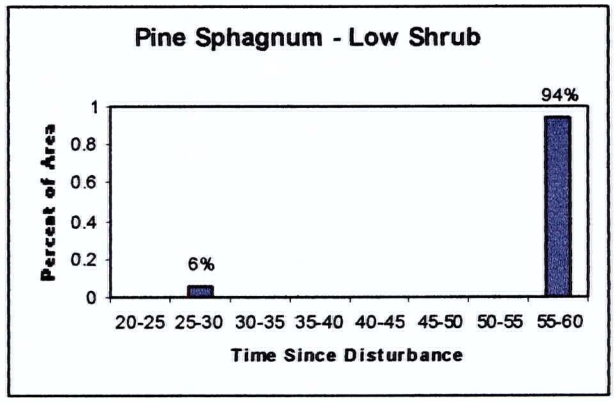


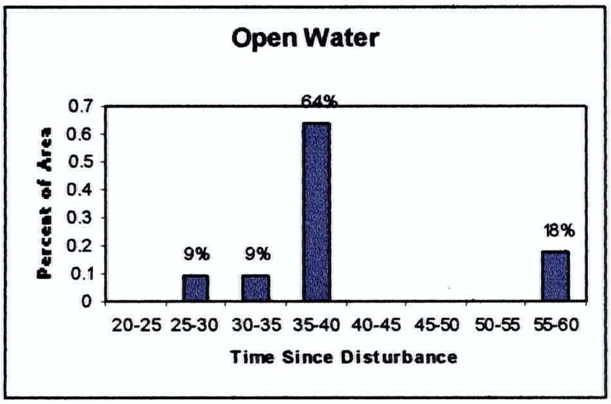
Appendix 9e: Native Soils of the Burns Bog Area (Source: Hebda et al., 2000)

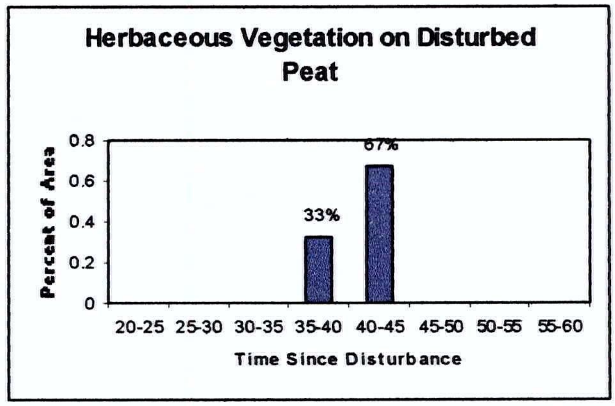


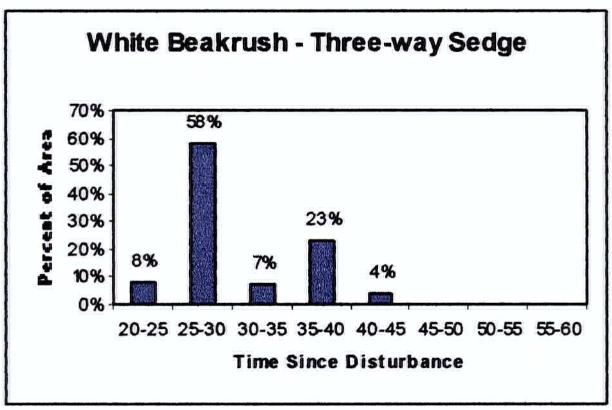
Appendix 10: Proposed Restoration Polygons and Future Plant Communities

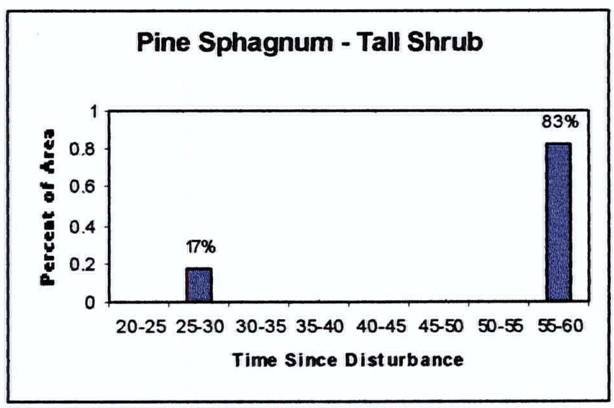


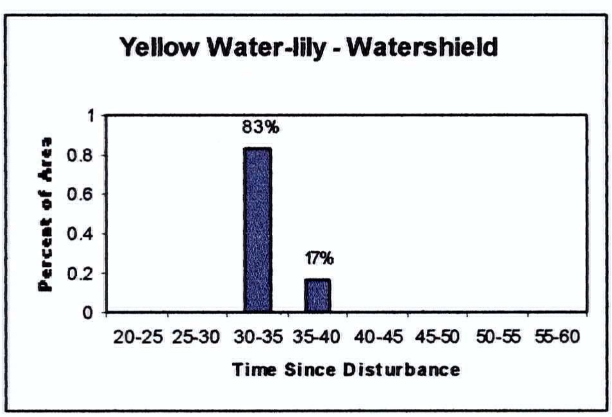


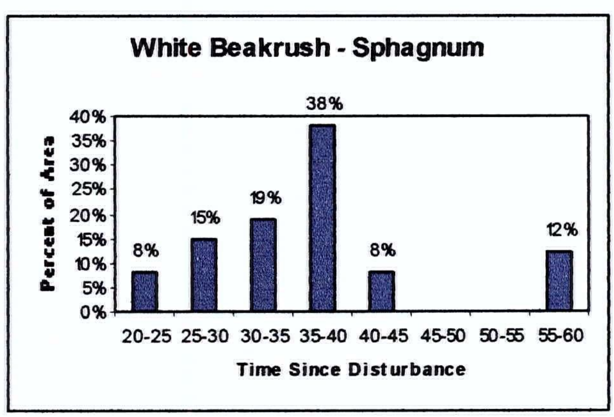




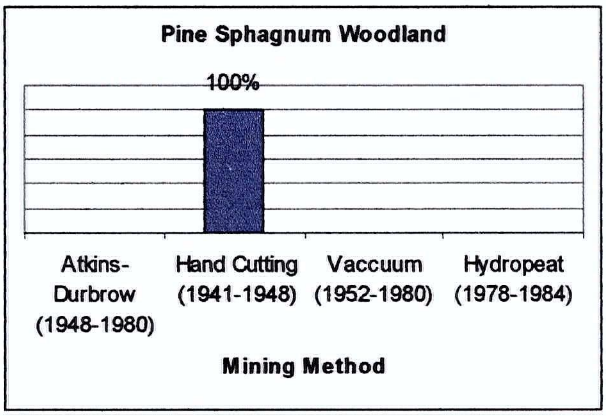


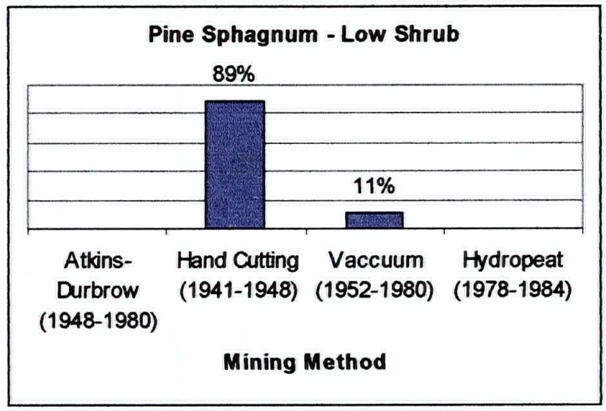


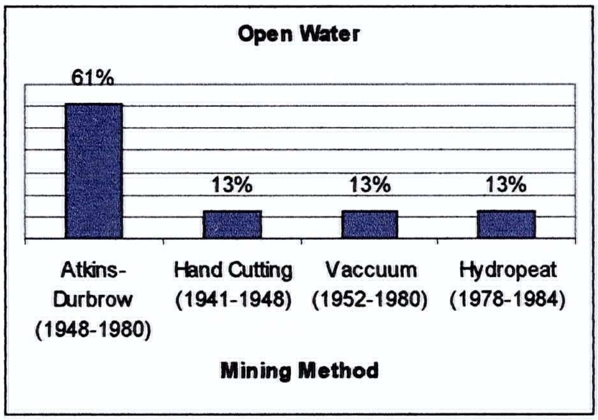


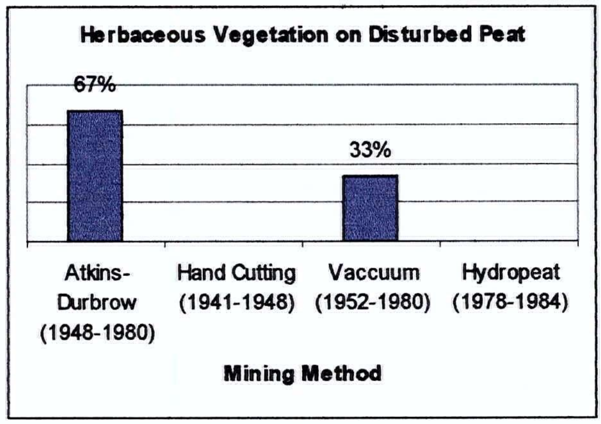


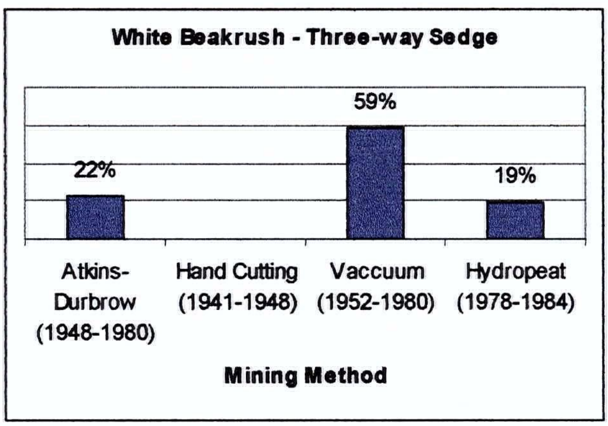
Appendix 11a: Graphs Developed from Time Since Disturbance Map

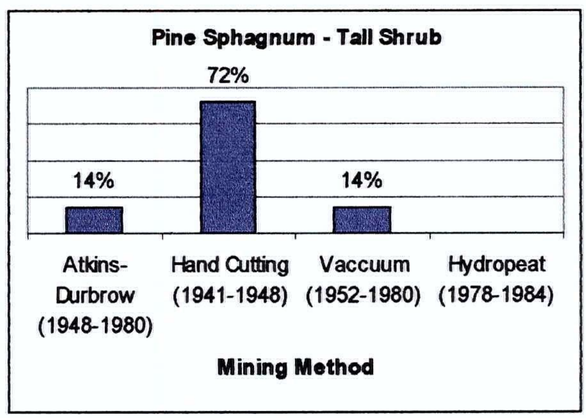


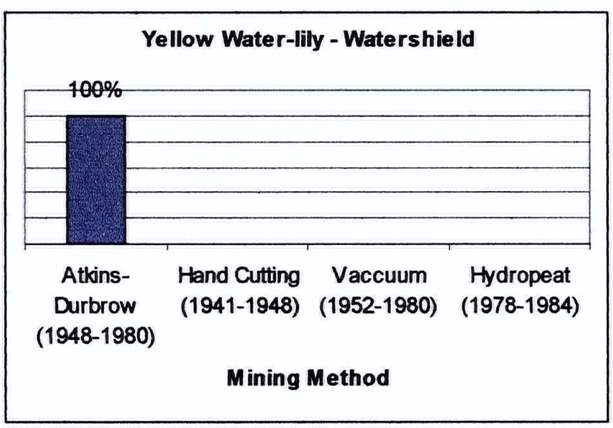


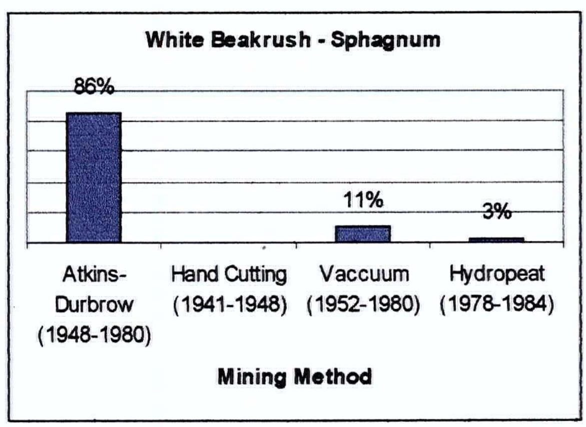




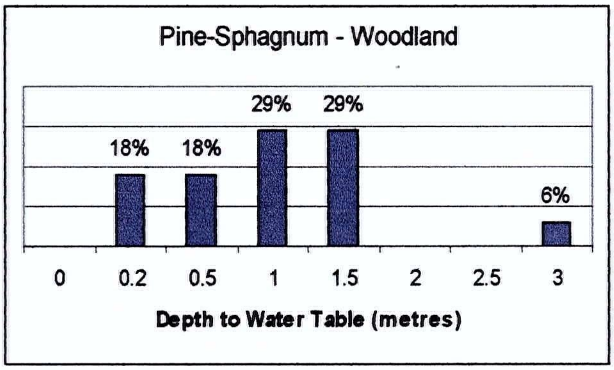


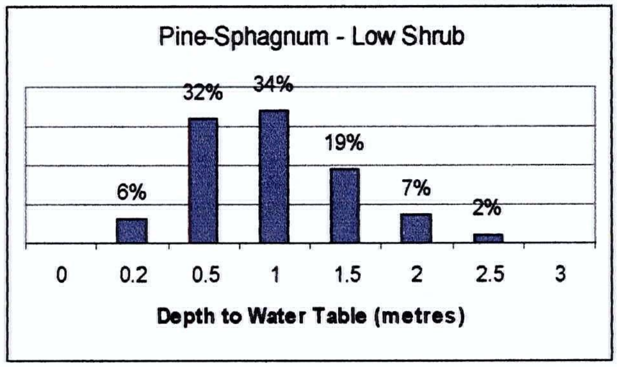


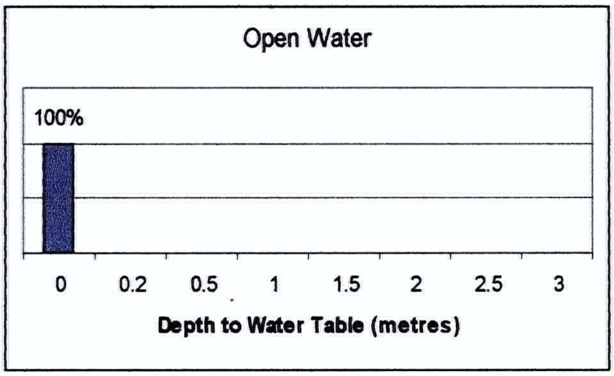


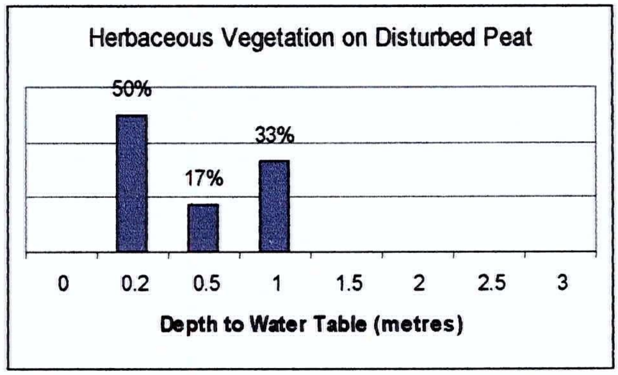


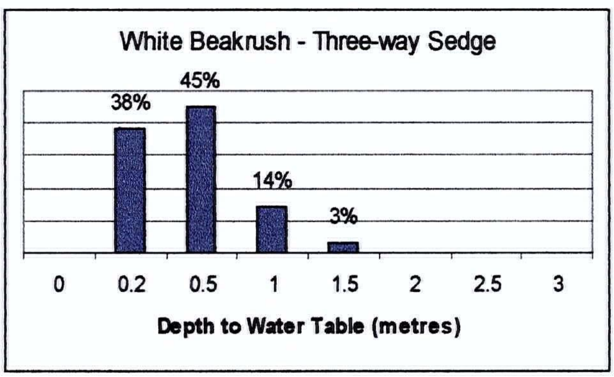
Appendix 11b: Graphs Developed from Peat Mining Method Map

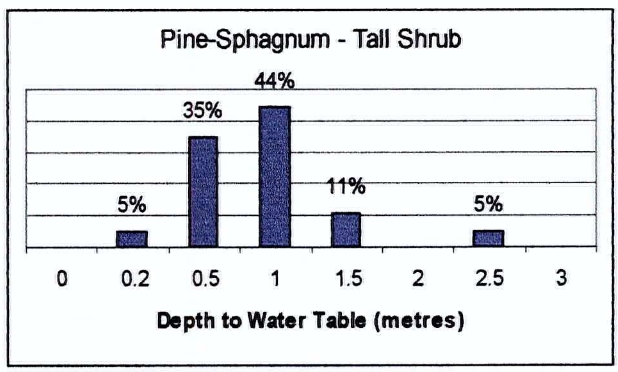


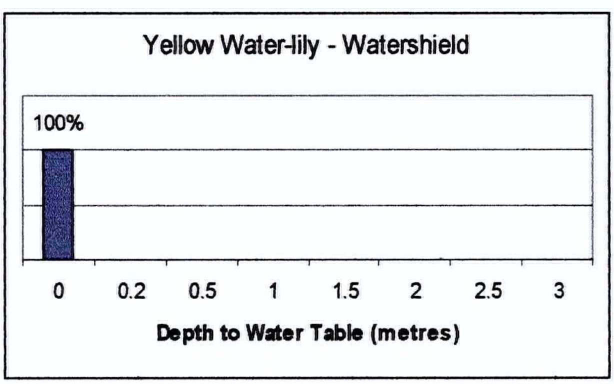


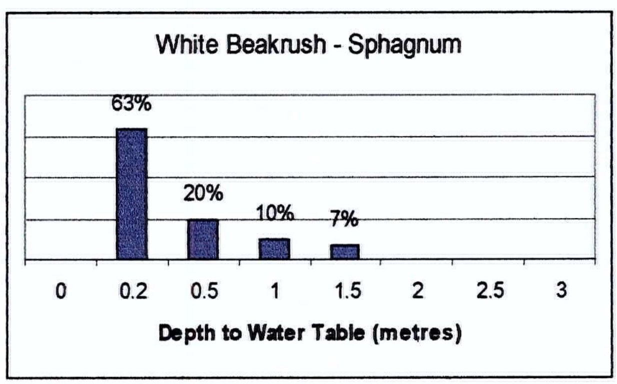




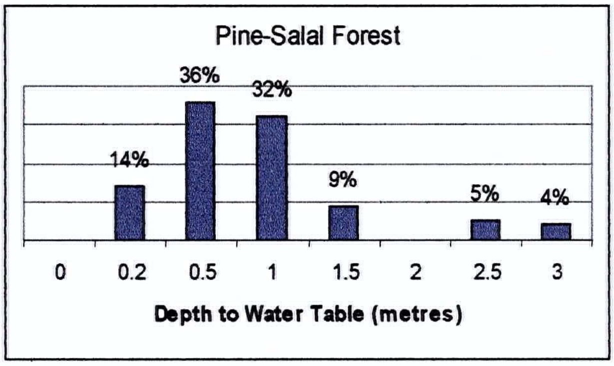


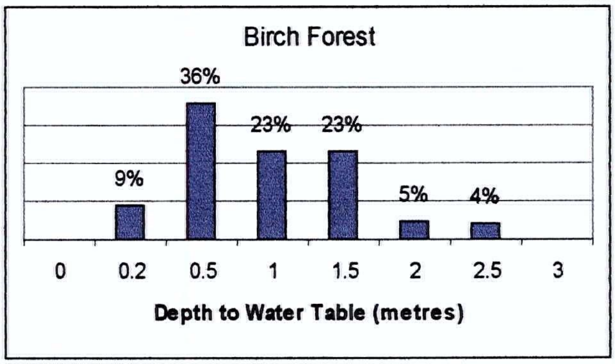


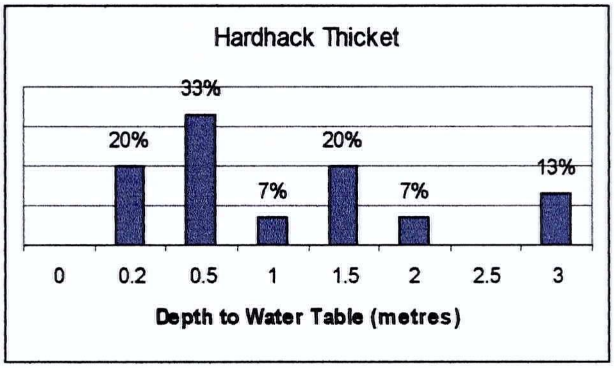


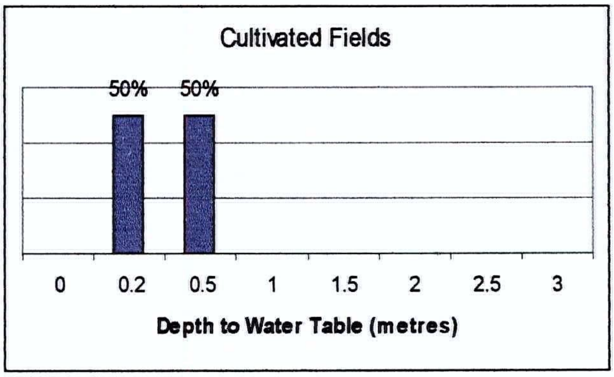


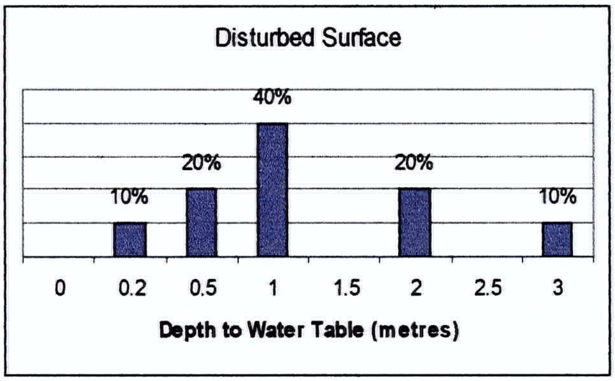
Appendix 11c: Graphs Developed from Depth to Water Table Map



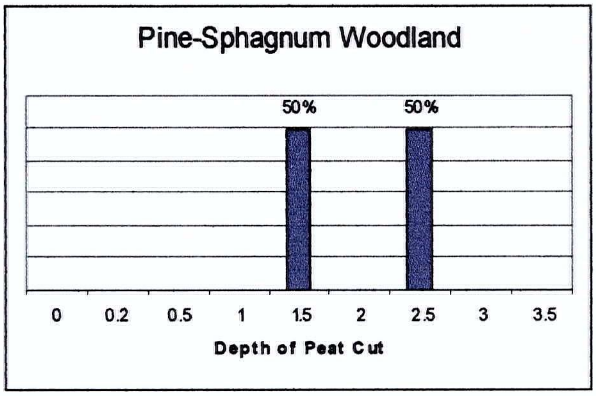


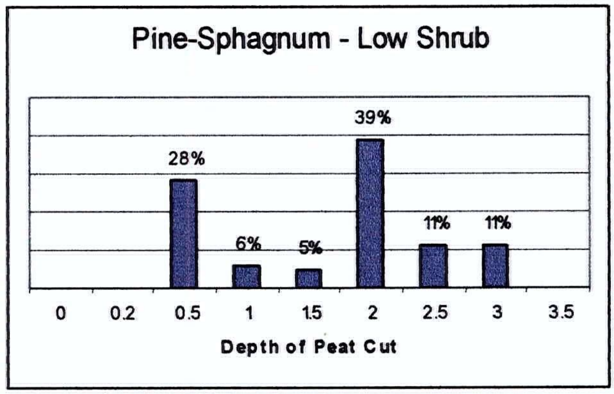


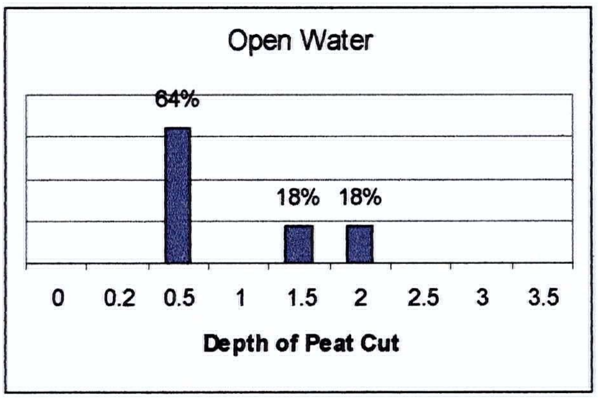


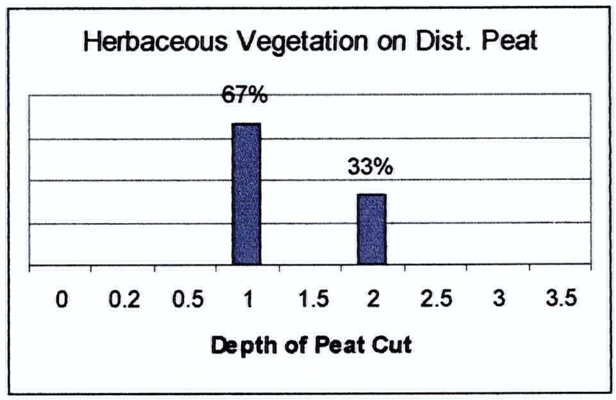


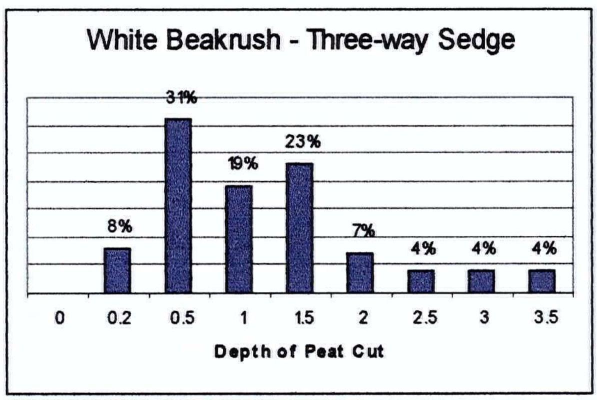
Appendix 11c (cont.): Graphs Developed from Depth to Water Table Map

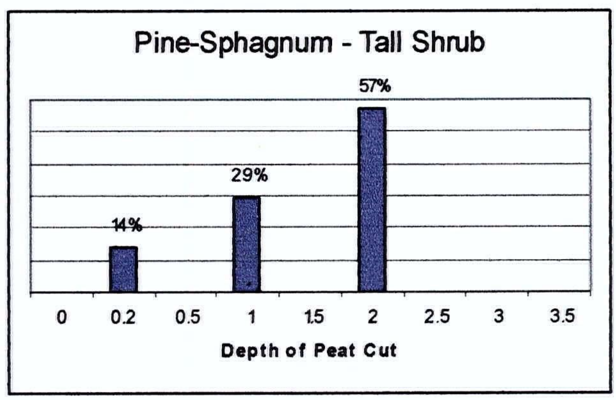


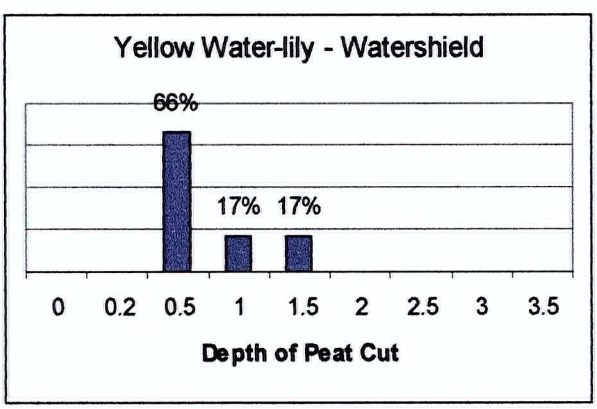


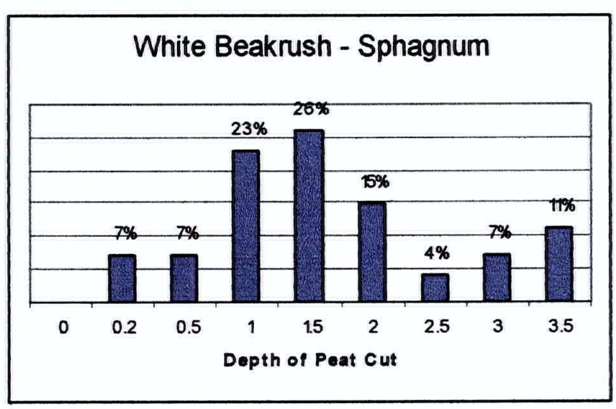




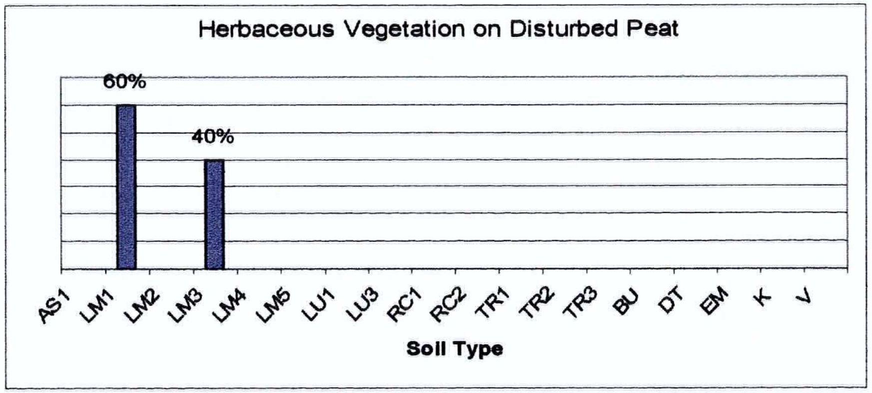


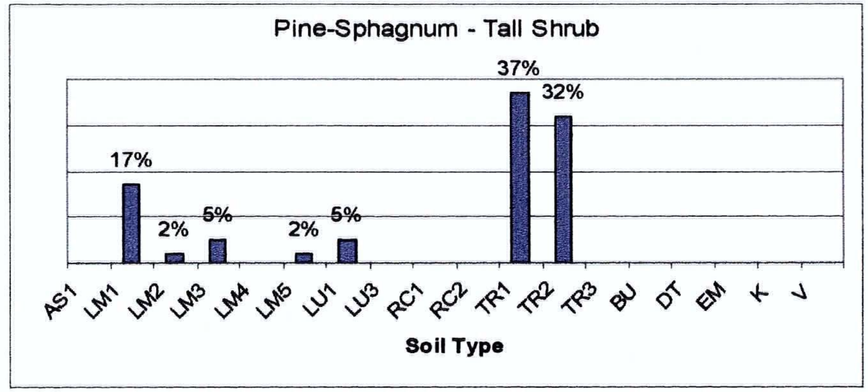


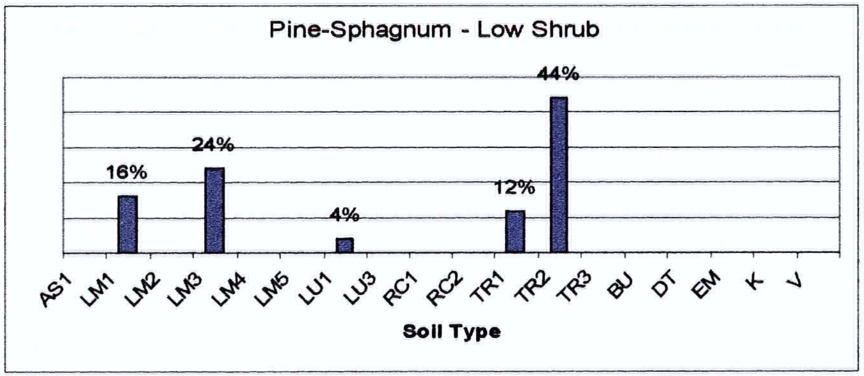


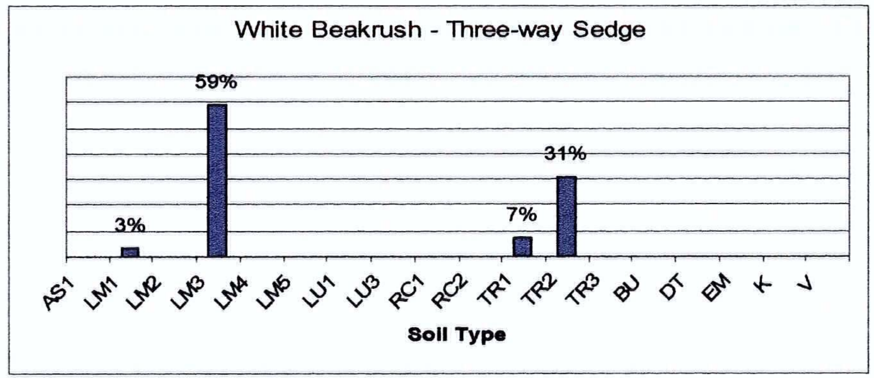


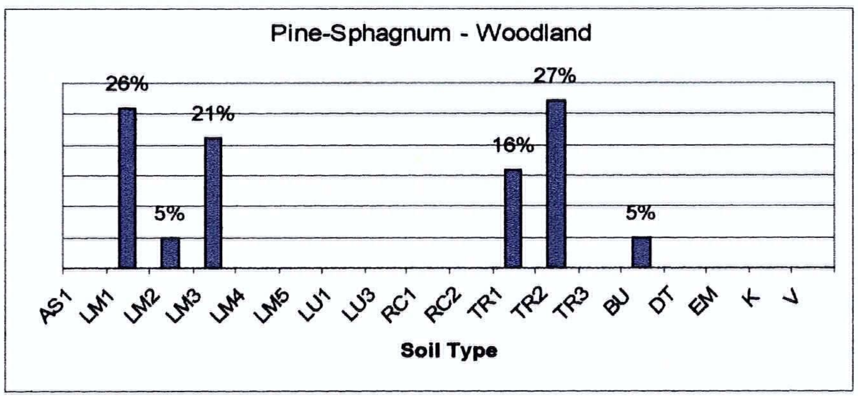
Appendix 11d: Graphs Developed from Depth of Peat Cut Map

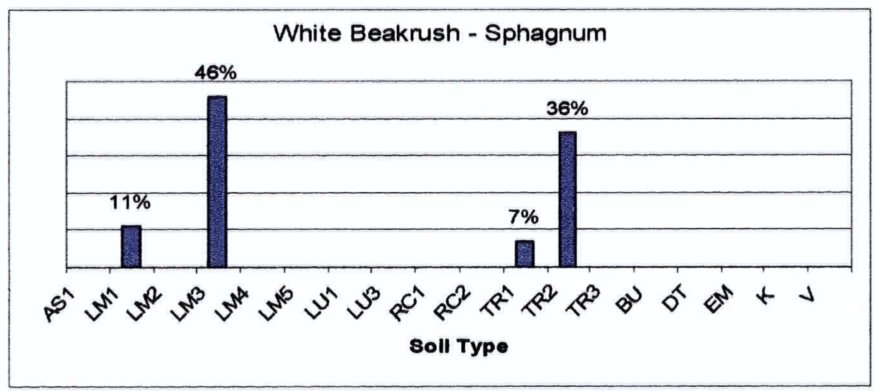




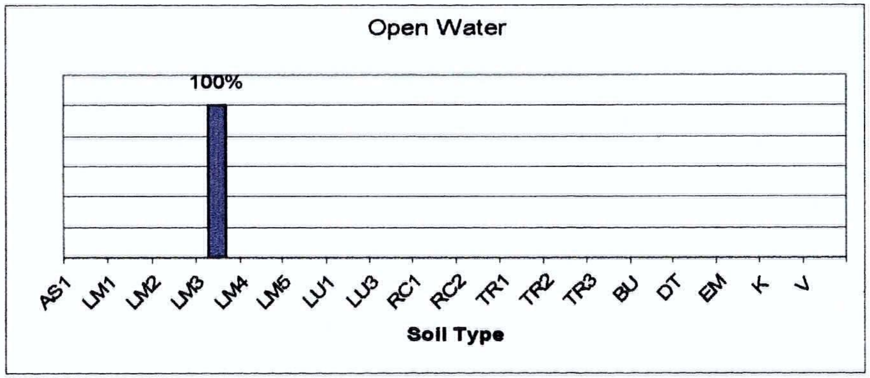


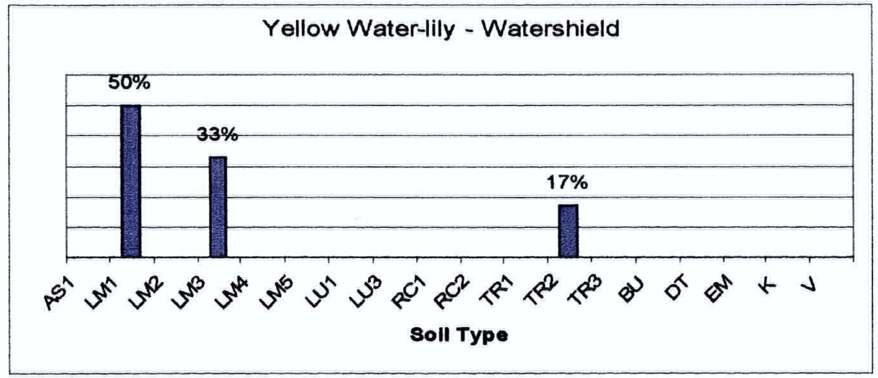


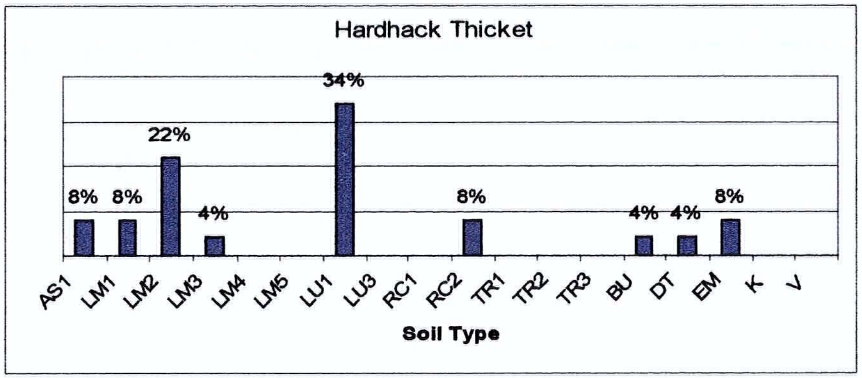


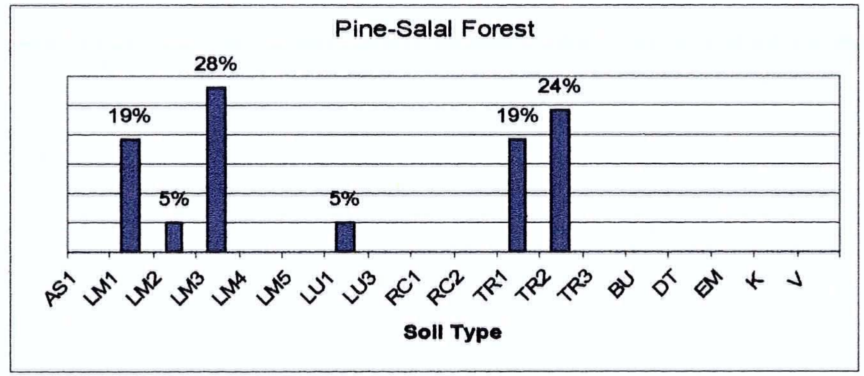


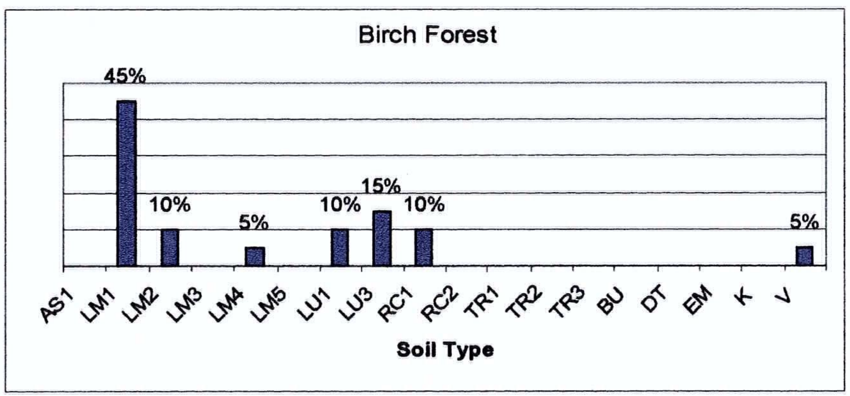
Appendix 11e: Graphs Developed From Soil Cover Map

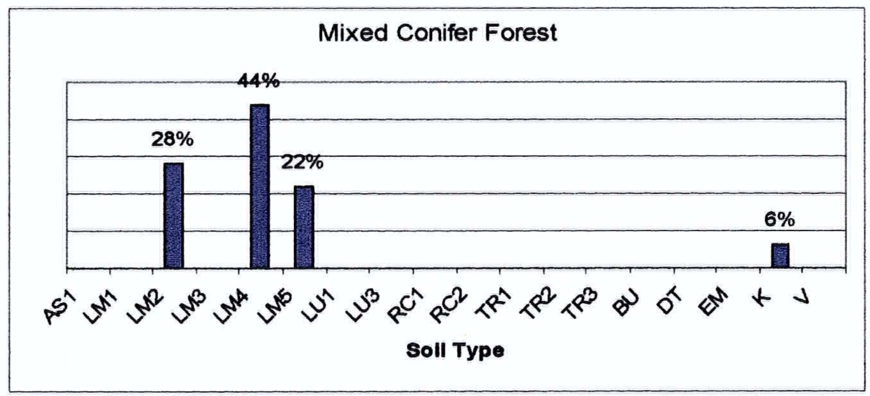




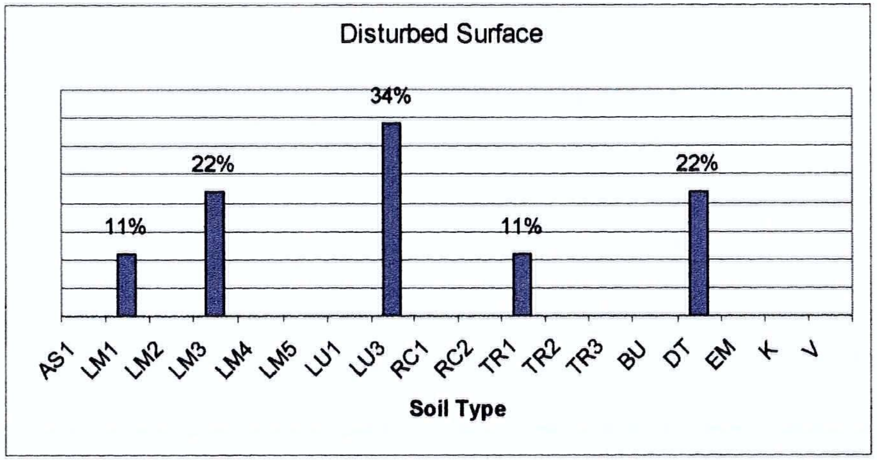


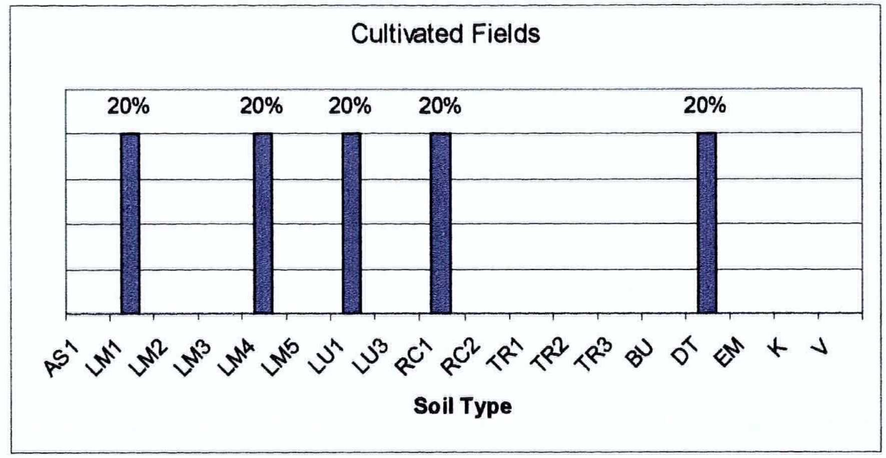






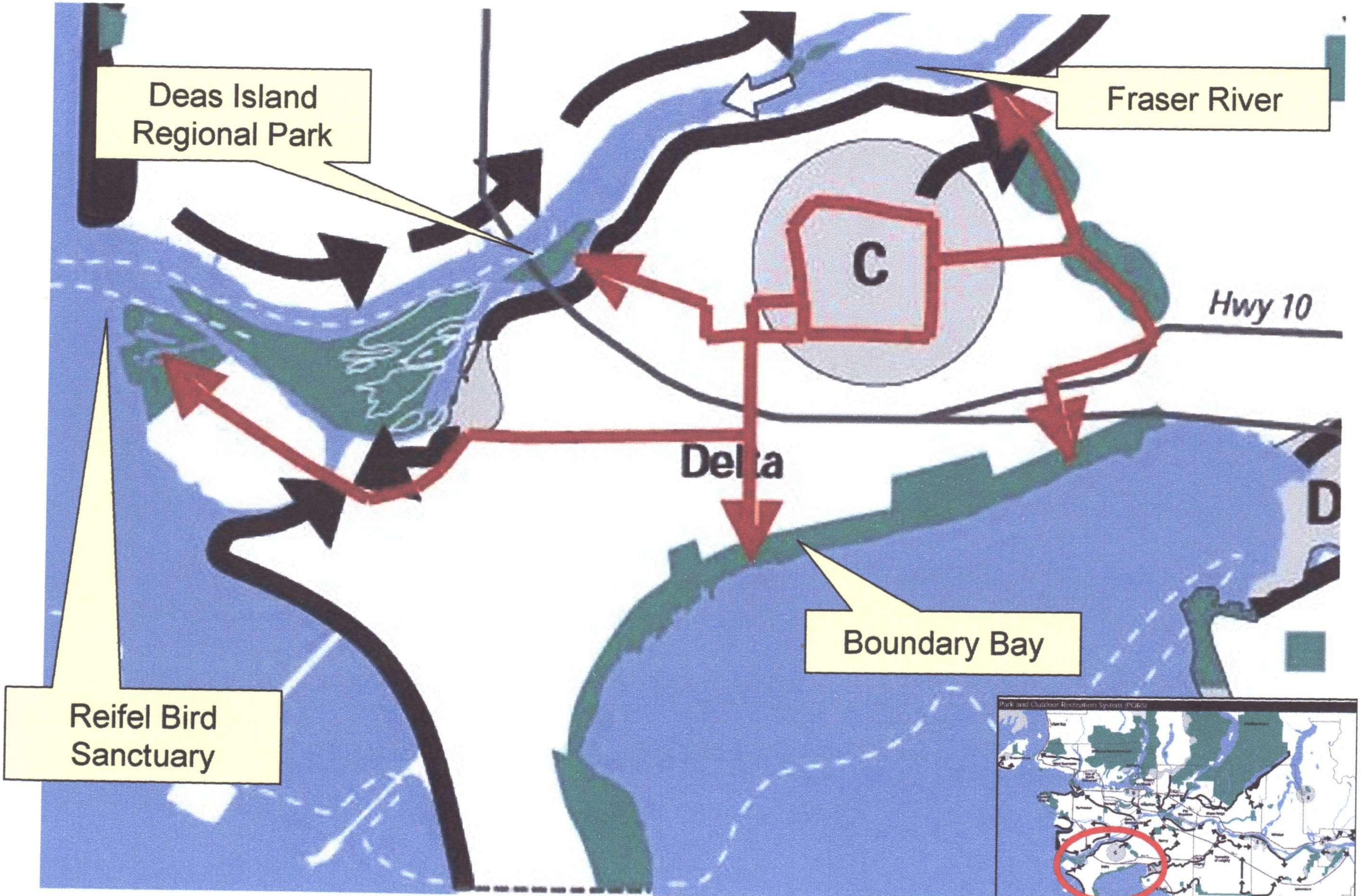
Appendix 11e (cont.): Graphs Developed From Soil Cover Map





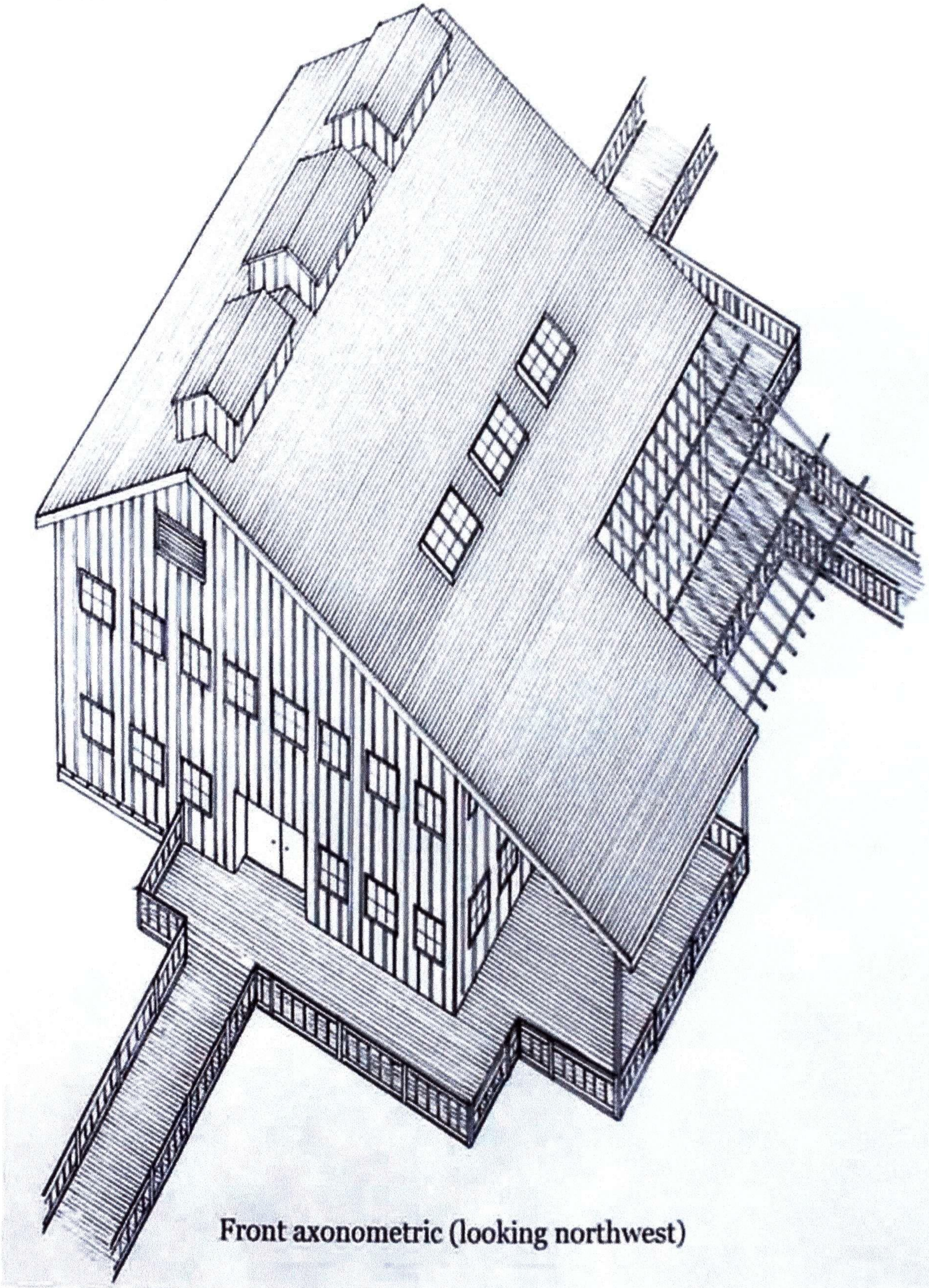
Appendix 11e (cont.): Graphs Developed From Soil Cover Map

Appendix 12: Example Long-term Strategy to Maintain Plant Community Diversity

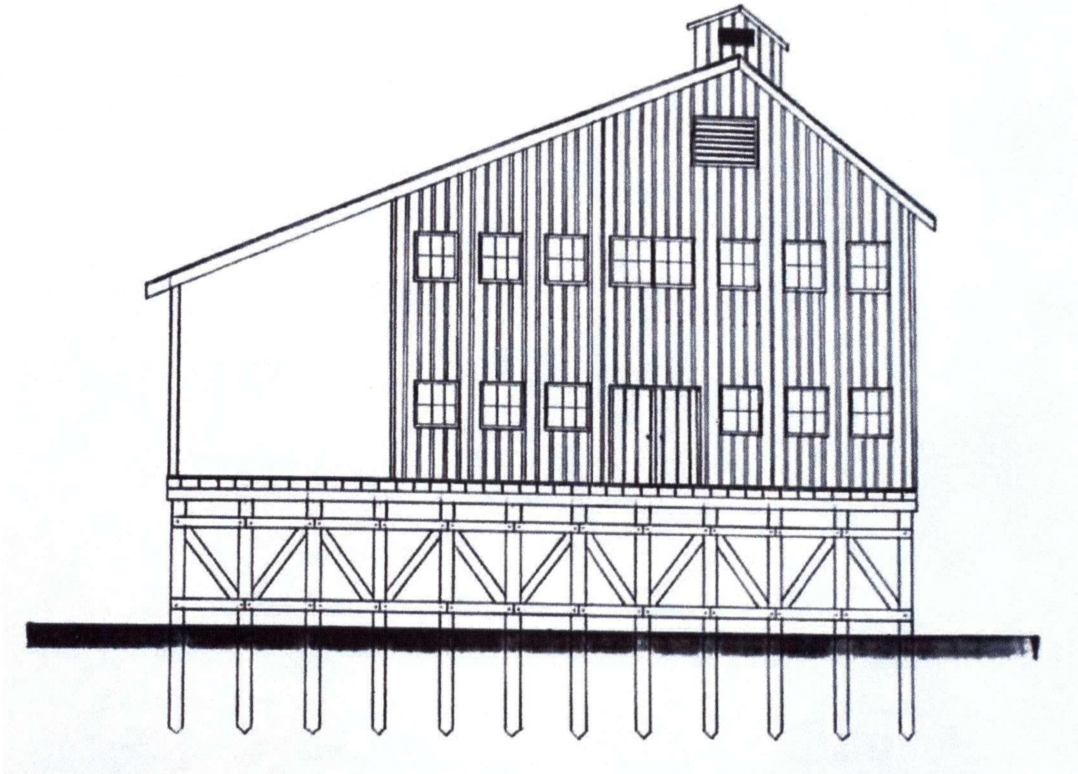


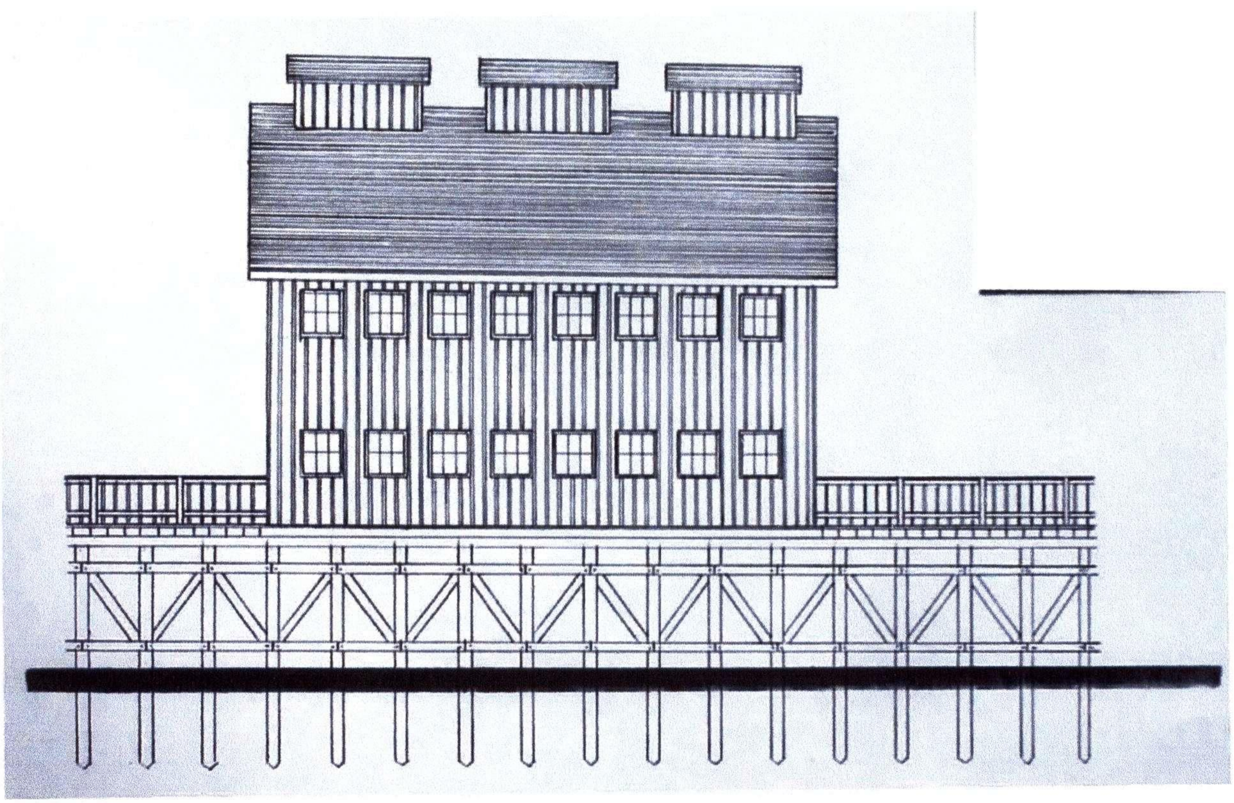
Appendix 13: Proposed Regional Greenway Plan (Source: GVRD, 1996); red lines and callouts added

Appendix 14a: Visitor Centre Plan and Site Section

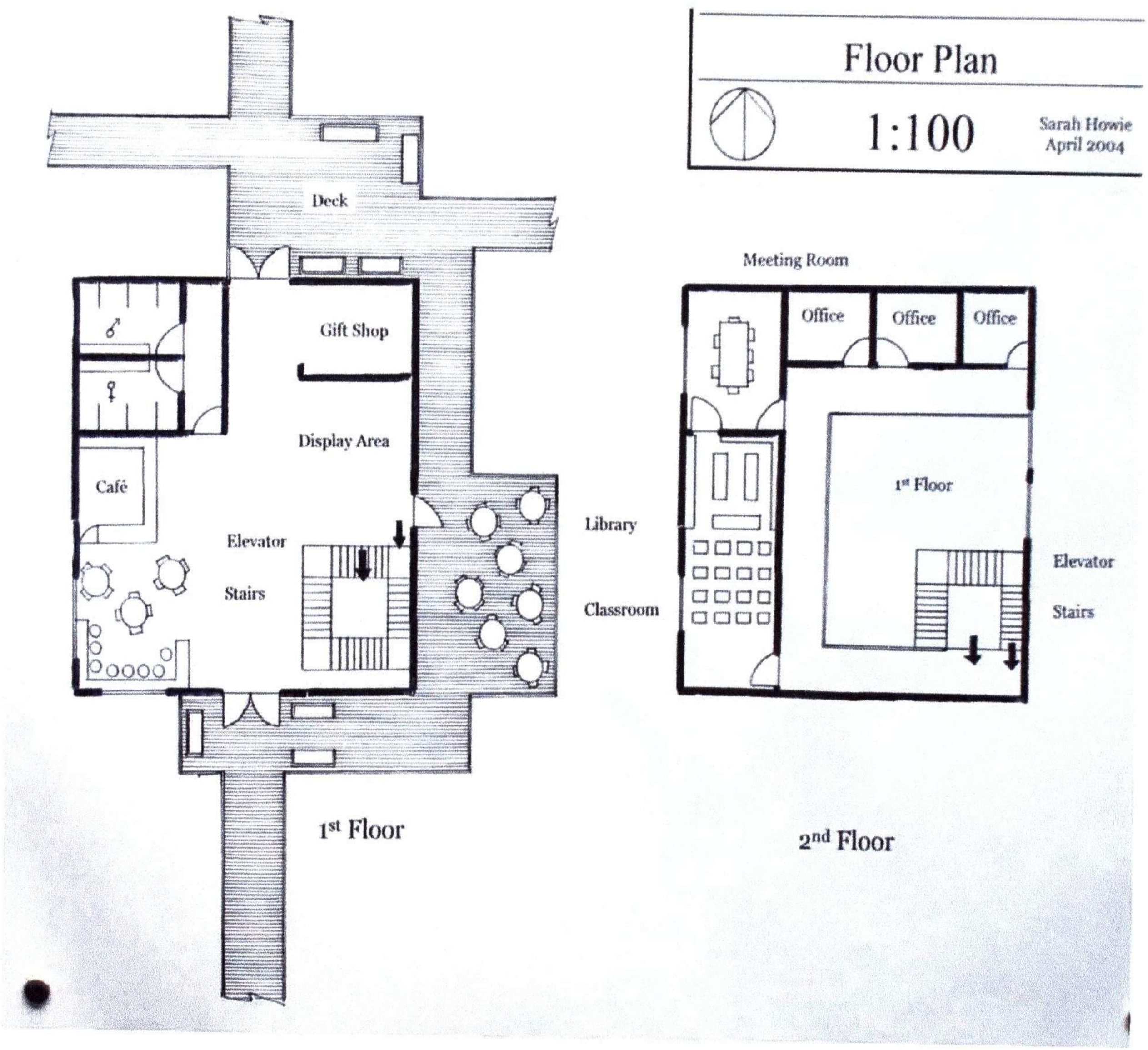


Appendix 14b: Visitor Centre Axonometric

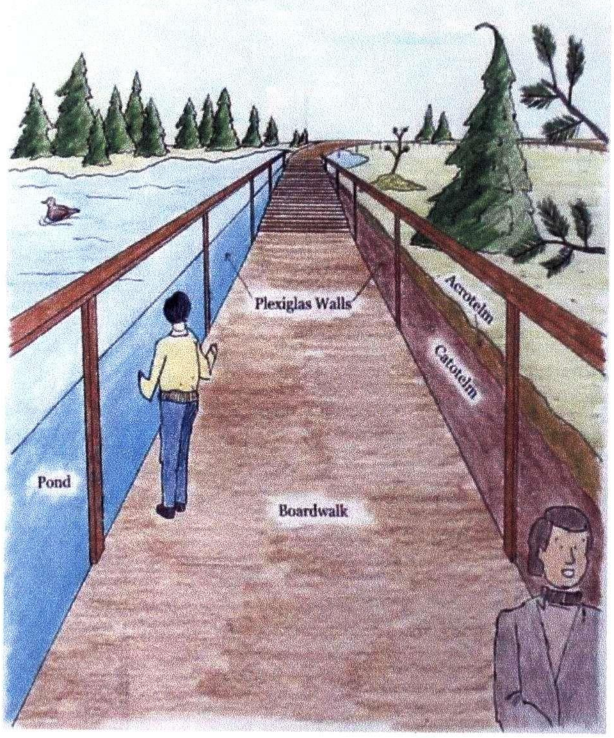


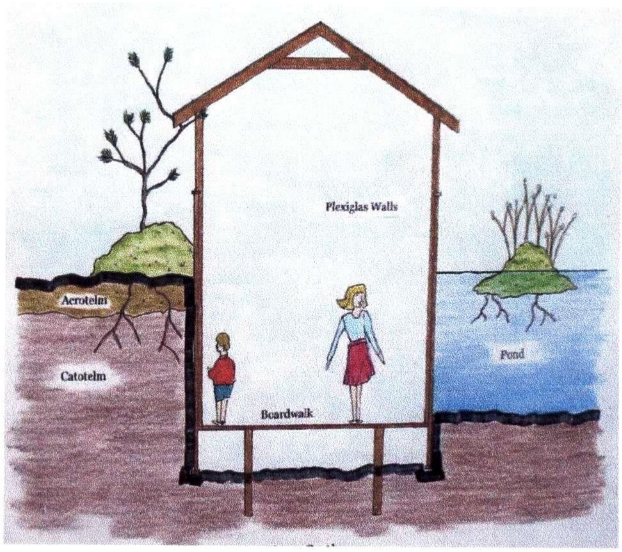


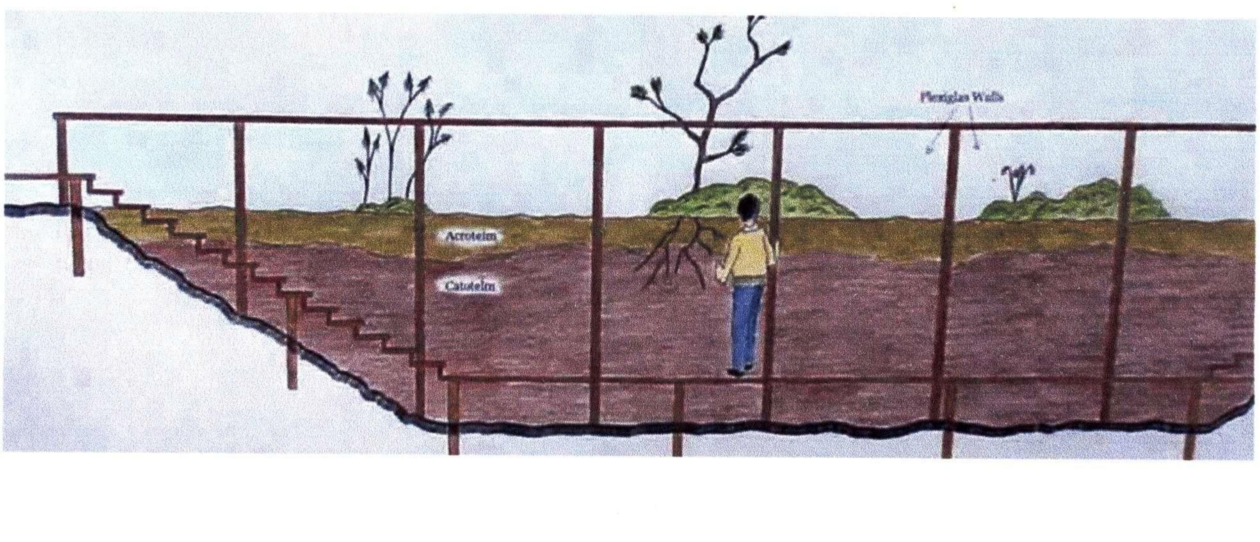
Appendix 14b (cont.): Visitor Centre Building Sections (back and side)



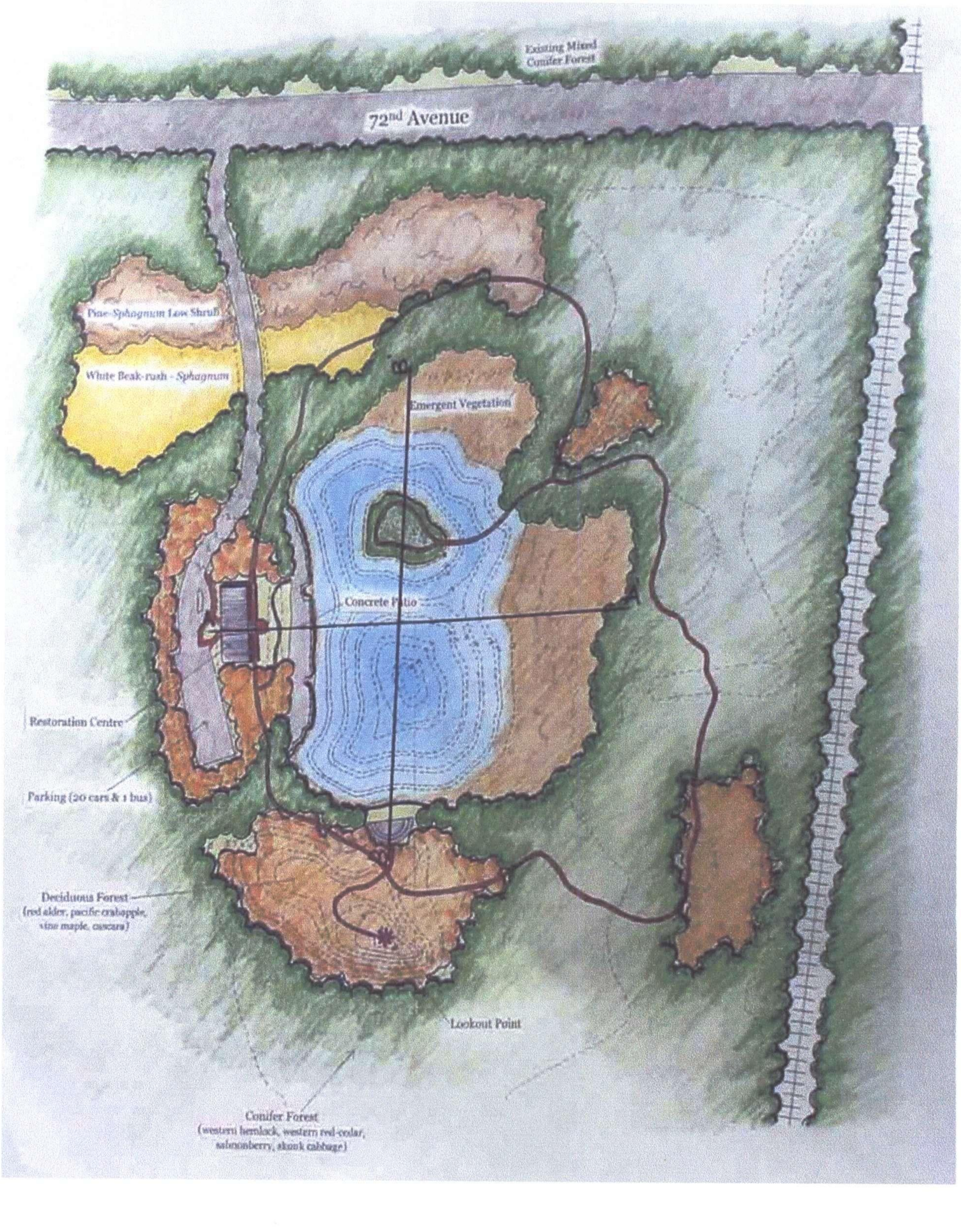
Appendix 14c: Visitor Centre Building Floor Plan



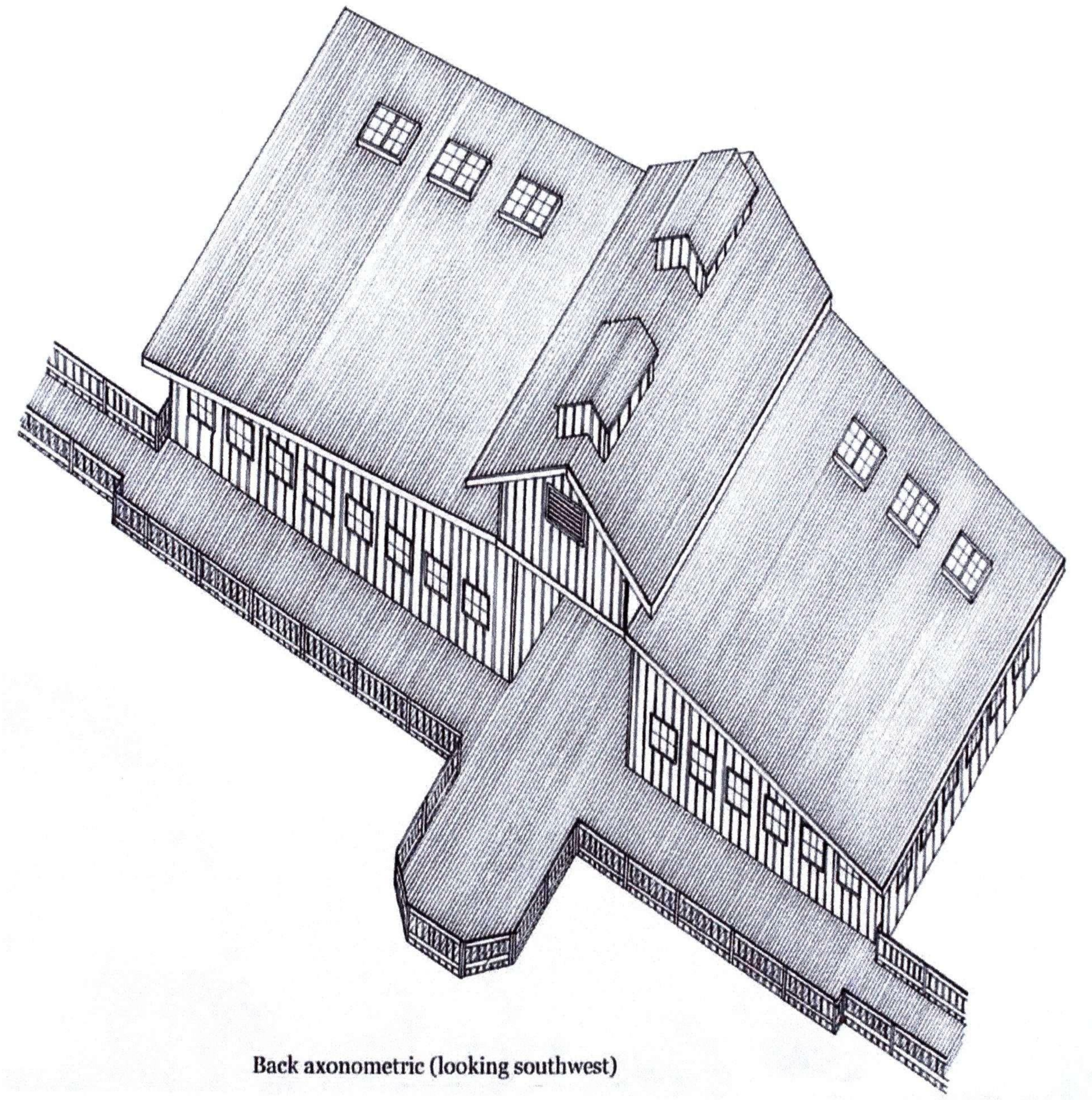




Appendix 14d: Bogarium (perspective, front section, side section)

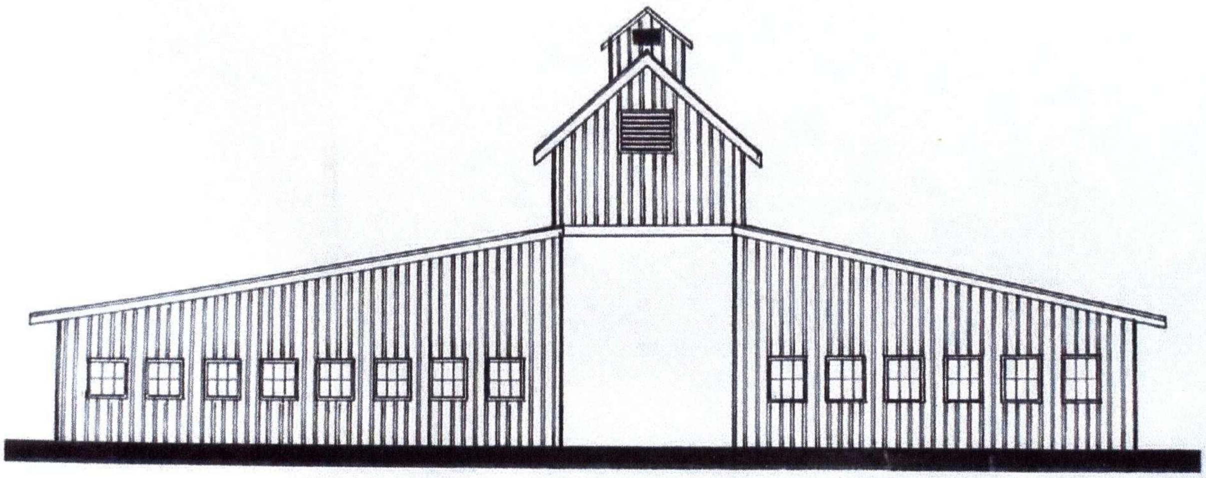


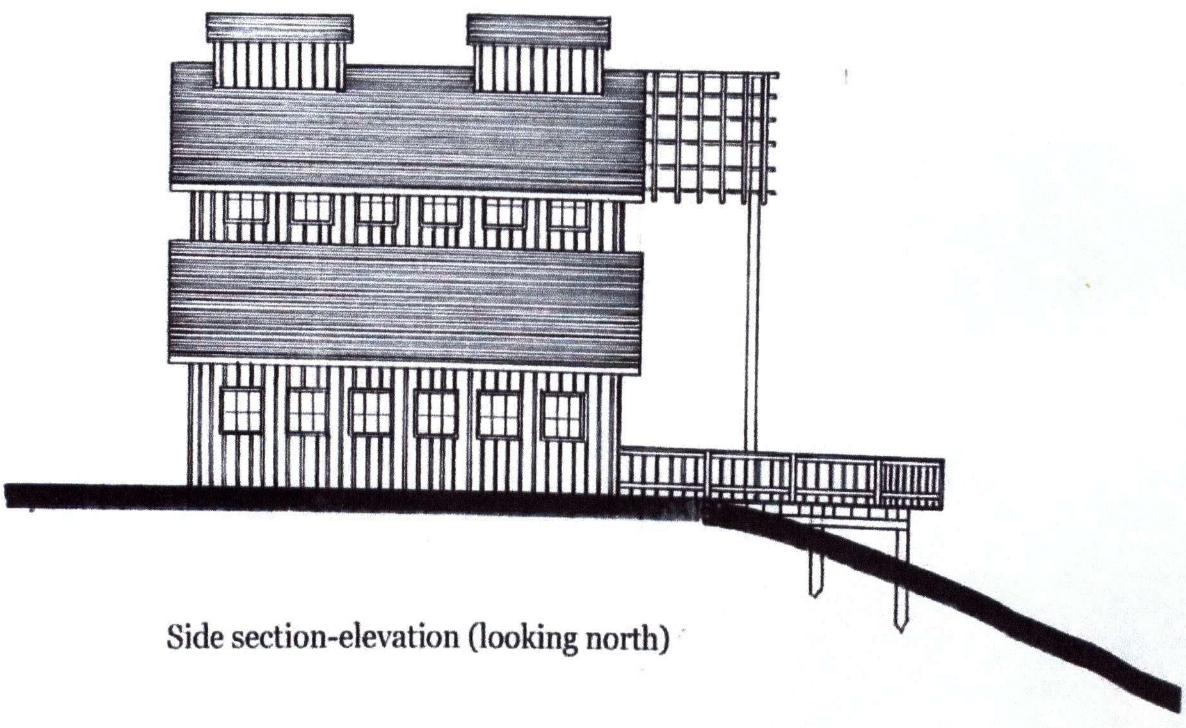
Appendix 14e: Restoration Centre Site Plan



Back axonometric (looking southwest)

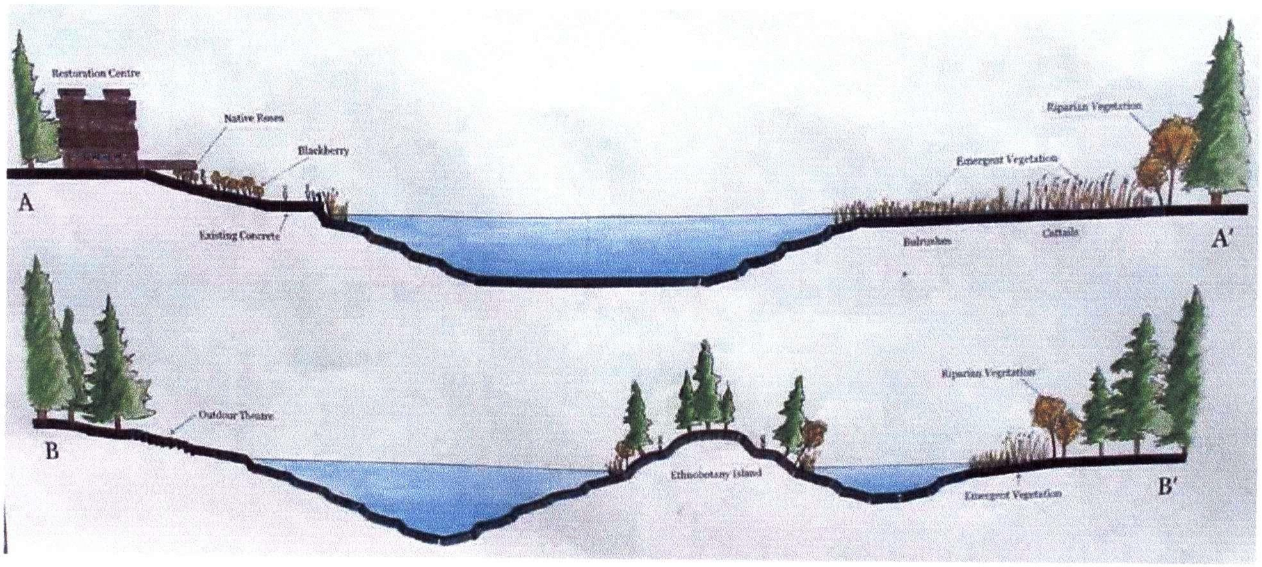
Appendix 14f: Restoration Centre Axonometric

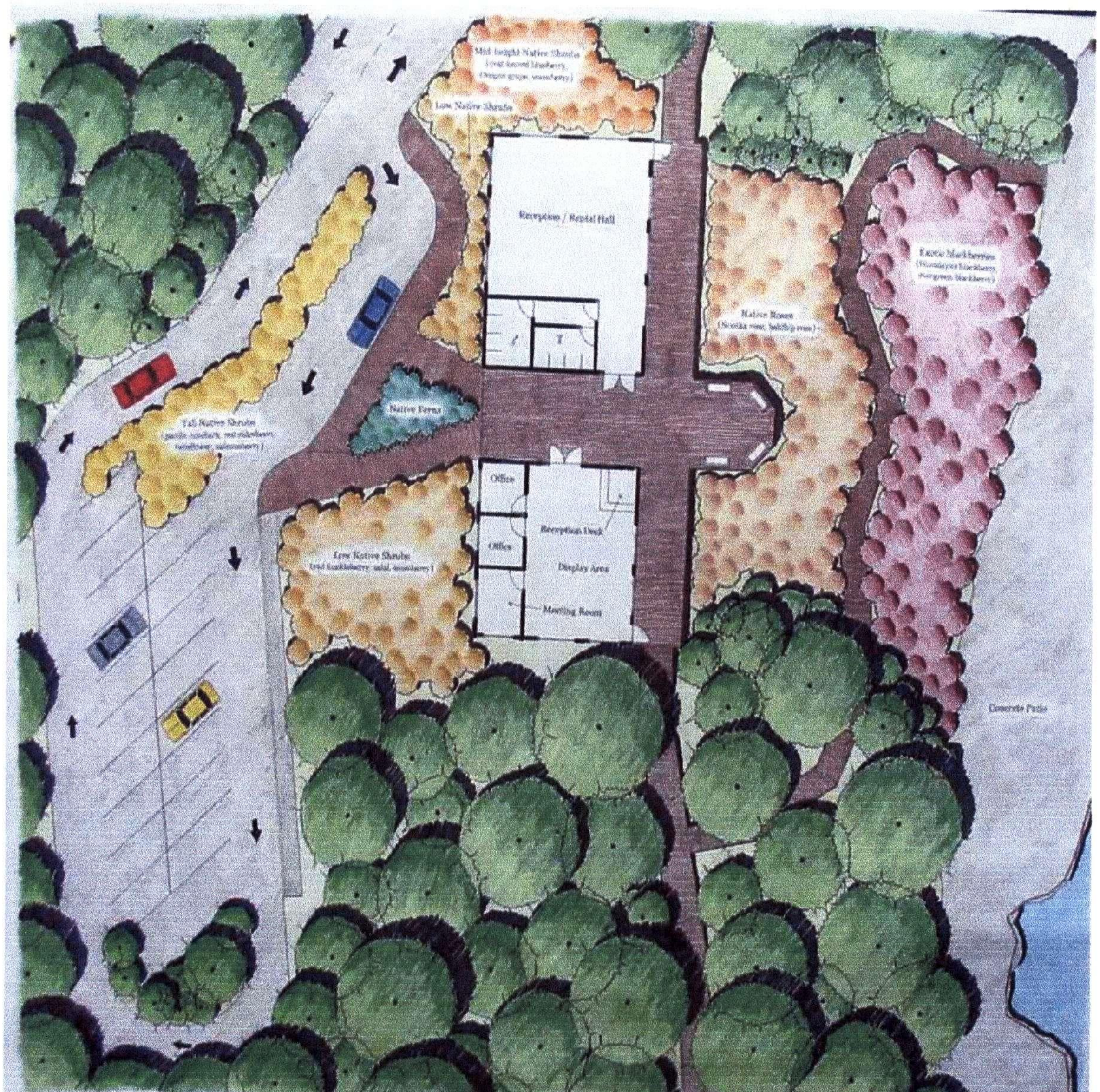




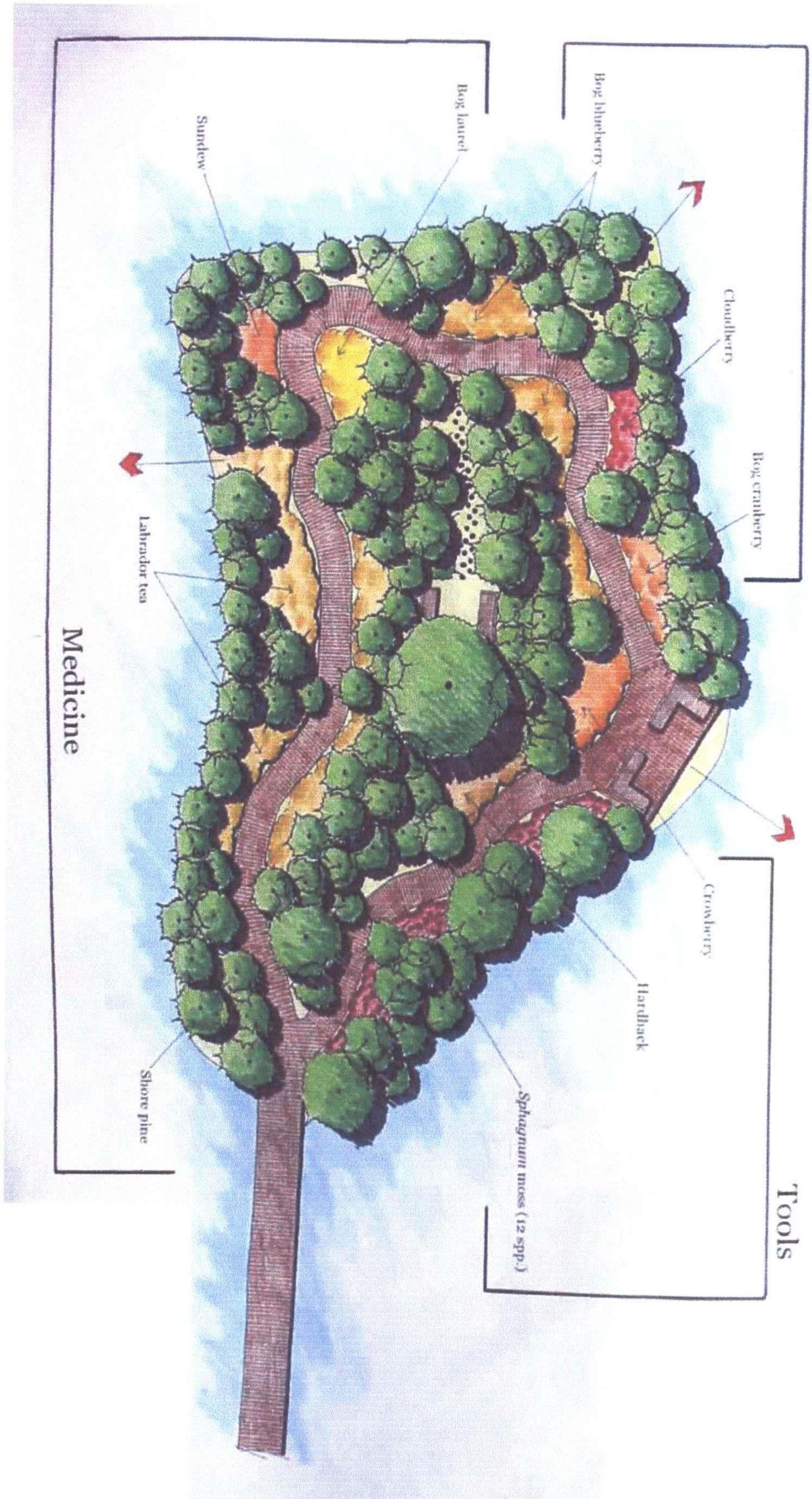
Side section-elevation (looking north)

Appendix 14f (cont.): Restoration Centre Building Sections (front and side)

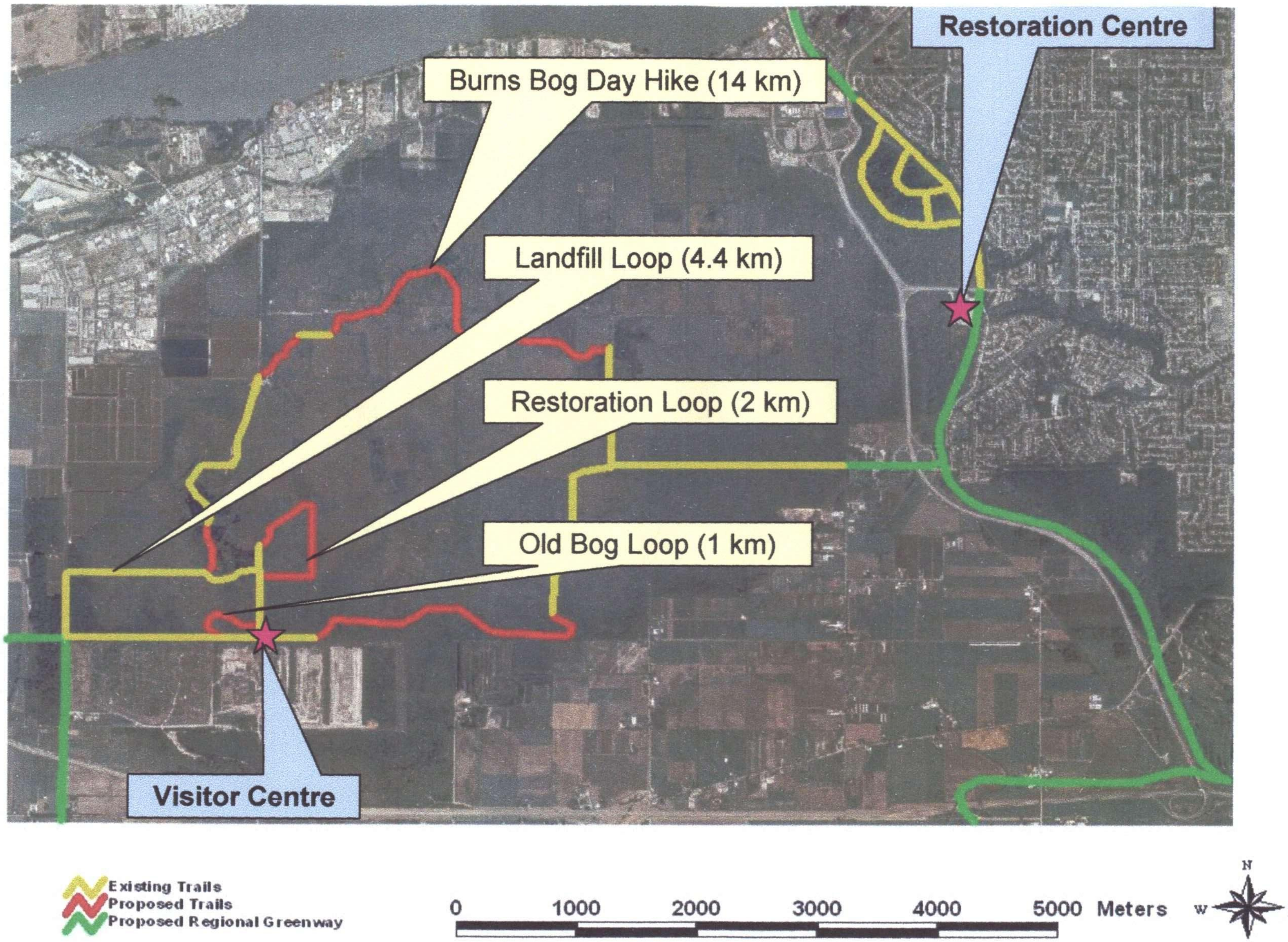




Appendix 14g: Restoration Centre Site Section and Floor Plan



Appendix 14h: Ethnobotany Island (Restoration Centre)



Appendix 15: Proposed Visitor Centre Locations and Trail System