Historical Changes in the Riparian Habitats
of Labrador's Churchill River Due to Flow Regulation:
The Imperative of Cumulative Effects Assessment

by

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Abstract

Extensive hydroelectric facilities were constructed in the upper watershed of Labrador's Churchill River during the 1960's and 70's. Two additional dams and generating stations are now planned for the lower reaches of the river. Despite the fact that cumulative effects assessment is a legal requirement under Canadian law, and is expected by people who hold aboriginal title to the land and wish to take a highly precautionary approach to further industrial development, environmental research to date has been restricted to a very narrow temporal and spatial scope, virtually ignoring changes that have already occurred throughout watershed.

River shorelines and their ecosystems are important parts of ecological and cultural landscapes and are always considerably changed by large-scale river regulation. The objective of this study is to demonstrate that despite the lack of formal data collection in the past, a rich understanding of patterns of change in the hydrological regimes and riparian vegetation communities of the Churchill River can be attained, and can contribute to a meaningful understanding of the cumulative effects of hydroelectric development.

Labrador Innu and Inuit/Metis shared empirical observationsn of changes in the river shorelines, and offered personal opinions about the significance of these changes. They also participated in botanical survey work in several reaches of the main stem of the river to collect data on riparian plant communities. Existing hydrological records were analyzed to relate pre-and post-development flow patterns to plant species richness and cover. Historical observations by travelers and scientists, time series air and ground photography, and research on the effects of flow regulation on riparian habitats in other boreal regions also informed the study.

Hydroelectric development has already had extensive and severe effects on the riparian zones of the river. It has reduced biodiversity, especially in the reservoirs, and has destroyed places of cultural value. Land use along several affected river corridors, as well as the traditional knowledge that developed within these riverine landscapes has been eroded. The river valley riparian zones downstream of the existing power stations have been altered, but continue to maintain substantial ecological and cultural integrity. The construction of additional dams on the lower Churchill River would further decrease the structural complexity and species richness of riparian zones, and flood almost all remaining sites of cultural significance along the main stem shores of the river.

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To my daughter Danika - I hope that as you grow, and throughout your life, you will have the opportunity to experience, love and learn from the spectacular natural world that we have been blessed with.

Chapter 1. Introduction

Damming of the world has brought profound change to watersheds. Nothing alters a river as totally as a dam. A reservoir is the antithesis of a river – the essence of a river is that it flows; the essence of a reservoir is that it is still. A wild river is dynamic, forever changing – eroding its bed, depositing silt, seeking a new course, bursting its banks, drying up. A dam is monumentally static; it tries to bring a river under control, to regulate its seasonal pattern of floods and low flows. A dam traps sediments and nutrients, alters the river's temperature and chemistry, and upsets the geological processes of erosion and deposition through which the river sculpts the surrounding land (McCully, 2001:10).

1.1 Study Objectives

The Boreal and Taiga biomes are two of the largest in Canada and are often viewed as vast and relatively untouched regions. On the contrary, in recent decades they have been experiencing rapidly increasing industrial development. More than one-third of all hydroelectricity produced in Canada comes from these northern regions, and almost half of the nation's large dams are located there. Because the basis of hydropower generation, the hydrological cycle, is renewable, hydroelectricity is often promoted as "green" energy. Nevertheless, extensive environmental change is inevitably caused by projects involving river regulation, especially those with large storage reservoirs. River fragmentation and flow regulation are recognized the world over as major threats to freshwater ecosystems (World Water Assessment Programme, 2006). The enormous spatial footprint of existing and proposed hydroelectric projects demands due consideration of their cumulative effects on the environment. Coupled with other industrial activities and climate change, the cumulative effects on freshwater and deltaic ecosystems are potentially critical (Schindler and Smol, 2006).

Natural flow regimes are recognized as the "key driver" of the ecological integrity of riparian zones[1] (Naiman et al., 2005), i.e. the magnitude, frequency, timing and duration of floods in rivers have a direct influence on the characteristics of riparian and floodplain ecosystems. Riparian habitats are therefore among those most altered by large-scale hydroelectric projects, because control of river flow is the primary mechanism used

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[1] Riparian zones are the shoreline habitats bordering rivers, lakes and streams subject to seasonal or occasional flooding.

to maximize power generation at these facilities. However, these effects are rarely adequately investigated prior to river regulation (Nilsson and Berggren, 2000). This has certainly been the case with the Churchill Falls project, one of the largest hydroelectric developments in the world. Constructed during the 1960's and in operation since 1971, prior to the introduction of environmental assessment legislation in Canada, this project has made extensive alterations to the landscape of central Labrador. The results of some post-regulation investigations into water chemistry and plankton (i.e. Duthie and Ostrofsky, 1974, 1975), waterfowl (i.e. Gillespie and Whetmore, 1973; Goudie and Whitman, 1987) and substantial work on reservoir fish populations are available. However, there has been relatively little published documentation of the longer-term environmental effects of this facility on riparian and terrestrial flora and fauna. Nor have the social and cultural effects on local people been well investigated (Adams, 2000).

In the late 1970s, a proposal to build two additional large dams on the lower reaches of the Churchill River was investigated under a federal policy directive to conduct environmental assessment. The environmental impact statement (EIS) completed in 1980 identified negative impacts on wildlife from the loss of riparian habitats as the most severe and unavoidable ecological consequence of the new dams (Lower Churchill Development Corporation, 1980). Due to economic constraints, the proposed dams were never built. Various plans have been studied, and new proposals have been on and off the table since 1998. In December 2006, the provincial crown utility, Newfoundland and Labrador Hydro, registered a new project to build two hydroelectric facilities on the lower Churchill River under the Canadian Environmental Assessment Act (CEAA)[2] and the Provincial Environment Act[3]. These facilities are virtually the same as those proposed over 25 years ago. Unfortunately, in the intervening years there has been little research on riparian habitats in this river system to monitor changes related to existing hydrological regulation.

Under the Canadian Environmental Assessment Act (CEAA), there is a legal requirement to examine the cumulative effects of new projects on local and regional ecological and sociocultural environments. This is intended to assist in making prudent

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[2] *Canadian Environmental Assessment Act*, S.C. 1992. c.37

[3] Newfoundland and Labrador *Environmental Protection Act*, SNL 2002 c.E-14.2

decisions regarding the acceptability of new developments that involve federal jurisdiction or funding, and to suggest mitigation measures for predicted negative impacts. Past assessment of proposals for additional dams and reservoirs on the lower Churchill River tended to consider the existing environmental conditions as the "baseline" against which to measure change (e.g. Beak Consultants and Hunter and Associates, 1978). Only cursory attention was given to the important environmental changes that have already occurred as a result of the construction and operation of the existing Churchill Falls project directly upstream. The environmental assessment conducted in the late 1970s (Lower Churchill Development Corporation, 1980) discussed some of the downstream effects of the Churchill Falls project and acknowledged that there would be cumulative effects. However, analysis was mostly confined to future changes in areas expected to be directly affected by the new hydroelectric facilities. An appropriate cumulative impact assessment will require a more in-depth consideration of the local and regional additive, and possible synergistic effects of all hydroelectric developments. The scope should include the entire watershed at the very least, and ideally would extend throughout the region (Canadian Environmental Assessment Agency, 2003).

The evolution of Canadian law towards increasing the acknowledgement, definition and protection of aboriginal rights is having an important influence over decisions regarding industrial development and land use. The Mishta-Shipu (Churchill River) is in the centre of the homeland of the Innu people. Their traditional territory is known as Nitassinan. The Innu have never relinquished any title to their lands in Nitassinan through treaty. They are currently in the process of negotiating a comprehensive land rights agreement with the federal and provincial governments. In 1998, the Innu staged a major public protest when the provincial government was preparing to announce plans for the new hydroelectric developments. The Innu had not been consulted or even informed about these developments which would compromise their aboriginal rights as recognized under the Constitution Act of 1982.[4] Several Supreme Court of Canada decisions[5] have

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[4] *Constitution Act, 1982*, s.35
[5] *Haida Nation v. British Columbia* (Minister of Forests), [2004] 3 S.C.R. 511, 2004 SCC 73
Delgamuukw v. British Columbia, [1997] 3 S.C.R. 1010
R. v. Sparrow, [1990] 2 S.C.R. 723

affirmed that the federal and provincial governments have a duty to consult with aboriginal peoples when these governments are involved in any undertaking that may affect inherent aboriginal rights. As a result of the attention brought to the situation through this protest, the governments conceded to consult with the Labrador Innu communities throughout the planning process. Since then, there have been extensive discussions with Innu about hydroelectric development within the context of ongoing land claims negotiations. Newfoundland and Labrador Hydro has worked with the elected Innu political representatives (Innu Nation) to conduct scoping for additional baseline research, to review and advise on baseline research reports, and to discuss approaches to environmental assessment. They have supported Innu-led community consultation sessions to gather Innu perspectives and provide detailed information about the project proposals in advance of the formal environmental assessment process (Innu Nation Hydro Community Consultation Team, 2000, 2001). Metis residents of the region also have an interest in environmental changes that may affect their traditional use of the land. However, they do not have recognized standing to negotiate land rights with the federal or provincial governments, and have not been involved in any formal consultation processes.

Environmental management provisions would be a key element of any final aboriginal land rights agreements. These would have legal precedence over the CEAA, and could be much stronger in terms of environmental protection tools specific to the settlement region. In the interim, federal and provincial governments have established more inclusive and comprehensive joint environmental assessment processes with aboriginal parties where outstanding land claims are recognized. The assessment of the Inco mine at Voisey's Bay with the Labrador Inuit and Innu is an example (Canadian Environmental Assessment Agency, 1997a, 1997b).

Labrador Innu and Metis elders have emphasized the importance of a gaining better understanding of the environmental effects of the Churchill Falls project prior to consideration of any of additional development on the river. In general, they advocate a precautionary approach to development that is highly focused on regional and long-term environmental effects. The cumulative effects of multiple hydroelectric projects on their lands are of great concern to many local people. They have identified the shoreline habitats as areas that have been severely degraded, in addition to many other elements of the regional ecosystem. However, despite the imperative of cumulative effects assessment, there has been little research done to describe the environmental effects of the existing Churchill Falls project.

Much can be learned from historical observations along the Churchill River and from research in ecologically comparable regions to build an understanding of the cumulative effects of multiple dams on this riverine system and in the region of the Québec/Labrador peninsula (Nilsson and Berggren, 2000). It is essential that sight is not lost of pre-regulation ecological reference conditions as planning is undertaken for additional major changes to Labrador's largest river. It is also important to recognize and give due consideration to the cultural landscape of the whole river. The perspectives expressed by the local people who use the river and are familiar with its history must play a central role in any assessment process.

The primary objectives of this study were the following:

1. To broaden the temporal and spatial scope of environmental assessment of hydroelectric development in the Churchill River by developing a primarily qualitative synthesis of the effects of flow regulation on shoreline vegetation communities throughout the watershed.
2. Work closely with Innu and Metis who have long-term experience living and traveling in the region to document some of the ways that these environmental changes may be viewed by local people familiar with the river in the pre-hydro past.
3. To offer some general predictions about how riparian habitats would change further with the construction of additional large dams in the lower reaches of the river, and to thereby begin to explore possible cumulative effects of multiple hydroelectric developments on riparian ecosystems.
4. To define some of the specific research questions that should be addressed to increase our knowledge of the changes that have occurred in the riparian habitats of this river system and adjacent watersheds affected by hydrological regulation.

This study is intended to lead us towards a better appreciation of the potential cumulative effects of changes on patterns of flow related to hydroelectric development on shoreline habitats in the region. The significance of these changes to local elders familiar with the landscape is explored as an integral aspect of understanding the importance of environmental change. It is hoped that the study will contribute to a more inclusive research and decision-making process regarding further development in this region. This means giving history and all relevant local knowledge and perspectives greater weight in the evaluation of all aspects of proposals affecting the landscape.

1.2 Assessment of the Environmental Effects of Flow Regulation on Riparian Habitats

> *In more than two-thirds of the planet's large river systems, humans are now turning the knobs that govern the flows of water, nutrients, and sediments in ways that do not resemble the natural rhythms to which river species are adapted* (Postel and Richter, 2003:76).

1.2.1 Increasing Flow Regulation of the World's Rivers

Many studies have shown that industrial development involving landscape-level hydrological manipulation creates numerous long-term changes in the habitat of native flora and fauna (e.g. Nilsson, 1992a; Naiman and Décamps, 1997; Jansson et al. 2000a). Reports emerging from the Millennium Ecosystem Assessment state that physical modification of rivers creating habitat change is among the most important direct drivers of biodiversity loss globally (Millennium Ecosystem Assessment, 2005). Such industrial development also strongly affects human use of rivers, lakes and surrounding watersheds (e.g. Rosenberg et al., 1995; Bill et al., 1996; Crozier, 1996; McDonald et al., 1997; Rosenberg et al., 1997; Berkes and Folke, 1998; McCully, 2001).

By the end of the 20th century, more than 45,000 large dams[6] had been constructed in over 140 countries around the world (WCD, 2000), regulating over two-thirds of the world's rivers to some extent (Nilsson et al., 2005). Large-scale utilities selectively focus hydroelectric development on the largest river systems because these have the greatest potential for energy production. It has been estimated that over 80% of the riparian corridors of North America and Europe have been altered by dams, dikes and levees over

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[6] A large dam is defined by the International Commission on Large Dams (ICOLD) as a structure that is at least 15 m high, or is between 5 and 15 m high and has a reservoir volume of more than 3 million m^3 (ICOLD, 1998).

the past 200 years (Naiman et al., 1993). Another wide-ranging tally over the northern hemisphere states that in Canada, the United States, Europe, and the countries of the former Soviet Union, over 85 of the 139 largest river systems are strongly or moderately regulated by dams used for power generation, irrigation and flood control (Dynesius and Nilsson, 1994). This extensive management of the world's rivers is having a considerable influence over the terrestrial hydrological cycle (GWSP, 2004).

Developments during recent decades have been relatively rapid. Since 1950, the number of large dams in the world has increased over nine-fold (Postel and Richter, 2003). The years between 1960 and 2000 witnessed the quadrupling of reservoir storage capacity such that currently there is three to six times the amount of water in reservoirs as there is flowing through natural river channels at any time. During that period, the global installed hydropower capacity doubled, making much more of the energy of flowing rivers available for human use as electrical power. It has been predicted that the proportion of river flow intensely managed by humans in inhabited regions will increase from just over 30% to nearly 70% in the next two decades (Vörösmarty and Sahagian, 2000).

In 2003, hydroelectric generation accounted for 59% of all electric energy production in Canada (Statistics Canada, 2005). There are about 849 large dams (10 metres or greater in crest height) in operation or under construction in the country (Canadian Dam Association, 2003). Approximately 70% of these were constructed for hydroelectric production. About 279 of these large dams are located in boreal regions and more are in the planning stages. Hydroelectricity has been described as the "backbone of economic development" in Canada's boreal regions (Urquizo et al., 2000). It provides much of the energy necessary to process mineral and forest resources, and creates a lucrative commodity for export to southern Canada and the United States.

However, the process of harnessing this energy has contributed substantially to biodiversity loss and other environmental degradation in freshwater systems (Millennium Ecosystem Assessment, 2005). With the lack of long-term studies in most regions, we can barely begin to understand the cumulative effects on global biodiversity caused by this level of hydrological manipulation. However, regardless of what has or has not been documented, as one author pointed out, "If the stream's physical foundation is pulled out from under the biota, even the most insightful biological research program will fail to preserve ecological integrity" (Ligon et al., 1995:183).

One author suggested that large hydroelectric projects have provided the means to better understand the ecology of boreal rivers and stated that, "It is perhaps through the consequences of such operations that the natural processes of the rivers are best illustrated and the mega projects can in a way be regarded as continent-size experiments" (Harper, 1992:411). However, should we not be asking whether "experiments" on such a scale could possibly be considered rational or prudent, especially if there is insufficient rigor applied to documenting, assessing and communicating the results? A better job certainly needs to done to learn from these landscape-level habitat conversions and incorporate the observations into sound public policy. One conclusion would likely be that large-scale hydroelectric developments cannot be deemed to be providing "green energy" as is frequently promoted.

The modification and destruction of riparian habitats is an important concern among ecologists (e.g. Johnson and Jones, 1977; Clark, 1979; Johnson and McCormick, 1979; Walker, 1985; Hellawell, 1988; Nilsson, 1992a; Schindler, 1998, Nilsson and Berggren, 2000). Riparian and aquatic habitats are among those most directly and consistently affected by the flooding, flow reduction and flow control associated with dams (Petts, 1984; Nilsson et al., 1991a; Malanson, 1993; Nilsson and Jansson, 1995; Jansson et al., 2000a and b). Much remains to be learned about the specific processes of change at work, and the variations in effects among regions (Jansson et al., 2000a). Nevertheless, Nilsson (1992b) lamented the fact that large dams continue to be built despite what is already known about the widespread losses in riparian biodiversity, in addition to numerous other detrimental ecological and cultural effects, and the high level of concern expressed by ecologists and other citizens (Rosenberg et al., 1995). In 2000, The World Commission on Dams reported on a two-year study that reviewed the current worldwide understanding of the social, economic, and environmental effects of large dams (WCD, 2000). The Commission concluded that generally, the negative effects on ecosystems and local societies are afforded inadequate attention in the decision-making processes by which these large industrial developments are planned and implemented.

1.2.2 Hydrological Regulation on the Labrador/Ungava Peninsula

> *It is very hard for any Innu people to look at the lower Churchill project without thinking about the Churchill Falls project. There is a very large portion of Labrador that is managed for one purpose alone and that is hydroelectric production. Innu have become strangers in their own land in many respects.*
> Elizabeth Penashue (Innu Nation Hydro Community Consultation Team, 2001:20)

The Churchill River watershed lies within the Boreal Shield and the Eastern Taiga Shield ecozones. Most of the central and northern Québec hydroelectric facilities are also within these two ecozones. Figure 1 depicts the watersheds in the Labrador/Ungava region that already have large hydroelectric facilities with multiple large dams and extensive reservoirs regulating major portions of their flow. The map does not highlight some rivers that have had portions of their watersheds merely diverted without control structures to further regulate flow, for example the Naskaupi and Kanairiktok Rivers. Several new smaller projects are currently under construction on the Péribonka, Toulnustouc, and Eastmain Rivers. Four generating stations on the La Romaine River are in the design stages; and others are being studied for the Churchill, Nastapoka, George, lower Caniapiscau, and Petit Mécatina Rivers (Hydro-Québec, 2003).

Depending on the nature of the development and the topography of the watershed, hydrological manipulation in deep river valleys may directly affect primarily the main stem of the river and mouths of tributaries, or in areas with low topography, it may flood wide terrestrial areas and wetlands, and/or divert waters from extensive systems of small tributaries and lakes. Most of the existing developments in Québec have multiple dams with stepped series of reservoirs. In consequence, the main stems of the rivers experience considerably altered hydrological conditions throughout much of their length. In addition, many of the facilities include very large, relatively shallow storage reservoirs. Since these were created in flat to undulating regions, flooding numerous small lakes and river valleys, they are generally quite dendritic in form (Kalff, 2002). The new shorelines in these reservoirs are thus lengthy. Since they are likely to be less biologically productive riparian zones than those that existed previously, the cumulative impacts on riparian habitats in the region are most certainly extensive.

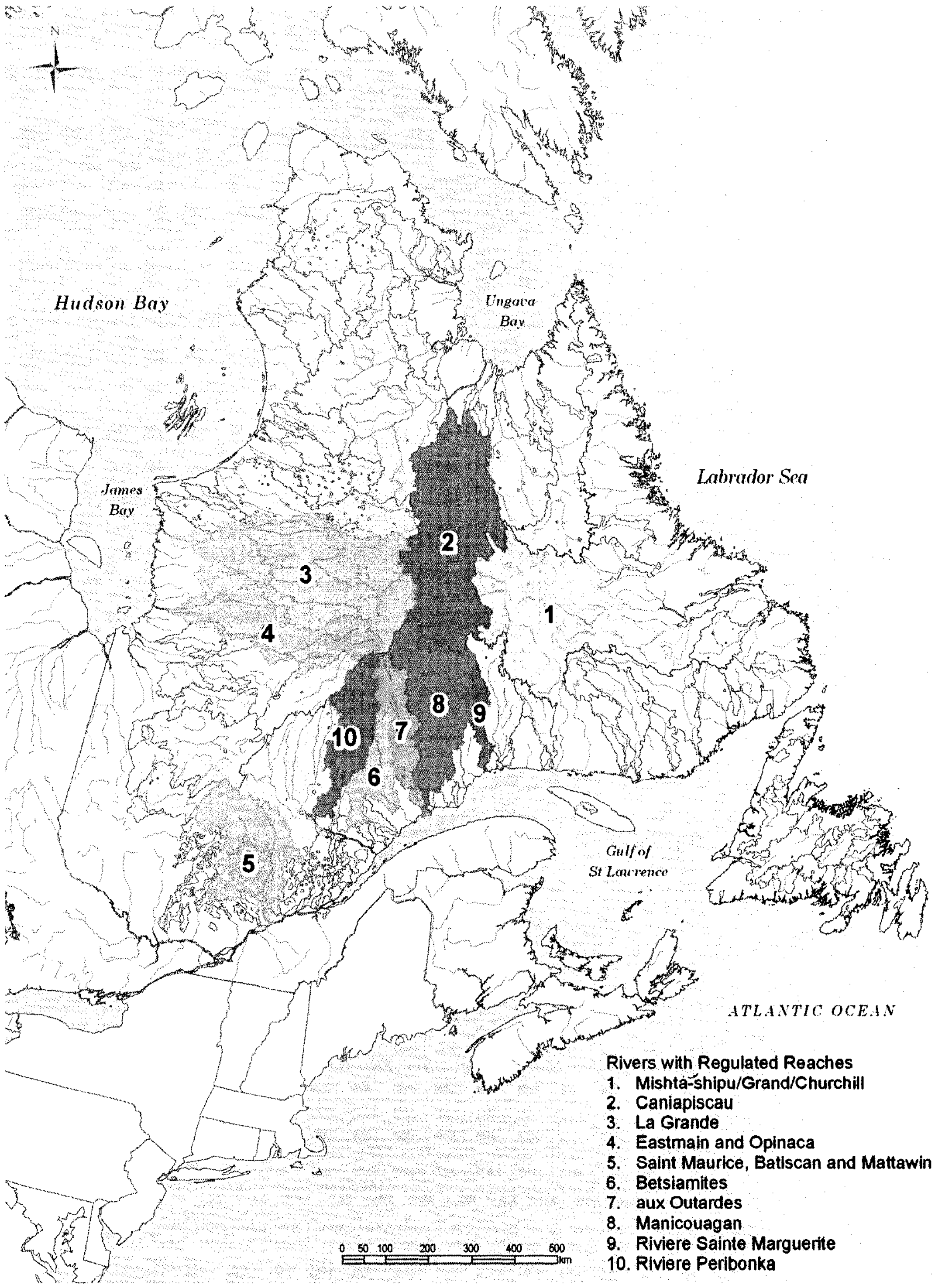

Figure 1. Watersheds with Regulated Reaches in the Ungava Peninsula Region as of 2006. Additional river regulation schemes for the region are in the planning stages. Regulated rivers in the Canadian Maritimes, Ontario, New England, or on the island of Newfoundland are not shown. (Map produced on ARC GIS by A.Luttermann. Base map data obtained from: Environmental Systems Research Institute (ESRI); Geogratis).

Some cursory attention has been paid to the additive effects of adjacent projects in environmental assessments such as that conducted for the proposed Great Whale project (Hydro-Québec, 1993c). A preliminary report also considered the potential cumulative effects on marine and estuarine environments where multiple regulated rivers flow into James and Hudson's Bays (Bunch and Reeves, 1992). I am not aware of any research that has examined the cumulative effects of this type of industrial infrastructure on inland riparian habitats in the northern Québec and Labrador region.

1.2.3 Cumulative Effects of Regulating the Flow of Labrador's Churchill River

> *The changes were not only in the immediate vicinity of the flooding but were also felt hundreds of miles from Churchill Falls. Water levels rose and fell to a great degree depending on where you were from the flooding. Natural lakes, ponds, streams, rivers, forests, and marshes situated in the immediate area were decimated by the flooding. Rivers and drainage areas that used to flow many miles from Meshikamau were affected by all the dams and built to contain the water in the Smallwood Reservoir. The water levels in these rivers were lowered as a result. The whole project brought about a huge chain reaction. Our homeland and our people were very much affected.* Daniel Ashini (Innu Nation Hydro Community Consultation Team, 2001:37).

As mentioned earlier, very limited environmental effects assessment was carried out prior to construction of the Churchill Falls hydroelectric project in Labrador during the late 1960's. Subsequent ecological monitoring during operations has also been extremely narrow in scope. In recent years, as a result of increased regulatory requirements in Canada and many other countries, large developments of this kind are now subject to more comprehensive environmental analysis during the planning and operational stages to develop a better understanding of the consequent ecological and sociocultural effects (Doyle and Sadler, 1996; Sadler, 1996; Ryan, 1998; Finlay, 1999). Moreover, under the Canadian Environmental Assessment Act[7], there is now a legal requirement to consider the cumulative effects of multiple development activities on broad spatial and temporal scales (CEAA, 1994).

In addition to the direct influence of dams and impoundments on the hydrological cycles of river systems, other infrastructure associated with hydroelectric developments,

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[7] *Canadian Environmental Assessment Act*, S.C. 1992. c.37.

(such as roads, quarries, generating facilities, transmission lines, work camps and town sites, etc.) can all contribute to changes in water tables, and in patterns of runoff and sediment transport (Lewis, 1996). They can also influence the introduction of non-native species to the watershed. Some of the most severe impacts on riparian habitat are localized along dikes, dams, and armoured shores. The Churchill Falls project has a considerable number of large dikes. In this study, I have not examined any of these topics, but rather I have focused on the general character of the shorelines in a variety of zones experiencing different types of regulated hydrological regimes.

There are currently several new industrial development activities proposed within the Churchill River watershed, including at least one large-scale hydroelectric project. It is imperative to develop ecological reference points on which to base predictions of future change, consider the significance of such change, and monitor the changes that do occur if these developments proceed. Substantial research is being carried out in this regard on many elements of the lower river ecosystem that would be directly affected, such as fish populations. However, the rest of the watershed, and adjacent watersheds affected by the Churchill Falls project, have received little attention in most of the recent research efforts (unpublished reports from 1998-2006 held by Newfoundland and Labrador Hydro). It is also important to develop better reference points further into the past in order to better understand long-term cumulative change in this river system, and how it is perceived and evaluated.

A more thorough examination of cumulative effects on riparian and other habitats within the watershed would also include potential changes associated with other activities such as forestry, mining, military operations, and municipal development. It has only been during the past fifty years that any of these activities has taken place in the Churchill River watershed, aside from some small-scale forestry and community development near the mouth of the river that began sooner. These topics are all beyond the scope of this preliminary investigation.

Patrick McCully of the International Rivers Network has stated that, "Coming to a decision on whether or not the environmental damage done by a dam will outweigh its benefits is ultimately a subjective and political decision which should be made by the affected people and the general public" (McCully, 2001:58). However, people first must become well informed about the environmental damage that results from such developments. Although my study has investigated riparian zones, it argues more generally for a spatially comprehensive research agenda and broader deliberation over new proposals to build additional dams on the lower Churchill River. The debate must not ignore the cumulative effects of development in the upper Churchill and adjacent river systems, or the wider bioregional context.

1.3 Local and Traditional Environmental Knowledge in Ecological Research

> *All too often, we read that traditional knowledge must be integrated into conventional scientific methods. The people of Old Crow say that scientific methods and conventional systems of resource management must learn to fit into their traditional ways of viewing and using the land, for these values form the basis for their future survival* (MacPherson and Netro, 1989:25).

The above statement is a reaction to the perception that scientific methods cannot encompass the full range of meaning inherent in the land, and its significance to the people that inhabit it. Furthermore, large-scale industrial development is so distant from traditional ways of viewing and using the land that assessing and managing such projects within a framework of traditional values is a major challenge. However, much progress has been made in recent years. Comprehensive land claims involving co-management boards represent a significant improvement in the ways that development decisions are being made in Canada's North (Usher, 2003). Canadian law now requires consultation with aboriginal peoples who have experienced loss of access and/or resources alienation from their recognized traditional lands or environmental degradation caused by industrial development.

Environmental assessment must be a collective educational process that incorporates various legitimate ways of learning about the land, its history, and potential that are meaningful to everyone involved in the decision-making process. The knowledge and perspectives of local people long living in close association with lands potentially affected by industrial development are now recognized in Canadian law and policy as an essential component of environmental assessment decision-making, together with approaches taken based on scientific methods and conclusions reached by academically trained scientists and resource managers.

The broader spatial and temporal scope of reference brought to the exercise of environmental impact assessment by members of cultures with a long history in a region is essential to the consideration of cumulative effects. The majority of project-based environmental assessments are short-term initiatives relative to the temporal influence of the activity proposed, and the potential range of natural variability in ecosystems (Nilsson and Berggren, 2000). Baseline scientific data compiled to predict and monitor possible effects is frequently insufficient to identify trends until the effect is substantial, or has continued over a long period of time (Ziemer, 1994). This is especially true in more remote areas that have not been subject to long-term scientific study. These are also areas in which many people continue to maintain land-based livelihoods, dependent on local and regional, intact ecosystems to a greater degree than the average person in more populated and urbanized regions.

If a rich knowledge of the natural history of these places is held by the local people, it is clearly beneficial to explore this knowledge in the context of environmental effects assessments to better understand change over longer time periods and to inform further research (Inglis, 1993; Mailhot, 1993; Sadler and Boothroyd, 1994; Stevenson, 1996; Berkes and Henley, 1997; Institute for Environmental Monitoring and Research (IEMR), 1997; Berkes, 1999; Wenzel, 1999; Usher, 2000). Moreover, the intimate knowledge of a landscape held by local people and the values they hold are fundamental to any understanding of the significance of changes in environmental effects assessment.

It has become more common in recent years to integrate local environmental knowledge into analyses of ecological change by documenting the empirical observations made by people who have used lands in question for subsistence activities (e.g. Armitage, 1989; Nakashima, 1990; McDonald et al., 1997; Clément, 1998; Huntington et al., 1999). Many of these studies have relied in part on the long-term memories of the participants. For example, a study of beluga whale ecology in the eastern Chukchi and northern Bering Seas provided longer-term observations of behaviour such as migration and feeding patterns, and the environmental conditions that might influence these in the local area (Huntington et al., 1999).

The four-year Northern River Basins Study (NRBS) included documentation of traditional knowledge related to changes in the environment subsequent to extensive industrial development along the Peace, Athabasca, and Slave River systems (Bill et al., 1996). The community-based research compiled observations from users of the land through a structured survey process, narratives, digitized mapping, and archival sources. A broad range of topics was addressed, including identification of historical and present patterns of resource use, trends in environmental change, and identification of significant environmental features or observations (Wrona et al., 1996).

Ten aboriginal communities were involved in the NRBS over a three-year period. Direct participation on the part of local people and creating opportunities for community development were considered key features of the research process and were embedded in the conceptual design of the project (Bill et al., 1996). In addition, archival research was conducted to compile the chronicles of early frontiersmen and explorers who described the ecological environment. This augmented information collected through the oral histories (Crozier, 1996). The information gathered was meant to enhance the physical science studies in all areas of enquiry pursued in the Northern River Basins Study and included acknowledgement of the spiritual elements of traditional knowledge. The subsequent Mackenzie River Basin Transboundary Waters Agreement has incorporated several mechanisms into its management structure to continue an interdisciplinary approach to studying the effects of development in the watershed, including the continued integration of scientific and traditional knowledge.

For this study of the Churchill River, I have endeavoured to integrate different forms of knowledge to construct an overview of the potential range of changes in shoreline plant communities across the landscape related to flow regulation. An important facet of this effort is to explore the significance of these changes from the perspective of people who know these habitats intimately. Many Innu, especially those of the older generation who lived a semi-nomadic lifestyle, have made observations of vegetation and habitat structure along river corridors prior to the industrial developments that occurred over the last few decades. Metis trappers who have used the land and rivers extensively in pursuit of their livelihood have also attained an intimate knowledge the landscape.

The Innu culture evolved in a sub-arctic and boreal ecosystem in a region currently straddling eastern Québec and Labrador. Here, the largest proportion of food energy obtained from hunting and gathering has traditionally come from wild animals. Many

Innu possess a detailed knowledge of the anatomy, life history, habitat requirements, and ecological relationships of many species of fauna. While numerous plants are used for food, material goods, and medicinal purposes, the level of detailed knowledge of plants is thought to be somewhat less than that of animals (Clément, 1995).

Several aspects of Innu ecological knowledge have been studied by Clément (1990, 1995, 1998). Individuals from the Innu communities of Mingan and Natashquan on the Québec North Shore worked with Clément to document their knowledge of botany and zoology in two separate studies (Clément, 1990, 1995). The Mushuau Innu of the former community of Utshimassits, Labrador prepared a submission for the environmental assessment of the Voisey's Bay mine and mill project. The work presented a general description of a wide range of ecological knowledge of the area, rather than specifically focusing on predicted effects of the mine development (Clément, 1995; Usher, 2000). These studies provide some material that is relevant to my investigation of riparian habitat.

There is a continual need for learning on the part of all parties involved in land management decisions. There is a need to pool our collective knowledge and learn from each other and to pursue a better understanding of the consequences of our actions together. Unfortunately, there are often overriding political and economic interests that impede our ability to fully consider the range of knowledge available to us.

1.4 Structure of the Thesis

Chapter Two discusses some aspects of the ecological importance of riparian areas. Some relevant literature on the effects of major hydroelectric developments on riparian habitats is briefly reviewed, primarily focused on rivers in circumpolar boreal and taiga regions.

Chapter Three provides a general description of the biophysical character of the Churchill River watershed. Historic patterns of human land use in the region and how they have shaped the cultural significance of the river corridors are briefly summarized. Details of existing hydroelectric development within the watershed are then outlined as are the ways in which the hydrology of the river has been manipulated.

Chapter Four explains the approaches used to gather and interpret the various forms of information consulted during the thesis research. These sources of information include:

- prior research on the effects of dams and impoundments in boreal riparian zones;
- historical written records of riparian habitat and relevant natural history in the Churchill River watershed;
- documentation of local environmental knowledge and local people's perspectives focused on changes in the river shorelines;
- a preliminary field survey of the current state of riparian vegetation along the main stem of the river; and
- historical and contemporary imagery and mapping data.

Chapter Five details the specific hydrological alterations in various parts of the watershed along with results of the research focused on observations of patterns of changes along the river shorelines and the structure and species composition of vegetation in the riparian zones.

Chapter Six explains the current proposals for additional hydroelectric development in the watershed. Potential implications of further river regulation for the remaining riverine landscape are discussed. Some of the ways in which this information may influence perspectives on the significance of expected changes are briefly explored.

Finally, in Chapter Seven, the need for a comprehensive cumulative environmental assessment of industrial development in this watershed and across the region is discussed, particularly in terms of the loss of specific elements of the regional ecosystem such as the riparian habitats of large rivers and their dependent species. Some of the possible challenges encountered in the review of new proposals for the development of the Churchill River are addressed, such as the subjective interpretation of environmental observations, limited ecological literacy, and perceptions of the conservation value of a partially regulated river. The thesis concludes with recommendations for further research to expand our understanding of riparian habitats in this region and their role in maintaining regional biodiversity.

Quotes from local people gathered through archival documents, community meetings, and personal interviews are integrated throughout the thesis to allow the voices of people to speak directly to the reader on relevant topics, and to maintain a sense of the human ecological and cultural dimensions related to these major hydrological changes in the landscape.

Chapter 2. The Ecological Importance of Riparian Areas

The shikau [shrubs] along the shores of the river are places where many animals like rabbits feed and that's important. But even though it's hard for us to walk in the shikau, the animals find their way. It doesn't bother them to walk there, that's important for their life. They live in the shikau (Pien Penashue pers. comm., 2005).

2.1 Definition of Riparian Areas

Riparian areas have received increasing attention in the scientific literature over the past twenty to thirty years as a better understanding of their unique ecological characteristics and cultural values has emerged, along with recognition of the extensive degradation of riverine habitats the world over (e.g., Rosenberg et al., 1995; Naiman and Décamps, 1997; Nilsson and Berggren, 2000; Naiman et al., 2005; Antheunisse et al., 2006). My study focuses on changes in riparian plant communities associated with a large hydroelectric development as these are among the habitat types most frequently and intensively altered by the manipulation of hydrological regimes in river and lake systems. Riparian habitats occupy a relatively small proportion of the total landscape, but they provide conditions necessary for the development and persistence of structurally diverse wildlife habitat and unique assemblages of plant species.

Definitions of the riparian zone of a river system vary among scientists and other observers depending upon the focus of interest and the nature of the ecosystem in question (Naiman and Décamps, 1997). Indeed, as Lewis observes, there is "no broadly used formal definition of the riparian zone either in law or in science" (Lewis, 1996: 9). Nor do the Innu or Metis who participated in this study appear to have a formal definition or specific nomenclature for these areas. The focus on the shorelines of the river for this study, while seen to be reasonably valid by local people, was generally considered to be a strangely narrow focus, since all parts of the land and water are ultimately connected and are important for plants and animals in various ways. Nevertheless, many attributes of lake and river shorelines are recognized by local elders as being essential to the lives of a variety of flora and fauna.

The word "riparian" is an anglicized version of the Latin "riparius", meaning "of or belonging to the bank of a river" (Naiman and Décamps, 1997). The term is generally used in spatial reference to areas along the shores of streams, rivers, and lakes. The physical and biotic characteristics of riparian habitats are directly influenced by the dynamics of the adjacent water body, especially through periodic flooding, shear forces of flowing water and ice scouring, events of sediment deposition and erosion, and higher water tables. These environmental factors, among others, differentiate riparian zones from their surrounding uplands.

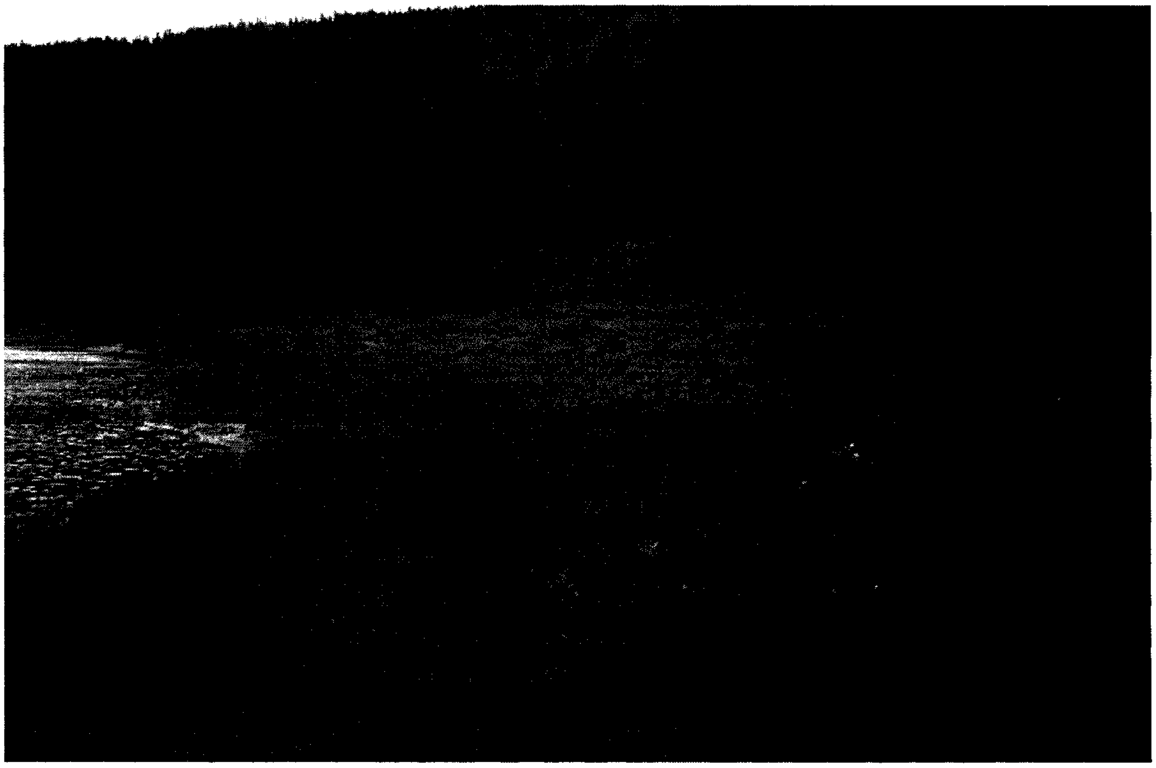

Figure 2. A Riparian Area along the Lower Churchill River in Labrador. This photo shows a zonation of vegetation types, from mixed forest at the top of the zone to a strip of high shrubs (Salix spp. and Alnus spp.), to low shrubs, herbs and graminoids (grasses, sedges and rushes), to dense growth of Equisetum fluviatile at the water's edge (Photo: A.Luttermann, 2001).

Riparian habitats are often viewed as dynamic interfaces or ecotones between aquatic and terrestrial ecosystems (Malanson, 1993; Naiman et al., 1993). They exhibit some characteristics of both aquatic and upland environments, and are constantly being disturbed and regenerated. Within the larger landscape, riparian zones form a particularly heterogeneous but linear mosaic of habitats, including floodplains, shifting sandbars, point bars, slopes of active terraces, and spray zones (Kalliola and Puhakka, 1988). As a result, they typically host a high level of biological diversity, particularly of vascular plants (Nilsson, 1983; Kalliola and Puhakka, 1988; Gregory et al., 1991). This diversity is created and maintained by active disturbance processes associated with seasonally fluctuating water flow and complex geomorphological dynamics operating within fluvial channels (Adams and Viereck, 1992; Naiman et al., 1993).

The characteristic seasonal patterns of hydrological disturbance through flooding and ice scouring prevent the development of late successional plant communities and allow the establishment and maintenance of a zone of diverse communities of shrubs, herbs, grasses and sedges adjacent to the water's edge. In boreal regions, a distinct vertical zonation of plant communities, ranging from forest to shrub to herbaceous associations, tends to form on the banks of lakes and large rivers (Fox 1992; Malanson 1993) (Figure 2). The width of the riparian habitat depends to a large extent on the difference in water levels between the highest floods in spring and the summer low-water period (Nilsson and Keddy, 1988; Jansson et al., 2000a). Peak flows from extreme flood events that may occur several years apart can also have a significant longer-term influence on the vegetation over a much wider zone.

Riparian communities are sometimes described as "wetlands", although that term is actually best used to refer to areas that are perennially saturated (National Academy of Sciences, 2002). The Atlas of Canada defines wetlands as lands that are "permanently or temporarily submerged or permeated by water, and characterized by plants adapted to saturated-soil conditions" (Natural Resources Canada, 2004). Included in this category are such areas as fluvial deltas and floodplain marshes. These may or may not maintain consistently higher water levels than the narrow strips of shoreline along large rivers that are subject to regular seasonal cycles of inundation and exposure. Wetlands may exclude most adjacent upland species of plants that are not adapted to prolonged saturation in the upper rooting zone. In contrast, riparian areas that do not generally have standing water during the growing season may host such species as alders and willows that require shallow ground water, as well as many species that do not have specific requirements or tolerance for a high water table (Lewis, 1996).

The classification system developed in Canada by the National Wetlands Working Group (1988) does not focus to any extent on the narrow, linear riparian zones along swift-moving rivers. Nevertheless, many of the riparian habitats bordering large rivers could be described under the freshwater marsh wetland class. These wetland types are characterised by mineral soils or well-decomposed peat that are periodically flooded by standing or slowly moving water, with seasonally fluctuating water levels. Zonal or mosaic patterns of vegetation are common in marshes, often including open-water pools and channels, with patches of emergent sedges, grasses, and rushes, borders of grassy meadows, and bands of shrubs and trees (National Wetlands Working Group 1988: 421). Drawdown zones may have matted vegetation or mudflats. In large rivers, marshes occur in active and inactive deltas, abandoned channels that are periodically inundated, and along the fluvial floodplain in depressions where water may at times be impounded for longer periods of time.

The category of boreal "shore meadow" marsh, in which no standing water usually exists during the summer dry season, most closely corresponds to portions of the riparian zone that formed the focus of my study. This category is described as occurring on the shores of ponds and lakes. The most common graminoid species (grass like plants) found in this wetland type include *Calamagrostis canadensis, Carex aquatilis, Carex lacustris, Carex pseudo-cyperus, Carex rostrata, Carex stricta, Carex vesicaria, Iris versicolor,* and *Scirpus cyperinus*. Forbs (broadleaf herbs) commonly growing in these marshes include *Cicuta bulbifera, Hypericum virginicum, Lycopus uniflorus, Lysimachia terrestris, Potentilla palustris, Potentilla norvegica,* and *Sium suave*. Common shrubs include *Alnus* spp., *Myrica gale*, *Salix* spp., and *Spiraea alba* (National Wetlands Working Group, 1988:137).

In the Peace-Athabasca delta, in fluvial marshes where standing water does not persist, a dominant species is *Calamagrostis canadensis*, along with lesser abundance of *Polygonum amphibium* and *Mentha arvensis*. *Salix planifolia* becomes dominant in drier areas. In sections of the Saskatchewan River delta that are only periodically flooded, *Carex* meadows with sparse willow shrubs are present. *Salix petiolaris* dominates the tall shrub layer, while the low shrubs consist mainly of *Salix pedicellaris* and *Salix planifolia.* Herbs include *Carex lacustris* and *C. aquatilis*, along with *Equisetum fluviatile* and *Galium trifidum*.

In the central plateau region of the interior of Labrador, extensive wetlands are present. String bogs are dominant in the south, while further north ribbed fens become more common. Shore marshes dominated by sedges such as *Carex aquatilis, C. lasiocarpa, C. limosa, C. livida, C. oligosperma,* and *C. rostrata,* make up a common fringe bordering lakes and ponds. *Myrica gale* frequently provides dense cover along with the sedges. The limits of these vegetation zones are governed primarily by the local hydrological regimes.

Alder and willow dominated swamps have not been as extensively studied as the wetlands classified as freshwater marshes. These tall shrubs tend to be found in stream and shore swamps, while conifers dominate the margins of peat swamps (National Wetlands Working Group 1988).

In discussing the values of wetlands in general, the National Wetlands Working Group observed that in contrast to bogs where there is less open water and low diversity of plant species, swamps and marshes are used more frequently by wildlife due to the variety of relatively productive plants and abundant open water.

Numerous factors influence the particular structure and patterns of riparian plant communities along rivers. These include the slope of the shoreline, substrate particle size and heterogeneity, nutrient availability, dispersal patterns of propagules, velocity of flow in the adjacent water body, erosional forces, and changes in microclimate associated with altitude along corridors (Nilsson, 1983, 1986, 1987; Nilsson and Wilson, 1991; Nilsson et al., 1991a, 1991b, 1991c; Malanson, 1993). However, the primary factor maintaining diverse riparian communities is the hydrological cycle of the system (Ligon et al., 1995; Lewis, 1996; Naiman and Décamps, 1997; Jansson et al., 2000a; National Academy of Sciences, 2002; Postel and Richter, 2003).

2.2 Disturbance-dependent Communities

A major advancement in ecological theory was recognition of the importance of intermediate levels of disturbance to the development of higher levels of biodiversity (Connell, 1978). High levels of disturbance as well as low levels tend to create ecosystems with lower biodiversity. It is well recognized in the scientific community that flow regimes are the single most important factor in shaping the form of a river and creating and maintaining diverse ecological communities (Nilsson and Svedmark, 2002;

Naiman et al., 2005). River flows can be described in terms of patterns of variables related to magnitude, frequency, timing, duration, and rates of change (Nilsson and Svedmark, 2002). The variability of these factors creates the typical habitat diversity in rivers. This diversity is lacking in more stable environments.

Riparian areas that are consistently disturbed provide opportunities for many plant species that may not compete as well for space, light, water, or nutrients in more stable parts of the landscape, but that possess adaptive characteristics that enable them to withstand the stresses of dynamic hydrological regimes.

> *"Disturbance is the creator of the complex character of riparian environments. Floods at various magnitudes and on diverse time and space scales create riparian habitat mosaics. Floods leave legacies for decades in much the same way that the trunk of a fallen old-growth tree furnishes a storehouse of accumulated nutrients and a unique microhabitat for seedlings to develop. Floods sort the substrates of channels according to their particle size; they deposit woody debris, and deposit nutrients on the floodplain to nourish plant growth. They move the channel laterally across the floodplain leaving side channel habitats and oxbows that are critical to the regional ecosystem."* (Karr, 1996a:44).

As Karr observes, an appreciation for the role of disturbance in creating ecological systems that has developed over the past few decades has led to a greater focus on the study of frequently disturbed areas, such as riparian zones (Karr, 1996a). These habitats and their biota have evolved with, and depend upon, a natural range of disturbance patterns that are unique due to their position in the landscape as transition zones between aquatic and upland habitats. These include seasonal and multi-year flood and drought cycles (Karr, 1996a). These seasonal patterns of influence, and their extent, are particularly characteristic along the lower reaches of large rivers which may have a larger flow volume, extended periods of spring and possibly fall flooding, with deposition of nutrient rich sediments, and often have wide floodplains. In addition, ice scouring makes an important contribution to erosional processes in northern rivers.

Studies of riparian zones in Europe, where flooding has been prevented due to river regulation, have shown a rapid decline in availability of nitrogen and phosphorus in soil (over a period of less than 30 years). They have also shown a reduction in water tables and changes in community structure over the longer term, including the disappearance of pioneer stages and hygrophilous species (Penka et al., 1991; Trémolières et al., 1998; Naiman et al., 2005).

Plants growing in riparian areas frequently exhibit specific morphological and physiological adaptations to enable them to tolerate the relatively harsh environments of active fluvial channels and floodplains (Naiman and Décamps, 1997). For example, the life history characteristics of many riparian plant species are well adapted to the natural cycles of submergence in spring followed by exposure throughout the summer months (Kozlowski, 1984). *Populus* spp. and *Salix* spp. disperse their seeds as the flood waters are retreating in the spring. This timing enables them to take advantage of moist, fresh seedbeds for germination and establishment of seedlings.

The adventious roots of *Alnus* spp., *Populus* spp., and *Salix* spp. equip them to thrive in riparian environments where sediment deposition and inundation are frequent. The stem flexibility of the latter two genera also allows them to endure mechanical disturbance such as the shear stresses of flowing water and ice (Naiman and Décamps, 1997). Species in the families Cyperaceae and Juncaceae tend have air spaces in roots and stems that help them to tolerate anaerobic conditions in flooded soil, making them well adapted to wetlands.

Many riparian plants also disperse seeds or vegetative propagules by flowing water in a process known as hydrochory (Nilsson et al., 1991b; Naiman and Décamps, 1997). The diversity of pioneering species in floodplain features along river valleys may be particularly dependent on water transportation, even for some species adapted to dispersal by wind (Leyer, 2006). In addition, the dispersal of many plant species across landscapes, such as colonization of a region following a glacial period, may be related to the connectivity provided by riverine corridors.

Species richness can decline for a period of time in slow-flow reaches of free-flowing boreal rivers due to anoxic soil conditions when subjected to extreme and prolonged flooding. However, species richness is preserved in turbulent reaches which can supply propagules to replenish depleted sites. Conversely, during periods of drought, the soils of tranquil reaches may have a better moisture holding capacity, and thus help to maintain species richness. Heterogeneity in hydrology and geomorphology throughout whole river systems is therefore important to their long-term ecological resilience (Renöfält et al., 2007).

2.3 Distinctiveness of Plant Communities

It has been suggested that riparian areas in general offer a unique set of habitat attributes that contribute disproportionately to regional biodiversity and are thus worthy of study in and of themselves as functional units (Petts and Amoros, 1996). The riparian zones of large rivers are often described as particularly biologically diverse ecotones that host many species that are not abundant in neighbouring upland areas.

The Colorado Division of Wildlife defines riparian plant communities as:

> *"...those plant communities adjacent to and affected by surface or ground water of perennial or ephemeral water bodies such as rivers, streams, lakes, ponds, playas, or drainage ways. These areas have distinctly different vegetation than adjacent areas or have species similar to surrounding areas that exhibit a more vigorous or robust growth form"* (Colorado Division of Wildlife, 1998).

It is certainly the case that the riparian vegetation that develops along waterways in arid regions is distinctly different in structure and species composition than that of surrounding upland vegetation. Moisture in these regions is a primary limiting factor to plant growth, so the periodic flooding and high water table in riparian zones is critical for many species.

In boreal regions, structurally distinct fringes of deciduous shrub and herb communities are maintained along the shores of lakes and rivers, in contrast to the predominantly conifer forest in adjacent uplands. However, in these relatively recent post-glacial landscapes, with long cold winters and short summers, water is held in almost every depression on numerous upland areas, especially in regions with permafrost. Nutrient-poor bogs are the most common wetland type, with relatively richer fens being rarer. Streams and seepages are abundant. Therefore, moisture is not a limiting factor to plant growth in many upland areas of boreal forest.

As mentioned, due to the seasonal disturbances by flooding and ice action, riparian areas immediately bordering large rivers and lakes do not support mature stands of the dominant forest trees such as black spruce (*Picea mariana*). Riparian habitats do provide opportunities for species that prefer moist, nutrient-rich sites but that may be out-competed in mature forest. However, it is not clear the extent to which the plant communities that occur in riparian areas of large rivers in the Labrador region are distinct from other early successional communities in the region. What are the similarities with riparian zones occurring along smaller rivers or tributaries, or those early successional communities that develop on disturbed sites such as recent burns or harvest blocks, or other open habitats and thickets in swamps, wet meadows, and roadside ditches? There has been little research to document whether the riparian zones of the Churchill River are habitat for species that are not typically found in other early successional habitats in the region.

Evidence also appears to be lacking that the riparian zones of large boreal rivers uniquely provide critical habitat for rare or uncommon species. The lower Churchill River valley is considered to be an ecologically diverse landscape compared to the surrounding region. The Churchill River watershed drains a region of predominantly open, sub-arctic lichen and feather moss woodland. No endemic plant species are known from the subarctic, which is a transitional zone between the boreal forest and the tundra (Johnson and Miyanishi, 1999). The valley of the lower reaches of the river supports a relatively rich, closed-crown forest and many boreal species reach their northerly limit here. Some species may grow predominantly along riparian areas and some may be present mainly in the larger river systems within the region. Studies in areas of the boreal-tundra transition closer to Hudson's Bay, and in northern Sweden and Finland, have shown that a relatively high proportion of the flora of these regions is found in the riparian areas of the largest rivers (Kalliola and Puhakka, 1988; FORAMEC, 1992a; Nilsson et al., 1994).

Areas disturbed by fire, wood harvesting, road building or other activities that remove the forest cover, including herbicide treatments along transmission line corridors, also provide opportunities for primary and secondary succession. They may host many of the same species that thrive in areas opened up by flooding, erosion, and sedimentation in riparian zones. The general composition of the boreal forest is much influenced or dependent upon fire cycles (Henry, 2002). Study of fire patterns has demonstrated that most of the boreal forest is probably burned every one to two hundred years. Many boreal species are well adapted to re-establishment after intense crown fires when shaded areas under the forest canopy are destroyed and mineral soil is exposed, providing openings for the more sun-loving shrubs, grasses, and herbs. Trees such as black spruce and white birch (*Betula cordifolia*) show strong adaptations to fire, as do beaked willow (*Salix* *bebbiana*), and fireweed (*Chamerion angustifolium* = *Epilobium angustifolium*).

Floodplains and islands are some of the few areas in the boreal forest that are almost immune to the effects of fire (Henry, 2002). Many of the early successional species that benefit from fire disturbance may also thrive in the fresh soils of riparian areas. However, the shores of large rivers may provide refuge for those species that require richer soils and higher moisture regimes, and are not well adapted to re-establishment after fire. These populations may be especially important as a source of propagules for recolonization along smaller tributary streams that may be more strongly affected by intense forest fires.

The relatively high density of deciduous shrubby and herbaceous vegetation that colonizes the riparian zones of large boreal rivers may provide an important portion of the allochthonous inputs of biomass energy into the aquatic environment of the river (Cummins, 1974; Waters, 2000). The tougher and more resinous leaves of conifers and upland shrubs such as Kalmia are more resistant to decomposition and much more difficult for microorganisms to process into useable food energy (Waters, 2000). Thus, early successional habitats such as recent burns and riparian zones may contribute a relatively higher proportion of the nutrition for instream organisms compared to spruce/fir/lichen dominated forest. Reservoirs in boreal regions, particularly those with large drawdown zones, do not support rich riparian or aquatic macrophyte communities in the littoral zones. This would be expected to decrease the productivity of aquatic environments (Gibson, 2002).

Depending on its structure and local context, riparian vegetation may also serve other important ecological functions within the riverine landscape. These include: provision of fish and wildlife habitat, bank stabilization, water quality protection by trapping sediment and pollutants, thermal cover, and flood control.

2.4 Riparian Areas as Wildlife Habitat

Riparian ecosystems in general are considered to be important for maintaining regional diversity of animal wildlife, due to the structural complexity of the vegetation, proximity to water, and abundance of food in these areas (Junk et al., 1989; Nilsson, 1992a; Naiman et al., 1993; Nilsson and Dynesius, 1994; Maisonneuve and Rioux, 2001, Coutant, 2004). In arid regions, riparian areas provide especially critical habitat for wildlife, and for maintenance of regional biodiversity (National Academy of Sciences, 2002). For example, in Colorado about 75% of wildlife relies on riparian habitats for all or a portion of their life cycle (Colorado Division of Wildlife, 1998). The degree to which various species of animal wildlife depend upon riparian habitats in boreal regions is less clear.

There has been comparatively little ecological research done on higher order rivers, especially in boreal and tundra environments, compared to streams and smaller rivers which are easier to study (Dodge 1989). Many reports argue that the structural diversity and forage quality of riparian vegetation provides key habitat features for a wide range of species in all regions – these qualities are essential for riparian obligate species, or are important for a portion of the life cycle of many others (e.g. National Research Council, 2002). Without doubt, the extensive floodplains of large alluvial rivers in areas of low relief create critical habitat that is essential to many species of wildlife (e.g. the Mackenzie River delta). However, the importance to regional wildlife biodiversity of the relatively narrow, linear strips of riparian vegetation bordering large boreal rivers in deeper valleys is not well understood. The shrubby zones that develop between lower water levels of summer and spring high water levels in lakes and rivers are certainly used extensively if not exclusively by many species of boreal wildlife.

Freshwater marshes, an important component of some riparian habitats, are relatively uncommon in Labrador (Meades, 1990). Together with salt marshes, they account for only about 10% of all wetlands in the region, bogs and fens being more abundant (National Wetlands Working Group, 1988). The more protected river valleys in Labrador are the sites of important fluvial marshes, such as the delta of Snegamook Lake, and along rivers and brooks in the Lake Melville area (National Wetlands Working Group, 1988). Examples on the island of Newfoundland include the Big Steady Marsh on the Main River used extensively by moose, and the King George IV Lake Delta frequented by caribou. Little research has been done in Labrador to characterize fluvial marshes within sheltered river valleys. However, it is thought that these relatively small areas provide some of the richest wildlife habitat within the large expanses of inland taiga (Goudie et al., 1988; Pien Penashue, pers. comm., 2001). In discussing the wetlands of

Atlantic Canada in general, the National Wetlands Working Group stated that:

> *Marshes provide some of the richest wildlife habitat. In many of the vast stretches of inland barrens in Newfoundland and Labrador, a river delta or floodplain functions like much like an oasis in a desert, and most species exploit the food and cover contained there. Herbivores consume the diverse array of tender herbs, grasses, and sedges that grow so abundantly on the rich mineral and organic soils* (National Wetlands Working Group 1988:286-287).

Dense vegetation close to the water's edge provides cover from predators for animals such as otter and mink that inhabit riparian zones. Beaver and muskrat use riparian vegetation for food and building materials. Moose, ptarmigan, grouse, and snowshoe hare utilize deciduous shrubs, sedges, and grasses for forage. These species may also winter in the comparative shelter of river valleys. The spring flush of herbaceous vegetation in riparian zones provides important food sources for species such as black bear early in the growing season. Riparian areas of the lower Churchill River valley were observed to green up several weeks earlier in spring than the surrounding upland landscape, especially along south-facing slopes (personal observation).

Riparian deciduous willow/alder thickets, especially on low islands and bars, provide excellent calving habitat for species such as moose, as there is abundant nutritious forage coupled with protection from predators. Moose prefer the forage of young deciduous shrubs and herbaceous vegetation also found in other early successional habitats, such as post-burn regeneration. This type of habitat is important throughout the boreal forest for moose as their diet depends upon deciduous foliage in summer, and twigs and buds of willows, birch, aspen, and other shrubs including some balsam fir (*Abies balsamea*) in winter (Henry, 2002). Aquatic vegetation in summer is also important to moose and they may thrive where it is abundant.

It has been suggested that large riparian corridors are regionally important for moose populations because they provide permanent habitat across the landscape, while other habitat types are more transitional (Telfer, 1984). Moose arrived in central Labrador from eastern Québec only during the early 1960s (Procter and Redfern, 1980). They may have utilized riparian alder/willow shrub and marsh habitats along the myriad streams and lakes of the upper Churchill River as they traveled, and upon reaching the lower river valley, were able to thrive in the sheltered valley. Some researchers speculate that they traveled up transmission line corridors from Québec as these areas are kept clear of larger trees and provide abundant browse of deciduous shrubs (Connor Pacific Environmental Technologies Inc. and Wentworth Associates Environmental Ltd., 1998). However, the combination of frequent fires and increasing wood harvesting in the region creates a shifting mosaic of early successional vegetation in many areas of this boreal forest. Post-fire habitat in the upper watershed has likely also been important in allowing moose to extend their range into Labrador.

Many species of waterfowl, whether they prefer flowing or still waters, require good vegetation cover bordering water for nesting and brooding. The interior of the Labrador Peninsula contains an intricate network of waterways. Smaller ponds with dense shoreline vegetation, with water levels relatively stable in summer, are breeding habitat for many species of waterfowl (Todd, 1963). Willow and alder thickets and sedge meadows bordering water bodies are also used by many species of breeding songbirds for nesting and foraging sites.

2.5 Effects of Dams and Reservoirs on Boreal Riparian Habitats

In the absence of pre-development research and long-term monitoring of riparian vegetation in the Churchill River watershed, interpretation of the existing patterns observed in this river must rely more heavily on studies conducted in other boreal regions that have investigated the effects of regulation on river shorelines. These studies can provide many useful insights into the ways in which the Churchill River riparian habitats may be responding to changes in hydrological regimes, and some basis for predicting the landscape-level results of additional regulation. Thorough consideration of research conducted in similar environments can contribute substantially to cumulative effects assessment of hydroelectric development in central Labrador.

Dams and impoundments create barriers that impede the longitudinal continuity of river systems, and result in upstream and downstream changes in biotic and abiotic patterns and processes in aquatic and riparian environments. The specific changes that take place depend on the geomorphological and ecological characteristics of the river system, and the numbers and location of the built infrastructure along the river (Ward and Stanford 1983, 1995; Naiman, 2005). A dam along a constrained reach in the headwaters of a catchment basin, for example, will have quite different consequences from that of a barrier placed in a wide, meandering reach of a lower river valley with a large floodplain. Changes that occur also vary with the distance downstream of a dam, and the particular hydrological regime created by operations of the facility (Ward and Stanford, 1983, 1995).

In general, changes in riparian habitats due to flow regulation include:

- conversion of lotic (swift-flowing) to lentic (slow-flowing) environments above dams;
- changes in sediment transport, depositional and erosional processes, nutrient, temperature and moisture regimes below dams;
- alterations in community composition and successional processes due to increased or decreased disturbance (Naiman et al., 2005).

Some of the most extensive and longer-term work on the effects of river regulation on boreal riparian vegetation has been led by the Landscape Ecology group at Umeå University in Sweden (Nilsson, 1986; Nilsson et al., 1991a; Nilsson and Jansson, 1995; Jansson et al., 2000a; Johansson and Nilsson, 2002). Generally, it has been concluded that the two most severe effects on wildlife from damming rivers result from the permanent loss through flooding of terrestrial and wetland habitats, and the loss of highly productive riparian habitats (Nilsson and Dynesius, 1994). River regulation tends to result in a simplification of shoreline habitats and decreased diversity of flora and fauna in these areas (Naiman and Décamps, 1997; Jansson et al., 2000a).

Various patterns of change in vascular plant richness, abundance, vegetation structure and cover have been observed that vary according to the particular changes in hydrological regimes experienced. These patterns have been shown to be broadly similar in boreal regions of different continents (Dynesius et al., 2004).

Hydroelectric development typically involves at least two of the following forms of regulation of the natural seasonal flow patterns of lakes and rivers: storage and control impoundments; diversions; and regulated downstream reaches influenced by releases from power plants. These are discussed below.

2.5.1 Impoundments

Water may be stored in impoundments behind dams and dikes above generating facilities for use when demand for power is highest. This usually involves flooding terrestrial and wetland habitats, and converting shallower, swift-flowing (lotic) waters to deeper, slow moving or lentic waters. Depending on the operating regime of the power plant, the water levels in impoundments usually fluctuate in ways that differ considerably from the seasonal patterns typical of natural lakes and rivers. In northern regions, spring melt waters are captured in reservoirs to supply higher flow to generating facilities during the following summer and winter seasons. Water levels in storage reservoirs therefore rise throughout the spring and often the summer, and then drop steadily throughout the winter. In a natural lake, water levels typically rise rapidly in spring, drop throughout the summer, and then stabilize in winter. There may be an autumn flush as well, corresponding to periods of heavy rain in the fall.

Figure 3. Extensive Drawdown Zone in a Large Storage Reservoir on La Grande Rivière, Québec. The shoreline is littered with drowned trees and is lacking vegetation cover (Photo: A. Luttermann, 2000).

Inundation of lakes, rivers, streams, wetlands and surrounding terrestrial habitat results in a direct loss of the seasonally disturbed shoreline areas, formerly colonized by early successional riparian vegetation. Although the difference between high and low water levels (the drawdown zone) may be much greater under regulation than under natural conditions, this does not result in the creation of an increased area of new riparian vegetation. In fact, the shorelines of reservoirs typically remain almost bare of vegetation due to the unnatural cycles of flooding and exposure, with water levels higher in the late summer than in spring. The lack of a spring flood along with periodic flooding and drawdown in summer and winter are the main factors preventing the development and maintenance of riparian vegetation in reservoirs (Johansson and Nilsson, 2002). In experimental studies, the establishment and productivity of many species of plants has been found to be impaired on the banks of impoundments due to hostile water-level regimes (Johansson and Nilsson, 2002). Longer-term studies have shown that the numbers of riparian plant species remain low in impoundments, even seventy years after regulation (Nilsson et al., 1991a; Nilsson et al., 1997).

Reservoirs that experience lesser drawdown over the winter and spring tend to maintain only narrow bands of riparian vegetation. This pattern would be typical of control reservoirs as water levels are kept within a more consistent range in order to feed the intake channels of power plants. Some hydroelectric facilities are designed to utilize the river flow according to existing patterns, rather than attempting to store large volumes of run-off for use at other times of the year. These operations are referred to as "run-of-river". However, such facilities do generally have reservoirs that serve to increase the head[8] available to the power plant. They maintain relatively consistent water levels with daily fluctuations within a narrow range similar to control reservoirs. Research in Sweden has demonstrated that the shorelines of run-of-river impoundments also support much lower riparian plant-species richness and abundance compared to free-flowing rivers (Nilsson et al., 1991; Jansson et al., 2000a; Johansson and Nilsson, 2002).

2.5.2 Diversions

Hydroelectric schemes often involve diverting the flow of surface water from the surrounding region to increase the availability of water in storage reservoirs. They may

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[8] The 'head' is the height of the drop from the intake tunnels to the turbines.

also channel waters from various sources to a location where a greater head can be attained to increase the potential energy.

Former riverbanks and floodplains, and riverbeds with finer substrates that are no longer flooded, will generally support the establishment of rich communities of early successional shrubs, herbs, and graminoids. Assani et al. (2006) found that the main determinant of higher species richness of colonizing riparian plants on new in-channel bars and islets exposed by low water levels in a reduced-flow river in Belgium was the proportion of fine substrates. However, new riparian zones that establish on the new shorelines of partially diverted rivers may be narrower over the longer-term due to the elimination of spring floods and the smaller seasonal fluctuation in water levels. In the absence of periodic disturbance of spring flooding and/or ice scour, these areas will eventually undergo a succession to mature community types similar to the surrounding upland forest (Jansson et al., 2000a).

2.5.3 Partially Regulated Downstream Reaches

Partially regulated reaches downstream of dams tend to experience decreased abundance of some groups of plants, although the shoreline vegetation remains relatively species-rich compared to reservoirs (Nilsson et al., 1991). Generally, regulated reaches with remnant riparian vegetation are more likely to support higher species richness (Nilsson et al., 1991a).

The downstream effects of dams on river morphology and riparian vegetation vary depending on the geomorphology, and the operating regime of the facility and how it affects the timing and quantity of water releases. Studies of reaches downstream of 21 dams on large rivers in the semi-arid western United States reported an increase in riparian vegetation in the former river channels. Data were collected 7 to 13 years following construction of the dams. The increased early successional vegetation was due to an increase in area of exposed substrates available for colonization as high spring floods were curtailed and low-flow levels increased making more moisture available during the dry season (Williams and Wolman, 1984). These studies did not investigate changes in species composition of the riparian zones. They concluded that an increase in riparian vegetation resulted if a dam operated to restrict high floods. However, if this reduction of high floods was sustained over the long-term, forest vegetation would be expected to eventually succeed the shrubs, forbs and graminoids typical of periodically disturbed riparian sites. A decrease in biodiversity throughout the river valley would be the ultimate result.

Williams and Wolman (1984) showed that because large dams trap up to 90% of the sediment load of rivers, the downstream reaches experienced high rates of riverbed degradation and bank erosion. The effect was most extreme a few kilometers below a dam, but some level of effect could extend hundreds of kilometers until an affected river regained its original level of sediment load from erosion and contributions from tributaries (Williams and Wolman, 1984). This study also demonstrated a wide variation in downstream morphological changes among different rivers, although most of them experienced channel-bed degradation immediately downstream from the dam. Channel width increased as much as 100% in some, decreased up to 90% in others, or in still others, there was no observed change. In some cases, the rate of change was linear, and in others, it was irregular. They concluded that changes in channel morphology following flow regulation are subject to many variables, making predictions prior to dam closure difficult.

2.5.4 Ice Regimes

The importance of ice to the ecology of northern rivers has only recently begun to be recognized (Prowse and Conly, 1996; Prowse et al., 2004). Because rivers in boreal and taiga regions typically remain ice-covered for at least six months of the year, ice regimes have a large influence on processes such as the timing, duration, and magnitude of river flows and associated scouring of shoreline habitats (Prowse et al., 2004). In northern areas, high and low extremes of water level are governed in large part by ice cover, along with the phenology of snowmelt in the terrestrial watershed. Flow regulation can create substantial changes in the behaviour of ice in reservoirs and in downstream reaches.

Northern hydroelectric facilities typically release high flows in winter due to strong electricity demand during that season. The release of relatively warmer hypolimnetic (below the surface) water from deeper reservoirs in winter can reduce the duration and extent of ice cover in downstream reaches of a regulated river. In some reaches, regulation may entirely prevent the establishment of ice cover (Prowse et al., 2004). Increased fluctuations in discharge during the winter months may also compromise the integrity of ice cover, change the location of open-water areas, and create rougher and thicker ice in some reaches. This may lead to mid-winter break-ups, with extreme flooding and ice scour events.

Prowse and Culp (2003) differentiate between two types of ice breakup. Thermal breakup, caused by ice melting and weakening in place, is contrasted with more active mechanical breakup by water fluctuations and flows, which results in more massive blocks of ice moving rapidly downstream. More erosion and sediment transport would be caused by an active than a thermal breakup. Floods and ice scour precipitated by winter reservoir releases may create greater disturbance of the shoreline due to the competence of the ice in mid-winter compared to the weaker condition of partially melted ice during spring break-up. Moreover, Prowse and Culp (2003) suggest that the fact that riverbanks are frozen in winter would not afford much protection from the action of direct ice impacts. Slope instability may also increase from rapid drawdowns during which saturated winter and springtime banks are exposed. Riverbank stability increases with the cover and seral stage of riparian vegetation (Gilvear and Bravard, 1996). Increased winter ice-scour that removes riparian woody vegetation may result in a positive feedback that accelerates erosion.

Under natural conditions, water levels usually continue to rise after spring ice breakup. However, under regulated conditions with large storage reservoirs upstream operated to capture most of the spring runoff, the downstream flow decreases dramatically in the spring. Large sediment loads are then deposited in the river channel rather than being flushed further to the estuary (Prowse and Culp, 2003). Vegetation in the lower riparian zones may then be either well scoured and/or buried under thick layers of sediment depending on local dynamics and geomorphology.

2.5.5 Northern River Basins Study

An extensive research program conducted under the Northern River Basins Study confirmed that flow regulation downstream of the W.A.C. Bennett Dam constructed in the late 1960s in British Columbia is having a substantial effect on such key functions as seasonal flow patterns, sediment transport, ice formation, river morphology, and riparian habitat formation downstream along the main stem of the Peace River (Northern River Basins Study Board, 1996; Prowse and Conly, 1996). Changes in the morphology of shorelines and plant communities related to this hydroelectric development were mapped along reaches of the Slave River delta (English et al., 1996) and the Peace River (Church et al., 1997). These studies used aerial photography taken during pre- and post-impoundment periods, combined with ground-truthing to develop general descriptions of riparian habitat.

In the study of the main stem of the Peace River, air photos at a scale of 1:20,000 were compared from 1968 and 1993. During this 25-year period, changes in morphology and riparian vegetation were most noticeable just downstream of the power plant, but were also apparent hundreds of kilometers downstream (Church et al., 1997). There has been a considerable narrowing of the main channel in some reaches because the peak spring floods have been reduced. Vegetation cover has become established in side channels between islands and the main shore, and on sand/gravel bars that are no longer submerged. Increased sedimentation is occurring in lower downstream reaches because the flow regime is not capable of moving as much sediment as it did prior to regulation. Less change occurred in sections of the river channel that were formerly relatively contained, for example, within bedrock channels. The effects of these changes on the aquatic and terrestrial fauna of the region are not well documented in the scientific literature.

Church et al. (1997) observed that scattered shrubs and graminoids would establish on the upstream surface of gravel bars, after which sand would be trapped by the vegetation, eventually allowing a continuous shrub cover to develop. On the bar surface surrounding old islands, riparian bands of shrubs have developed. Overall, the changes were most extensive in areas that previously had many islands and where the river had always been unstable. These are places where the sediment is transiently stored on its way down the river. It was predicted that these sites would likely remain unstable and would have continued renewal of early allogenic[9] plant succession.

2.5.6 Potential Upstream Effects

It is known that upstream aquatic ecosystems are strongly affected by dams. For example, dams can create a barrier to the migration of fish. However, it is not known whether riparian vegetation growing along unregulated tributaries could be affected by changes in hydrology downstream. Some authors have suggested that regulation may alter opportunities for the upstream dispersal of plant propagules (Naiman and Décamps, 1997). For example, riparian plants that are dispersed by zoochory (e.g. seeds carried in the feces of birds) may experience changes in populations along upstream tributaries if plant populations and/or their associated avifauna decrease on the main stem of a river because of significant hydrological changes.

2.5.7 Interpretations of Research on Riparian Habitat Change in Northern Québec

Although a large body of scientific literature examines the largely negative effects of flow regulation on riparian habitats, there are divergent perspectives on the importance of some of these changes. Hydro-Québec is the largest producer of hydroelectricity in Canada, and it has a vested interest in promoting additional developments. It has conducted an extensive program of pre- and post regulation research and monitoring of rivers in boreal and sub-arctic environments since the 1970s, when a series of very large hydroelectric facilities was constructed on rivers flowing into James and Ungava Bays. As part of this work, effects on riparian vegetation related to the operation of several large storage reservoirs have been monitored, including downstream reaches and rivers with reduced flows (Julien et al., 1985; Société d'énergie de la Baie-James et al., 1985; Coté, 1998; Denis and Hayeur, 1998). The use of riparian habitats by animal wildlife has also been investigated (Doucet and Giguère, 1991; Morneau et al., 1992; Morneau, 1998). Hydro-Québec has also produced one of the most extensive impact assessment studies in Canada for any proposed hydroelectric project (Hydro-Québec, 1993a, 1993b, 1993c). The Grande Baleine project, shelved in 1994, was assessed for predicted effects

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[9] The term allogenic refers to the process of succession whereby one plant assemblage is replaced by another as a result of changes in substrate due to sedimentation (Church et al., 1997).

on riparian habitats (FORAMEC, 1992a, 1992b, 1992c). A summary of observations and predictions generated from three decades of monitoring many aspects of regional ecosystems was published in 2001 (Hayeur, 2001).

In earlier internal research reports evaluating the effects of the La Grande project, it was estimated that about 95% of the original riparian zones were essentially destroyed in areas flooded for the reservoirs (Julien et al., 1985). Along the approximately 83,300 km of new shorelines, the unseasonably fluctuating water levels, coupled with increased erosion and poor substrates, prevented most natural regeneration of riparian plants and impeded the success of experimental attempts to replant shorelines (Julien et al., 1985).

The original shrub zones were the most severely affected of the riparian habitats (Ouzilleau and Brunelle, 1988). Prior to regulation, these areas had provided good quality moose habitat. There was also an increase in disturbed forest throughout the region due to the construction of facilities for electricity generation, residences, roads, transmission lines, and other infrastructure. Some of those host early successional deciduous shrub communities for various periods of time and provide good forage for moose providing a partial offset for the loss of riparian habitat (Julien and Nault, 1985). Vascular plant species richness was not reported for these regenerating upland areas.

About 7000 pairs of breeding waterfowl were forced to nest elsewhere because of the loss of suitable riparian habitat in the flooded areas (Hydro-Québec, 1990). Widespread loss of habitat for ptarmigan and hare along the shores of large rivers and reservoirs was also reported (Julien, 1986). It was suggested that about 20% of the new shores provide some good wildlife habitat (Hydro-Québec, 1990, cited in Harper, 1992), primarily along reaches of rivers that had been diverted and now support early successional shrubs and herbs colonizing former exposed riverbed substrates.

Patterns of development of riparian vegetation under reservoir conditions associated with La Grande Complex were considered to be predictable enough to estimate losses of comparable habitat for subsequent projects in northwestern Québec (i.e. FORAMEC, 1992a). Quantitative analysis of the changes in riparian habitat was attempted within the context of an environmental assessment for the proposed Grande Baleine or Great Whale project, in a watershed just north of La Grande, flowing into Hudson Bay (Deshaye et al., 1992; FORAMEC, 1992a; Hydro-Québec, 1989; Hydro-

Québec, 1993a, 1993b). In that exercise, all former shorelines in areas that would be converted to reservoirs were considered to represent a net loss of productive riparian habitat. The new shorelines were not expected to develop a rich cover of riparian vegetation. Therefore, the area of riparian habitat predicted to be lost if the Great Whale project were built was quantified by multiplying the length of river course that would be flooded by an estimated average width of the zone of existing riparian vegetation. A percentage loss of the total riparian habitat was calculated on this basis.

The Great Whale project was expected to submerge an area of 3650 km^2 and result in the loss of 132 km^2 of riparian habitat representing 13% of this type within the study area (FORAMEC, 1992a). In the reservoirs, 97% of the existing riparian habitat was predicted to be lost by flooding. The most important losses were considered to be the herbaceous communities on sandy substrates because these were the most species rich and regionally unique. It was estimated that about 11 km^2 of new productive riparian habitat could eventually become established, mainly along diverted reaches where former riverbed substrates were exposed. These areas would likely support early successional herb and shrub growth. However, the authors did not discuss whether these new habitats would likely persist without some level of appropriate hydrological or other disturbance.

The research report on effects on riparian vegetation concluded that the loss of that habitat would represent an ecological impoverishment that would be difficult to offset (FORAMEC, 1992a). This is especially so because the largest and most floristically diverse riparian zones in the region occur along slower-flow reaches of the largest rivers, which would be severely affected by the hydroelectric development.

The plant communities in unregulated riparian zones were believed to be important to wildlife. However, the environmental impact statement (EIS) concluded overall that the Great Whale project would be ecologically acceptable because it would affect less habitat than the previously constructed La Grande development (Hydro-Québec, 1993b). This section of the EIS briefly discussed the possible implications of cumulative losses from the two projects in the region. They noted that there would be an additive loss of waterfowl habitat. Nevertheless, the ecological implications of the predicted reductions in riparian habitat for the region were described as small (Hydro-Québec, 1993b).

In the report focused on assessment of cumulative impacts, Hydro-Québec stated that the total losses of wetland habitat suitable for waterfowl breeding from the Great Whale, La Grande, and Churchill Falls projects combined would amount to about 2800 km^2 (Hydro-Québec, 1993c). This would affect an estimated 1% of the waterfowl population breeding in Québec, (not counting losses caused by Churchill Falls development). It was suggested that geese and dabbling ducks could find other nesting locations, but that diving ducks would experience a net loss of breeding population.

Hydro-Québec argued that loss of breeding habitat for waterfowl was not likely a limiting factor, since their populations were believed to be well below the carrying capacity of the existing habitat (Hydro-Québec, 1993c). Reductions in southern wintering habitat along the Atlantic flyway were considered to have a much more important influence on the reproductive capacity of Ungava peninsula waterfowl populations. As such, Hydro-Québec considered the cumulative effects of these large hydroelectric developments to be not important for waterfowl (Hydro-Québec, 1993c). However, it could be argued that the conversion of large tracts of riparian and wetland habitat to unproductive shoreline constitutes an important local and regional degradation of potential land use and biodiversity.

More recent interpretations of the effects of these projects on riparian zones have been elaborated (e.g. Hayeur, 2001). In their "Summary of Knowledge", Hydro-Québec concluded that no vulnerable or economically valuable species were threatened by the effects of the La Grande project (Hayeur, 2001). Moreover, in their analysis of cumulative impacts there is a focus on the idea that new shrubby communities that have developed in reduced flow reaches of diverted rivers partially offsets similar habitat lost in other parts of the watershed of the La Grande river, implying that this should be considered a longer-term ecological condition.

Furthermore, Hydro-Québec states that even the drawdown zone of the reservoirs is used by some species of wildlife and therefore, rather than being an ecologically sterile zone, there is "… un certain dynamisme écologique associé à la zone de marnage des réservoirs" [… a certain ecological dynamic associated with the drawdown zone in reservoirs] (Doucet and Guigère, 1991: 7). These habitats, it is suggested, should not be considered waste places with no value to wildlife, but as places where a "drawdown zone ecology" exists (Hayeur, 2001: 57). Observations that form the basis of this assessment include the occurrence of tracks of caribou and black bear on the shores of reservoirs. The summary of impacts concludes that "even though this [drawdown] zone can vary from one year to the next and does not always have the same value for the species using it, it clearly constitutes a habitat and must be considered as such" (Hayeur, 2001:57). However, many boreal and sub-arctic animals are extremely mobile and opportunistic and there is likely no area in the entire territory, including the unvegetated gravel roads over the dikes, that is not traversed by some creature at some time. For example, I observed bear scat on a gravel dike adjacent to the Whitefish control structure in Labrador. Animals may be occasionally observed in the extensive drawdown zones, but this does not indicate that they are utilizing these areas in a productive way, and it does not temper the fact that these "new habitats" represent serious ecological degradation compared to the original riparian zones.

Hydro-Québec also cites the use by waterfowl of some shallow habitats with tangled woody debris of dead trees and shrubs, and the presence of numerous aquatic invertebrates near the high water level as evidence of abundant life in the reservoir riparian zones (Hayeur, 2001). The observations referred to in this document are associated with internal research reports, in which the authors state that it is generally known that hydroelectric reservoirs are almost unused by waterfowl for breeding (Morneau et al., 1992; Morneau, 1998). Morneau (1998) had concluded that observations of waterfowl using the Laforge-1 and Robertson reservoirs to raise broods in 1998 were explained by the shallow depth, low slope, and partially submerged shrubs and trees that were exposed that year when water levels were lowered and kept relatively constant throughout the breeding season. The partially submerged trees and shrubs provided good hiding places for dabbling ducks, in particular, Green-winged Teal. The mobilization of nutrients and abundant woody debris also provides new habitat for aquatic invertebrates, which are food for waterfowl, for a short period of time (Morneau 1998). However, it was clear in the above report that these conditions were not expected to persist. Moreover, these sorts of conditions are not consistent with most of the large storage reservoirs in the system. The summary report of effects (Hayeur, 2001), thus presents a selective and overly optimistic interpretation of the ecology of drawdown zones.

Hydro-Québec's overview of impacts (Hayeur, 2001) also cites the results of one study of island biodiversity (Crête et al., 1997) to support the claim that the drawdown zones are not as much a hindrance to wildlife as once thought. Hayeur explains that the Crête et al. study showed that plant and animal species diversity, richness, and composition were similar between islands in the La Grande 3 reservoir 11 years after impoundment and islands in nearby natural lakes. However, a close review of the study cited reveals that the surveys specifically excluded riparian zones, sampling only a 50 m radius surrounding a centre point on the islands, to avoid the "edge effect" (Crête et al., 1997). Only woody vegetation was reported in the surveys, 13 species in total from all sites. In fact, the results give little indication of the actual differences between reservoir islands and those in natural lakes in terms of total plant species richness and composition, riparian habitat structure, habitat quality of the shorelines, or their use by wildlife.

Denis and Hayeur (1998) examined the progressive recolonization of vegetation along the banks of the Caniapiscau River which lost 40% of its mean annual flow when the upper portion of its basin was diverted into La Grande Rivière in 1981. The upstream reaches closest to the dams experienced the greatest reduction in flow and had little spring flooding. In the early years following diversion, periodic releases of high flows into the Caniapiscau River prevented vegetation from establishing in dewatered parts of the riverbed. These releases also destroyed revegetation efforts associated with aerial seeding of the exposed banks of Lac Cambrien, a lake expansion of the main river. Since then, the flow of the upper river basin has been diverted entirely, allowing colonization of the dry riverbed by herbaceous and shrubby plants (Denis and Hayeur, 1998).

By 1988, there was an expansion of riparian willows, particularly on silty-clay, and sandy substrates. Several pioneer species were establishing in the interstices of rocky substrates where silt and organic matter had collected. On some moist, sandy shores, it was reported that a "mosaic" of plants had developed, but drier areas were not yet colonized.

In 1996, steep slopes stabilized by rock at the base were being colonized by herbs and shrubs. On shores with low slopes, more varied vegetation was developing. Denis and Hayeur (1998) reported a richness of 15 plant species on the river shores 15 km downstream of the Caniapiscau Reservoir. Along the lower portion of the bank at this site, *Myrica gale* had colonized and was becoming more abundant than willows. Alders and glandular birch were sparsely present. On the upper portion of the banks, 1-m high larch were present among young spruce shoots a few centimeters tall. Distributed throughout the riparian zone they reported *Achillea* sp., *Epilobium* sp., ferns, fungi, gentians, grasses, *Potentilla* spp, and *Vaccinium* spp. (Denis and Hayeur, 1998).

Varied vegetation was also developing on the exposed banks of Lac Cambrien, demonstrating they state, "…un élargissement marqué de l'écotone riverain" [a considerable expansion of the riparian ecotone] (Denis and Hayeur, 1998:15). This new habitat, "…qui a déjà l'allure d'un écotone" [that already had the appearance of an ecotone] (Denis and Hayeur, 1998:15), they remark, did not escape the attention of wildlife that frequent such places. They observed that one can see a thousand geese and black ducks browsing in this "new ecotone" all along the shores of the lake. They also noted the presence of gulls, rodents, hares, black bear, wolf, fox and caribou, as evidenced by numerous droppings and tracks. The authors of the report conclude that:

> *"… ces observations démontrent que les rives du Lac Cambrien n'ont rien perdu de leur valeur écologique, mais qu'elles se sont plutôt un peu enrichies. C'est le constat que l'on peut faire pour l'ensemble des berges de la rivière Caniapiscau"* […these observations demonstrate that the shores of Lake Cambrien have not lost any of their ecological value, but rather, they have been somewhat enriched. This is the conclusion we can reach for all of the banks of the Caniapiscau River] (Denis and Hayeur, 1998:15).

Twenty years after the diversion of the Eastmain River, also to increase the flow of La Grande Rivière, it was reported that the herbaceous and shrubby vegetation along the river was more developed than on the reservoir shores. In general, Hydro-Québec's summary of the impacts describes how the banks of reduced flow rivers throughout La Grande Complex have generally become covered with vegetation, "leading to an extension of the former riparian ecotones" (Hayeur 2001:55), in their interpretation.

However, despite these positive observations, it is not accurate to conclude that the riparian ecotone will be enlarged and enriched in reduced flow rivers over the long-term. The exposed banks that are colonized by pioneering riparian species will provide good early successional habitat for several years, but in the long-term absence of flooding and scouring, much of this habitat will eventually develop into later successional vegetation typical of uplands. The young larch and spruce along the reduced flow Caniapiscau River are indicative of the early stages of this natural progression. Because there is a much smaller volume of run-off in the spring in these diverted rivers, they are likely to support a more restricted riparian zone than prior to diversion. Moreover, although the new vegetation would provide some productive wildlife habitat for a time, there have been no published studies of the species richness of the plant communities compared with that of the previous riparian zones.

Hydro-Québec has made recommendations on future research to address the effects of new hydroelectric development in comparable environments. The stated perspective is that any additional research on new projects should focus only on the habitats of species to which particular value is attached, primarily by resource users. Any inventory work must be confined to "the essential" and conducted only to describe the "scope" of the habitats (Hayeur, 2001: 90). Furthermore, Hydro-Québec recommends that research should be focused on developing mitigation or compensation measures for recognized impacts. The question of whether or not the effects of a new project may deemed acceptable, even after efforts to reduce them are made, is evidently not considered to be valid.

It would appear that ongoing monitoring of the reservoir riparian zones at the very least would be prudent and valuable, especially if there is indeed an evolving "drawdown zone ecology". The rates and patterns of vegetation succession over the longer-term on exposed riverbeds in reduced flow reaches would also be important to monitor in order to reach overall conclusions regarding habitat change. Although there are similarities, the effects of flow regulation cannot be entirely generalized from one basin to another. It is also reasonable and important to consider rare species, even if these are not used or valued economically.

Much can be learned about generic effects of flow regulation on riparian zones from research that has been conducted in other boreal regions. My study seeks to contribute to a better understanding of the specific changes that have occurred in the Churchill River basin, particularly in the riparian habitats that exist today, and some of the likely cumulative implications of further regulation in the lower river reaches. A reasonably clear and specific view of the landscape is necessary in order to formulate any reasonable assessment of the existing and proposed hydroelectric developments on the Churchill River. To date, this basic information has not been well described for the watershed as a whole. Environmental assessment work for new dams on the lower Churchill has focused primarily on the lower river reaches. Most maps produced do not even cover the whole watershed.

Chapter 3. Study Area

3.1 Physical and Biological Characteristics of the Churchill River Watershed

3.1.1 Geomorphology

The watershed of the Churchill River is located in the eastern region of the Canadian Shield (Sutton, 1972). It is the longest river in Labrador and has the largest watershed, draining an area of 9.34 x 10^4 km^2 eastward through the Lake Melville estuary to Hamilton Inlet and then into the Labrador Sea (Figure 4). The mean annual discharge at its mouth at Goose Bay is 1.90 x 10^3 m^3/s. This is an increase of about 15% over the original unregulated mean annual flow of 1.63 x 10^3 m^3/s.

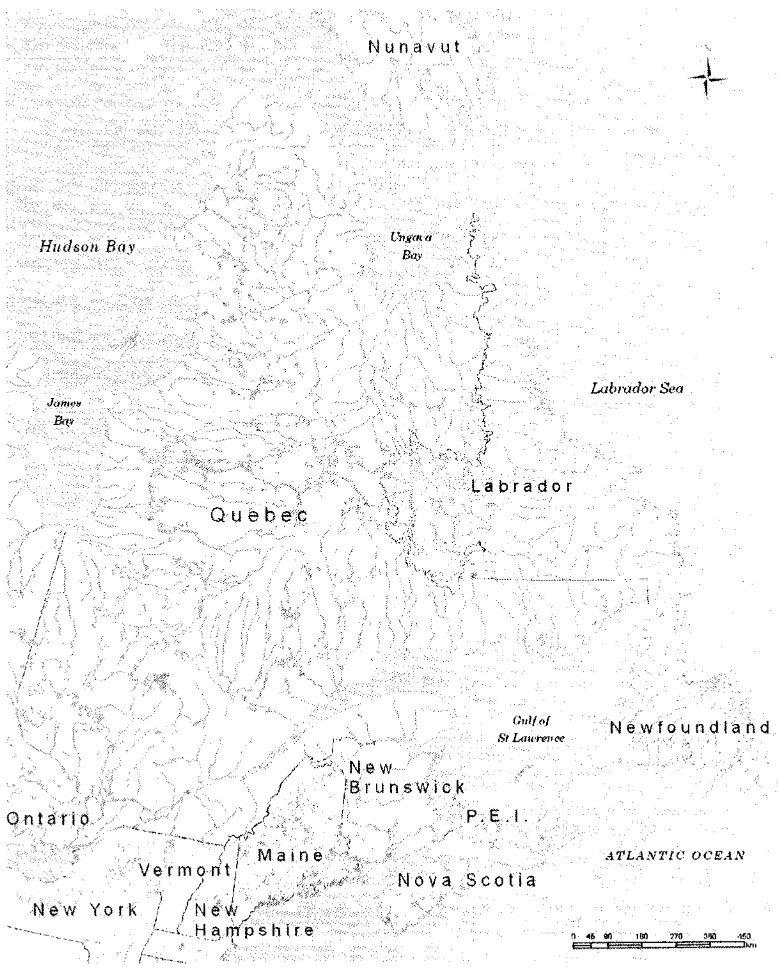

Figure 4. Location of the Churchill River Watershed. In Labrador, this river is still commonly known as the Mishta-Shipu or Grand River. It is in the heart of the Innu homeland, Nitassinan (Map produced on ARC GIS by A.Luttermann. Base map data obtained from: Environmental Systems Research Institute (ESRI); Geogratis).

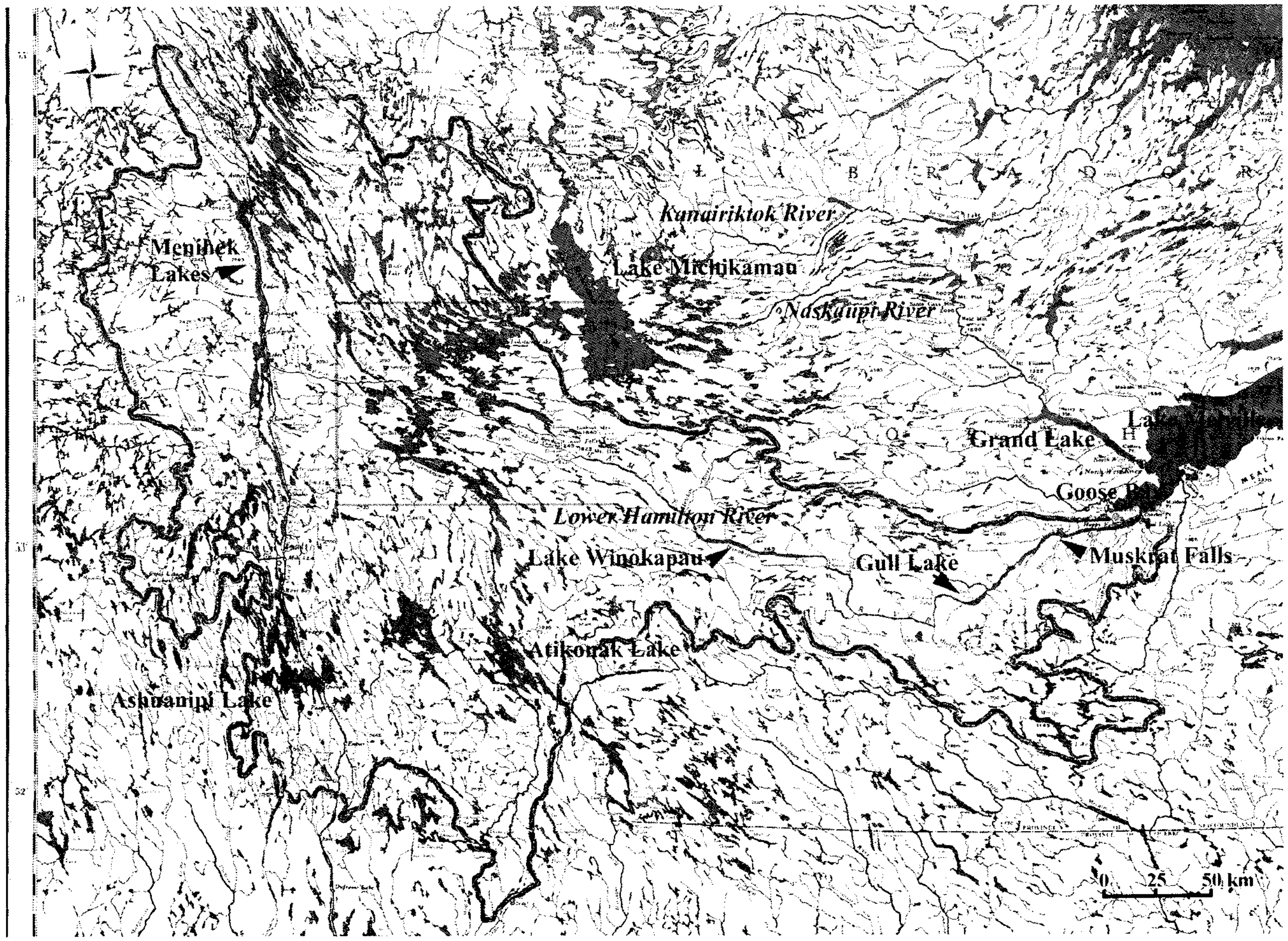

Figure 5. The Churchill River Watershed Prior to Regulation. The watershed boundary is represented by a dark line. Note that Lake Michikamau was originally part of the Naskaupi River drainage basin, although occasionally its waters overflowed into the upper Churchill. [Some place names mentioned in the text are added. The grey box indicates the area enlarged for the next map.] (Modified from base map obtained from: Department of Mines and Resources, Crown Lands and Surveys Branch. 1960. Labrador, Province of Newfoundland).

The course and physical character of the Churchill River prior to hydroelectric development were determined by a complex combination of ancient bedrock physiography, glacial influences, and fluvial processes acting over extended periods of time, including those predating the most recent glacial period. The river flows for much of its 856 km length through a landscape of Precambrian quartzitic bedrock, predominantly of gneisses and granites. The western boundary of the watershed delineates part of the border between Labrador and Québec at the height of land. The upper reaches of the watershed drain an extensive, undulating plateau, approximately 6.93×10^4 km^2 in area, representing 24% of the area of Labrador (Anderson, 1985).

The natural hydrological regime followed a strongly seasonal pattern controlled by the continental boreal climate; with a long cold winter and a short warm growing season. The highest flows occurred in spring, usually in June, with the melting of snow and ice. The lowest flows were generally experienced in late winter, when the land and water bodies are well frozen.

From its headwaters to the brackish Lake Melville at sea level, the Churchill River drops 529 m in elevation. A large portion of the original drainage on the plateau flowed south to NNE from two major basins – Ashuanipi and Atikonak Lakes (Figure 5). Prior to inundation, waters were collected from hundreds of small streams, rivers and lake expansions meandering over the plateau before turning south and narrowing into a main channel a few kilometers above Churchill Falls. At that point, the river flowed as a huge rapid until it plunged spectacularly over the brink of a 76-m meter cliff into a massive rock bowl.

During an early survey for the Geological Survey of Canada, A.P. Low described the course of the Grand River (Low, 1896). His writings provide some of the most graphic detail of the river system prior to the hydroelectric development. In the following passage, Low records his observations of the river on the plateau upstream of the falls.

> *Above Grand Falls, the character of the river changes completely; it no longer flows in a distinct valley cut deep into the surrounding country, but nearly on a level with the surface of the tableland, spreading out so as to fill the valleys between the long, low ridges of hills that are arranged in echelon all over the country. The river in passing around the ridges is often broken into several channels by large islands formed by separate ridges, and in other places, where there are wide valleys between the hills, it fills long, shallow lakes, with deep bays,*

and often studded with islands. The river now is so divided into channels and so diversified with island-covered lakes, that without a guide it is almost impossible to follow its main channel, and much time is lost tracing its course through the lakes, which often have several channels discharging into, as well as out of them. The current instead of flowing regularly, now alternates between short rapids and long lake stretches (Low, 1896:145).

This passage reveals the complexity of the drainage patterns of the river in the upper plateau, and indicates that extensive and variable shoreline habitats would have characterized the system (see Figure 6).

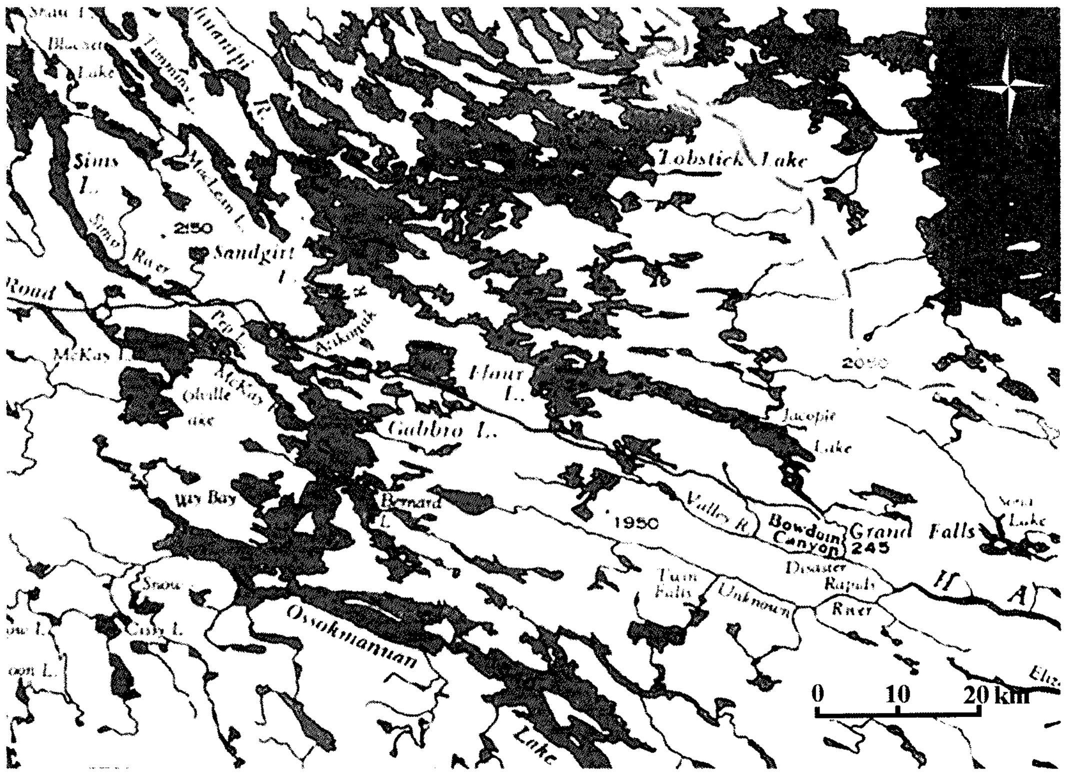

Figure 6. Detail of a Map of Labrador from 1960. A complex series of island-studded lakes and swift-flowing reaches characterized the upper Churchill River. The main flow of the river from the south-west was through Ossokmanuan Lake, while from the west it flowed through Lobstick, Sandgirt, Flour and Jacopie Lakes before plunging over the falls into Bowdoin Canyon, and on to the lower river valley. The Unknown River also flowed from Ossokmanuan Lake to join the lower Churchill (Hamilton River) (Base map source: Department of Mines and Resources, Crown Lands and Surveys Branch. 1960. Labrador, Province of Newfoundland).

The river valley below the Grand Falls makes an abrupt turn to the east (Figure 7) and continues for 19 km through a deep canyon with vertical rock walls until it meets the mouth of the Unknown River, a tributary draining the plateau from Ossokmanuan and Atikonak Lakes in the south-west region of the watershed.

Figure 7. The Former Falls Known Variously as Grand Falls, Mishta Paushtuk or Patsheshunau. The name was formally changed to Churchill Falls following diversion of the river above the falls shortly after this photo was taken. The roads, borrow pits, bridge and construction camp adjacent to the river are all associated with the hydroelectric development under construction at the time of the photo. The Jacopie control structure where the flow has since been diverted is located further upstream (Photo: Churchill Falls Labrador Corporation: circa 1970).

Low described how the river downstream of the Grand Falls differed from the upper plateau:

Owing to the great difference in physical character between its upper and lower portions, the Hamilton River is naturally divided into two parts at the Grand Falls *some 250 miles above its mouth. The lower part occupies a distinct valley, cut out of Archaen rocks, with the present river-level from 500 to 800 feet below the general level of the surrounding country. The valley varies in width from 100 yards to more than two miles, and the river flows down it between banks of drift, with a strong current broken by rapids in several places, especially along the upper stretches, but only in one place does it fall over an obstruction of rock.* [at Muskrat Falls]

This valley is well wooded where unburnt, and the timber is all of fair size and of commercial value, in marked contrast to the small stunted trees found partly covering the rolling country of the tableland, on either side of the valley. (Low, 1896:129)

The reaches of the river downstream of the former falls below the plateau are now referred to as the "Lower Churchill" in discussions surrounding additional hydroelectric development proposals. Here the main stem of the river flows through a deep valley that gradually broadens as it winds eastward for 360 km to its mouth. At least 241 tributaries including ten relatively large rivers enter the main stem of the lower river over this distance, draining an area of 2.42×10^4 km^2. The swift, lower river is punctuated by a series of rapids, but it is navigable by canoe with only one portage at Muskrat Falls, where the flow drops about 8 m over a bedrock sill, about 40 km from the mouth of the river. A large and deep lake expansion, Lake Winokapau, stretches for about 50 km in the mid-reach of the lower river, following the course of an ancient structural fault. It is bordered along much of its length by steep cliffs.

The lower reaches of the river, from Gull Lake east, exhibit a distinct geomorphology. The valley of the lower Churchill River, the Lake Melville basin, and Double Mer are all part of an ancient rift valley where two tectonic plates began to pull apart 500 – 600 million years ago (Thurlow, 1974). The valley was subsequently filled with glacio-fluvial sediment. During the Pleistocene Epoch (1.8 million to 10K years BP), successive periods of glacial advances and retreats modified the surficial topography by scouring out the valley, scraping the bedrock, and depositing thick till and glacio-fluvial sediment. Glacial action during the Quaternary period may have scoured about 10 m of bedrock in central and western Labrador (Jacques Whitford Environment, 2000).

As recently as 10,000 years ago, the entire Labrador/Ungava peninsula was covered by the Laurentide ice sheet. Deglaciation of the Goose Bay area is thought to have occurred between 7,550 BP and 10,000 BP (Jacques Whitford Environment, 2000). As the ice sheet retreated, the sediment filling the river channel was eroded by the flush of melt waters. At the same time, higher sea level resulting from glacial melt waters and the depressed continental land mass allowed the marine estuary to inundate the river valley to about 8 km downstream of the confluence of the Churchill and Minipi rivers (Jacques Whitford Environment, 2000). As the land uplifted following deglaciation, sea level dropped leaving terraces of fine marine clays covered with glacio-fluvial sand deposits in the lower reaches of the river. Subsequent stream flows have cut into these glacio-fluvial and marine terraces, shaping the present topography of the lower river basin, a process that continues to this time (Thurlow, 1974; Jacques Whitford Environment, 2000).

The lower Churchill River thus does not have a wide floodplain as it flows mainly through a broad, steep-sided valley. The active riparian zones are relatively narrow all along the river except at the confluence of some of the major tributaries with the main stem of the river, and in areas of higher deposition.

3.1.2 Ecological Land Classification

According to the Canadian ecological land classification framework, the Churchill River watershed spans two "ecozones", the broadest categories in the framework (Canadian Council on Ecological Areas (CCEA), 2006) (Figure 8). Much of the drainage basin, including the upper plateau region, and all of the uplands surrounding the lower river valley are included as part of the Taiga Shield Ecozone, which spans a large portion of Canada's subarctic from Labrador to Alaska. The taiga biome[10] also stretches across Siberia and Scandinavia. The Russian word "taiga" is used to describe the regions forming the northern edge of the boreal coniferous forest (CCEA, 2006). The taiga is thus an intermediate zone between boreal and tundra ecosystems.

The vegetation is influenced by cool temperatures, a short growing season, frequent forest fires, and thin, acidic soil. Taiga forests are relatively stunted, open-crowned stands dominated by species such as black spruce and jack pine (*Pinus banksiana*), with scattered patches of birches (*Betula papyrifera* and *B. cordifolia*) and

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[10] A biome is a major regional community of organisms usually defined by the botanical habitat in which they occur and determined by the interaction of substrate, climate, fauna and flora (Hale et al., 1995).

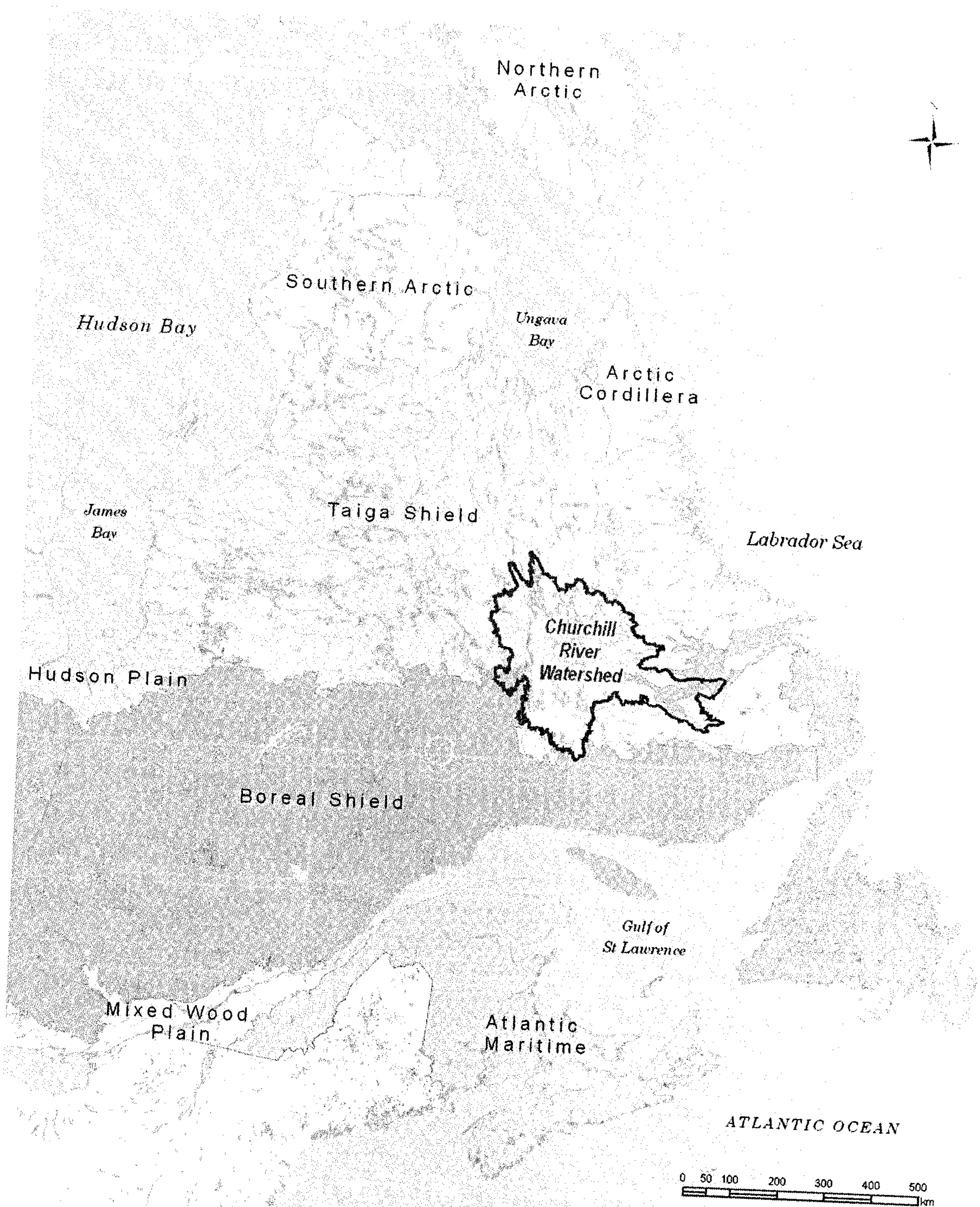

Figure 8. Terrestrial Ecozones of the Ungava Peninsula Region. Most of the Churchill River watershed is classified as characteristic of the Taiga Shield Ecozone. Relatively small portions of the drainage system are considered to be part of the Boreal Shield Ecozone (Prepared by A.Luttermann in ARC GIS. Base map data obtained from: Environmental Systems Research Institute (ESRI); Geogratis).

trembling aspen (*Populus tremuloides*). Balsam fir (*Abies balsamea*) and white spruce (*Picea glauca*) are more common in the riparian floodplain forests. Jack pine had not naturally extended its range into central Labrador since deglaciation. However, this species has been planted in recent years in the Goose Bay area near the mouth of the Churchill River. Numerous lakes and wetlands, most commonly bogs, punctuate the taiga landscape. These are settled into bedrock depressions carved by glacial activity, or held by beds of permafrost (CCEA, 2006).

Most of the lower valley of the Churchill River is categorized as part of the Boreal Shield Ecozone, as are the lowlands around Grand Lake and Lake Melville. These areas are sometimes referred to as a northern outlier of the boreal forest since they are virtually surrounded by the sub-arctic taiga (Lower Churchill Development Corporation Ltd., 1980). The plant life of the Boreal Shield Ecozone faces many challenges similar to those of the taiga. However, the somewhat warmer temperatures, reduced permafrost, and richer soils support a more diverse assemblage of tree species growing in denser, closed-crown stands, in contrast to the more open spruce/lichen parkland of the surrounding taiga regions. The southern regions of the Boreal Shield Ecozone also host some species more typical of temperate forests.

Ground cover in the closed-canopy black spruce, white spruce, and Balsam fir stands is dominated by sphagnum, feather mosses and lichens (i.e. *Cladonia rangifera*). Ground cover on drier sites with closed-canopy black spruce and white birch stands consists predominantly of feather mosses and ericaceous shrubs.

A finer level of resolution in the ecological land classification is the "ecoregion". Ecoregions represent areas where local climatic patterns further influence the particular characteristics of soil development and vegetation. The Churchill River watershed spans portions of four ecoregions, including areas of the High Subarctic Tundra, the Mid-Subarctic Forest, the Low Subarctic Forest, and the High Boreal Forest (Figure 9).

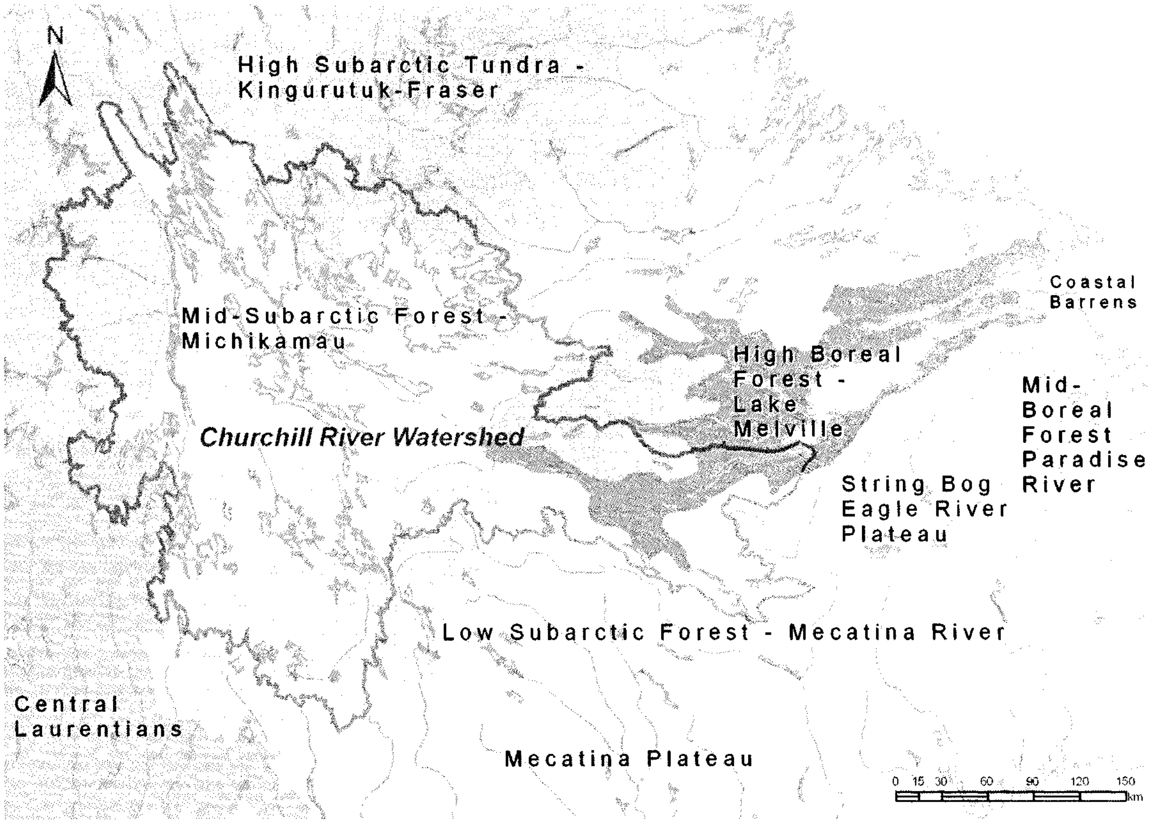

Figure 9. Terrestrial Ecoregions in Central Labrador. The Churchill River watershed spans portions of five terrestrial ecoregions (Map produced on ARC GIS by A.Luttermann. Base map data obtained from: Environmental Systems Research Institute (ESRI); Geogratis).

High Subarctic Tundra - Kingurutik-Fraser Ecoregion

Portions of the uppermost headwaters of the Churchill River drainage area, including a high, rocky plateau along the western edge of the watershed, are described as part of the High Subarctic Tundra (Kingurutik-Fraser) Ecoregion (Protected Areas Association of Newfoundland and Labrador, 2000). This ecoregion extends throughout much of the inland territory north of the Churchill River watershed. In these areas, the summers are short and cool and winters are long, severe and very cold. Annual rainfall averages 950-1000 mm and annual snowfall is typically 3 to 4 m. Mean daily temperatures in July range from 9 to 13 degrees Celsius. The growing season is no more than 80-100 days. The land is characterized by frequent areas of exposed bedrock. In these higher areas, continuous vegetation is supported only in snow bed communities, where snow staying late into the growing season provides sufficient moisture for many plants. Tundra vegetation predominates in the region including patches of willows, lichens, sedges, mosses and dwarf shrubs. Scattered stands of spruce occur primarily in the river valleys. In areas of poor drainage, there are shallow fens with sphagnum, sedges, and bog laurel. White birch and willow (*Salix* spp.) thickets often form in the transition zone between higher and lower elevations. In low areas, open stands of black spruce with scattered white birch, larch (*Larix laricina*), and balsam fir are typical.

Mid-Subarctic Forest - Michikamau Ecoregion

The upper reaches of the Churchill River watershed lie predominantly within the Mid-Subarctic Forest - Michikamau Ecoregion (Lopoukhine et al., 1976; Meades, 1990). This ecoregion also experiences short, cool summers and long, severe winters. Annual precipitation is somewhat greater than in the High Subarctic Tundra Ecoregion; with annual rainfall in the range of 900 to 1100 mm and snowfall 3.5-4.5 metres. Mean July temperatures are also slightly warmer from 11-13 degrees Celsius. The growing season here is 100-120 days. This is a flat to rolling plateau with numerous drumlins and eskers. Open black spruce/lichen woodlands are characteristic, and sphagnum/black spruce forests are common. This region encompasses the northern limit of trembling aspen (Meades, 1990).

Low-Subarctic Forest- Mecatina River Ecoregion

The Low-Subarctic Forest – Mecatina River Ecoregion includes the area immediately surrounding Churchill Falls, and extends south of the Churchill River into the North Shore region of Québec (Protected Areas Association of Newfoundland and Labrador, 2000). In these areas, cool to warm summers and cold winters are the norm. Annual precipitation comes in the form of 1000 to 1300 mm of rain and 3.5 to 5 m of snow. Mean daily temperatures in July are 13 degrees Celsius. This region is characterized by rolling terrain covered with shallow glacial till, divided by flat river valleys throughout. Much of the ecoregion is forested with open black spruce stands (in contrast to the High Boreal Forest where closed-crown stands are more common). These stands typically host a ground cover of lichens of the genus *Cladonia* in drier areas, while moister areas have ground covers of sphagnum mosses. Shrubs such as Labrador tea (*Rhododendron groenlandicum*), dwarf birch (*Betula glandulosa*), and blueberries

(*Vaccinium* spp.) are common. Deciduous trees are uncommon. Balsam fir and white spruce occur mainly on moist slopes with good drainage. Areas with poor drainage have string bogs and fens.

High Boreal Forest - Lake Melville Ecoregion

The main portion of the lower Churchill River valley lies within the High Boreal Forest - Lake Melville Ecoregion (Meades, 1990; Government of Newfoundland and Labrador, 2001). This region has the most favorable climate and most productive forests in Labrador, composed of closed-crown black spruce, balsam fir, white birch and trembling aspen. River terraces are composed of coarse-textured alluvial soils, with richer slopes dominated by balsam fir, white spruce, white birch, and trembling aspen. Black spruce dominates on the shallower soils of the upland areas, while lichen and feather moss woodlands occupy river terraces (Lopoukhine et al., 1976). Ground cover in these open spruce-lichen forests is dominated by lichens such as *Cladonia rangifera, C. alpestris, C. mitis, Cetraria* spp. and *Stereocaulon pascale* (Johnson and Miyanishi, 1999). In this region, closed canopy forest occurs only on moist, nutrient rich, and protected sites such as incised drainages (Johnson and Miyanishi, 1999). The High Boreal Forest Ecoregion has a growing season of 120 – 140 days, annual rainfall of 1000 to 1100 mm, annual snowfall of about 4.0 m, and mean daily temperatures in July of 13-14 degrees Celsius (Government of Newfoundland and Labrador, 2001).

A portion of the headwaters of the Ashuanipi River in the western region of the Churchill River drainage flows from the Central Laurentians Ecoregion. This area has physical and biological characteristics similar to those of the High Boreal Forest Ecoregion of the lower Churchill and Lake Melville.

3.1.3 Recent Precipitation Trends

Precipitation data have been recorded in the Churchill River watershed region for less than 50 years, making predictions of longer-term trends using this information speculative at best. The total annual precipitation recorded at Wabush Lake in the western region of the upper Churchill River watershed (Figure 10) has shown a downward trend in recent years (Table 1). During the period 1984 to 2005, Wabush Lake received on average 10.6% less precipitation than it did between 1962 and 1983. Similarly, data reported from Churchill Falls since 1969 show that annual precipitation has decreased, especially since the early 1990s.

Table 1. Annual Precipitation Recorded at Wabush Lake, Labrador
(Data source: Environment Canada).

	1962-1983	1984-2005
Average Annual precipitation (mm)	914	817
Range	679-1099	674-1000
Median	838	679
Percent Difference		-10.6%

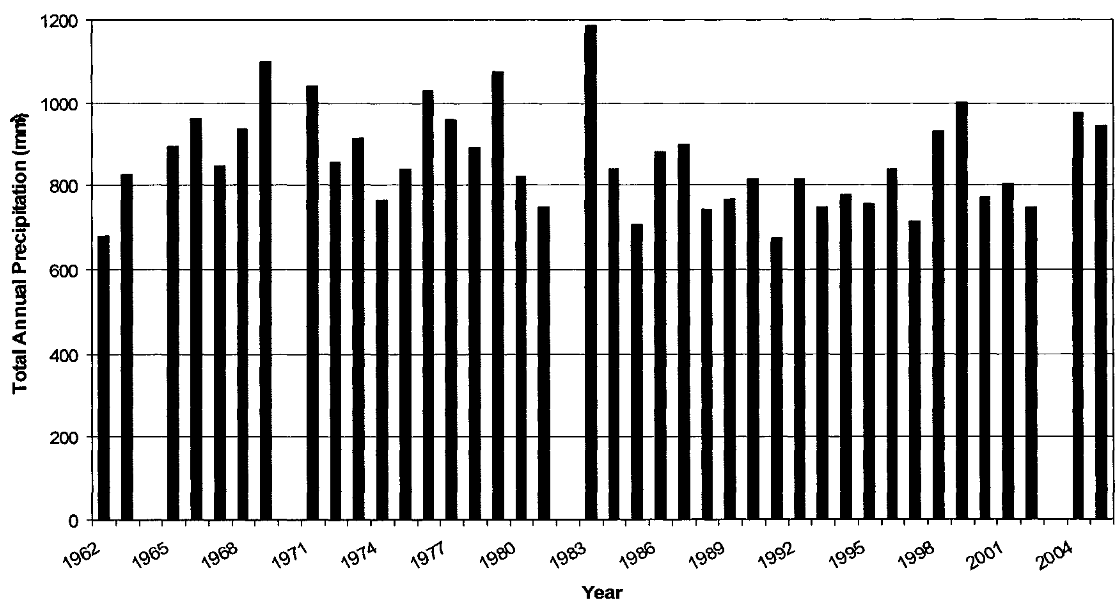

Figure 10. Total Annual Precipitation at Wabush Lake, Labrador 1962-2005
Note: data are lacking for three years. (Data source: Environment Canada).

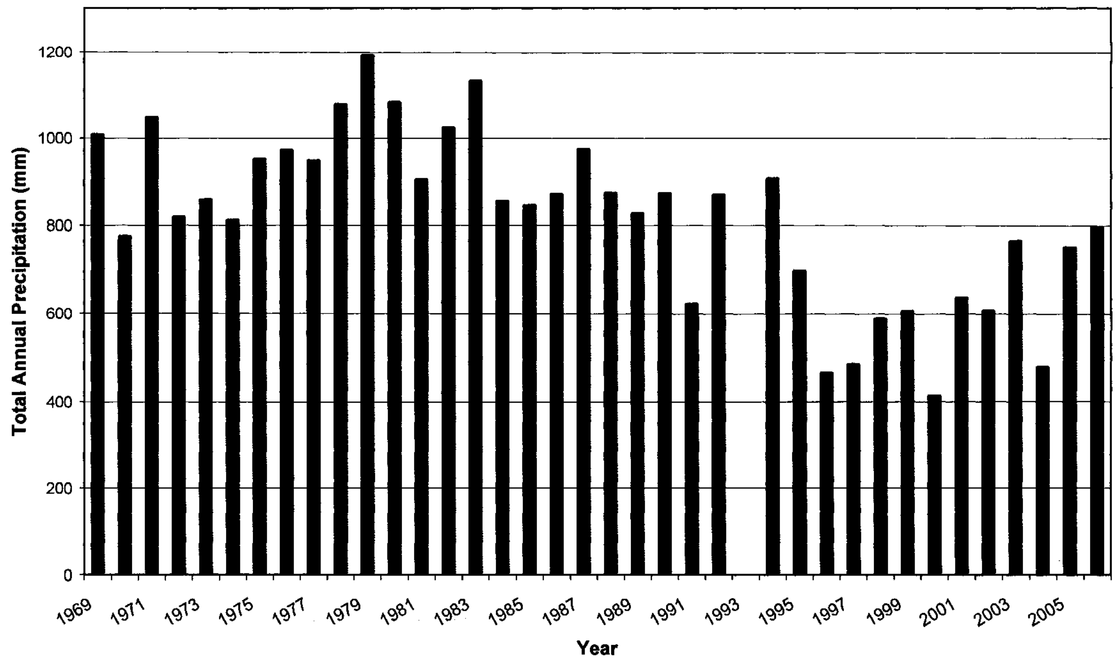

Figure 11. Total Annual Precipitation at Churchill Falls, Labrador, 1969-2006.
Note: data for 1993 are unavailable, and some years have incomplete data. (Data source: Environment Canada).

As these data represent a relatively short time period they do not necessarily indicate long-term trends. If precipitation does continue to decrease there may be some implications for the operation of hydroelectric facilities and cumulative environmental effects. These are discussed briefly in section 6.2.5.

3.2 Human Land Use and Industrial Development

> *"Where's it's dammed at Menihek (Meneikut), that's as far as the water level reaches now... I saw how it looked. A lot of trees were killed and islands are underwater. And the small mountains, the ones which are small, they are under water too. It's flooded everywhere. The hunting territory there, where the Innu used to hunt, used to be very good territory. Now it's all destroyed."* (Joe Nuna, unpublished interview, 1993)

The shores of navigable rivers are important and well-known features of the landscape to the local people who frequent these corridors. Throughout human history, settlement patterns in many regions of the world have concentrated along the shores of large rivers and other water bodies (Emerson, 1996; McCully, 2001). In less populated regions such as northern Canada, river valleys may not be necessarily permanently settled, but most have been used extensively as travel routes by semi-nomadic peoples, sometimes over periods of thousands of years since the retreat of the last ice sheets. Other more recent newcomers have continued to use inland waterways for travel, resource harvesting and recreation.

These riparian landscapes are punctuated with well-known camping and stopping places; portages; spots for good fishing, hunting, and gathering of plants for food, shelter or medicines; and places where significant events have happened – births and deaths, personal memories and family history (Horace Goudie, pers. comm., 2005; Pien Penashue pers. comm., 2005). In addition to familiarity with prominent landmarks such as islands, points, tributary mouths, beaches, and promontories, all of these places are significant within the cultural and environmental body of knowledge held by local people. Some of these features may change relatively quickly over time within the dynamic fluvial landscape (i.e. beaches and point bars), and observations of these patterns of change also form part of a body of local environmental knowledge.

Figure 12. Campsite on a Point Bar along the Lower Reaches of the Churchill River Main Stem (Photo: A.Luttermann, 2001).

The Churchill River in Labrador is a culturally and ecologically important waterway. Human populations have used this river for several thousand years, and their patterns of use have likely shifted relatively gradually over time. Based on current archaeological evidence (JWEL/ INEN, 2001), the shores of the Churchill River have been frequented by various human groups more than most other areas of Labrador's inland regions.

The large hydroelectric development that began in the 1960s created many important environmental changes in the watershed that have contributed to rapid cultural change. Other major influences on land use and culture in the region include mining developments, military installations and operations, governmental social and economic programs, forestry, road development, tourism, and urbanization (Armitage, 1989; Mailhot, 1997). These have all affected land use patterns, human population movements, and choices of livelihoods. Moreover, they have influenced perceptions of the nature and importance of additional changes predicted for the landscape in relation to any new development proposal.

In their paper reviewing observations of water chemistry and plankton shortly after flooding of the Smallwood reservoir, Duthie and Ostrofsky began by remarking that:

> *The Churchill Falls project has received less critical attention from conservation groups and the public than perhaps any other recent large hydro project in Canada. There are several reasons for this: it is situated in a remote region which before development was unpopulated; it has not threatened the economy or culture of any group of native people; and there is no single large concrete structure on which attention may be focused. However, the physical changes to the environment have been considerable.* (Duthie and Ostrofsky, 1975:118).

Over the past thirty years, critical attention has remained at a relatively low level, except among those local people who did in fact lose large areas of traditional territory under the reservoirs, and who have first-hand experience of the changes in the land and river systems surrounding the flooded areas. Members of the semi-nomadic Innu[11] culture had

[11] The Innu are culturally and linguistically related to the Cree and Mi'Kmaq. They were formerly known by Europeans as Montagnais-Naskaupi. The Labrador Innu, represented by the Innu Nation, live predominantly in two communities, Sheshatshui and Natuashish. The 14,500 Innu who live in the Québec region of Ntessinan live in nine communities along the North Shore and are represented by two political organizations: Mamit Innuat (Innu of the East) and Mamuitun (Together). The territory traditionally used by the Innu as a collective extends from the east coast of Labrador, north in the

been using these lands and waters on a seasonal basis for many hundreds of years as hunting, gathering, traveling, and meeting places, and places where loved ones had been laid to rest. The lands described by Duthie and Ostrofsky were therefore not simply "unpopulated". The Churchill Falls hydroelectric development has arguably had a profound influence on the culture and economy of both the Innu and the Inuit-Metis[12] of the region. Older people who know the region well often refer to the "destruction and devastation" caused by the project, but they have not had a strong voice in the broader political arena or in the media.

The Churchill River watershed forms the center of the homeland of the Innu of Labrador and Québec. Innu refer to their lands as Nitassinan[13]. The glacial ice retreated from the coastal areas of Labrador only about 7000 years ago following the most recent glaciation. The entire Labrador Peninsula became ice-free only 1,500 years later, and the interior was essentially unavailable for human occupation before that time (Mailhot, 1997). Archaeological evidence suggests that human occupation of the Churchill River valley occurred as early as 4,000 years ago near the mouth of the river, and 3,500 to 1,800 BP further up the river valley (JWEL/ IEDE , 2001).

The majority of human archaeological sites have been located in the river valley, and relatively few in the immediate surrounding upland region (JWEL/ IEDE, 2001), (although less archaeological research has been conducted in upland areas which may introduce some bias into the data). This suggests that the riverine landscape was used preferentially over time. The river valley was probably used as a seasonal travel route to move from Lake Melville to interior locations in the west and southwest. The Naskaupi and Beaver Rivers were also well-used travel routes from the interior plateau, in the Lake

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interior to Ungava Bay, west to Lac St. Jean, and south to the North Shore of the Gulf of St. Lawrence.

[12] The Inuit-Metis are primarily descendents of Inuit women and European men who settled along the Labrador coast following employment with fishing and trading companies as early as 1775 (Fitzhugh, 1999). Most of these families became involved in the fur trade and began to move inland to settle in the western Lake Melville region in the late 1800s. In the early 1900s Inuit-Metis trappers established traplines all along the Grand River, competing with the Innu for resources even in the remaining Innu territory above the Grand Falls.

[13] The term "Nitassinan", referring to the Innu homeland, is also spelled variously Ntessinan or Nitessinan. Dialects have developed among the Innu of different regions, and there is no standard orthography used to write the Innu language (Innu-aimun).

Michikamau/Lake Michikamats area, to the coast.

The most common places where people left evidence of their presence are along the riverbanks near confluences, at narrowings in the river channel, on points of land, and along rapids and falls. The majority of these were probably temporary stopping places. There is evidence that sites in the Gull Lake area and the mouth of the Churchill River may have been used for longer-term seasonal settlement for harvesting fish, migratory waterfowl, furbearers, and small game, especially in the spring and fall (JWEL/ IEDE, 2001).

It is well known that in historic times, and likely earlier, the region surrounding Michikamau and Michikamats lakes (now under the Smallwood Reservoir) in the northwest portion of the Churchill River watershed was used seasonally as an intensive harvesting area by Innu, particularly for caribou. They traveled from across the Labrador-Ungava peninsula and the northern shore of the Gulf of St. Lawrence using rivers such as the Moisie from the south and the Naskaupi and Beaver Rivers from the Lake Melville area. As Anthony Penashue described:

> *Many Innu from different parts of our land hunted at Meshikamau and they would come together at one place for gatherings. The gatherings were short back then, and the different clans of Innu people would then set out for the different areas where they hunted in the region* (Innu Nation Hydro Community Consultation Team, 2000: 28).

The Hudson's Bay Company established trading posts in the Churchill River watershed that operated during the 1800s. Fort Nascopie (1838-1868) was the first, built at Lake Petitsikapau on the plateau in the northwest area of the watershed. Another post operated from 1863-1874 at the west end of Lake Winokapau in the lower river valley. Settlers of mixed European and Inuit descent who pursued commercial trapping as the basis of their livelihood began moving further inland from the Labrador coast during the 1800s, and by the latter part of the century had started to trap up the Churchill River valley (Mailhot, 1997; Fitzhugh, 1999). The shores of the entire lower river valley, and some of the rivers and lake expansions in the upper plateau, were divided into personal trap lines used by people settled in the Mud Lake and North West River areas. At the same time, the Innu began to abandon the river as their main travel route, in part because of changes in location of trading posts and the Oblate mission (Mailhot, 1997).

Many changes in land use occurred prior to and following the Churchill Falls hydroelectric development. The decline of the fur trade during the 1930s and 1940s and the opening of the Goose Bay airbase near the mouth of the river in 1941 had a strong influence on the use of the river for trapping (Goudie, 1991).

The entire Churchill River watershed is regarded by local people as holding considerable cultural historical importance. Local families have many stories associated with travel on this river in the past and in recent years. Its lower reaches remain highly valued for their ecological diversity, beauty, and economic and recreational benefits to present and future generations (Blake-Rudkowski pers. comm., 2006).

3.3 Hydroelectric Development in the Watershed

Hydroelectric development within the watershed since the 1950s has been responsible for creating an extensive infrastructure across the landscape, including dams, control structures, roads, towns, transmission lines, and transformer stations (Figure 13). The natural hydrological regimes of innumerable streams, rivers and lakes have been destroyed or changed considerably (Figure 14). The effects of these changes on riparian habitat vary according to the function that any specific portion of the basin has been assigned with relation to the design of the reservoirs and powerhouses.

Some areas are flooded so that water can be conserved for longer-term use, as in the storage reservoirs. Adjacent rivers and lakes have been diverted to increase the water available in these large storage reservoirs. Flows to diverted water bodies may be reduced, or in some cases entirely removed. Certain of the reduced-flow reaches of lakes and rivers are designated as "overflow areas" into which water can be spilled if the reservoirs are too full and the generating station does not have the capacity or demand to use all of the available water. These areas may experience infrequent and unpredictable periodic flooding over the course of many years. Other flooded areas are intended to store water for shorter periods of time, and to maintain consistent water levels or ice cover where they feed into a powerhouse, as with the forebay reservoirs. Finally, the river reaches downstream from a powerhouse are partially regulated, since they receive flow variations that correspond to the patterns of release through the turbines as electricity is generated, in addition to flows from unregulated tributaries.

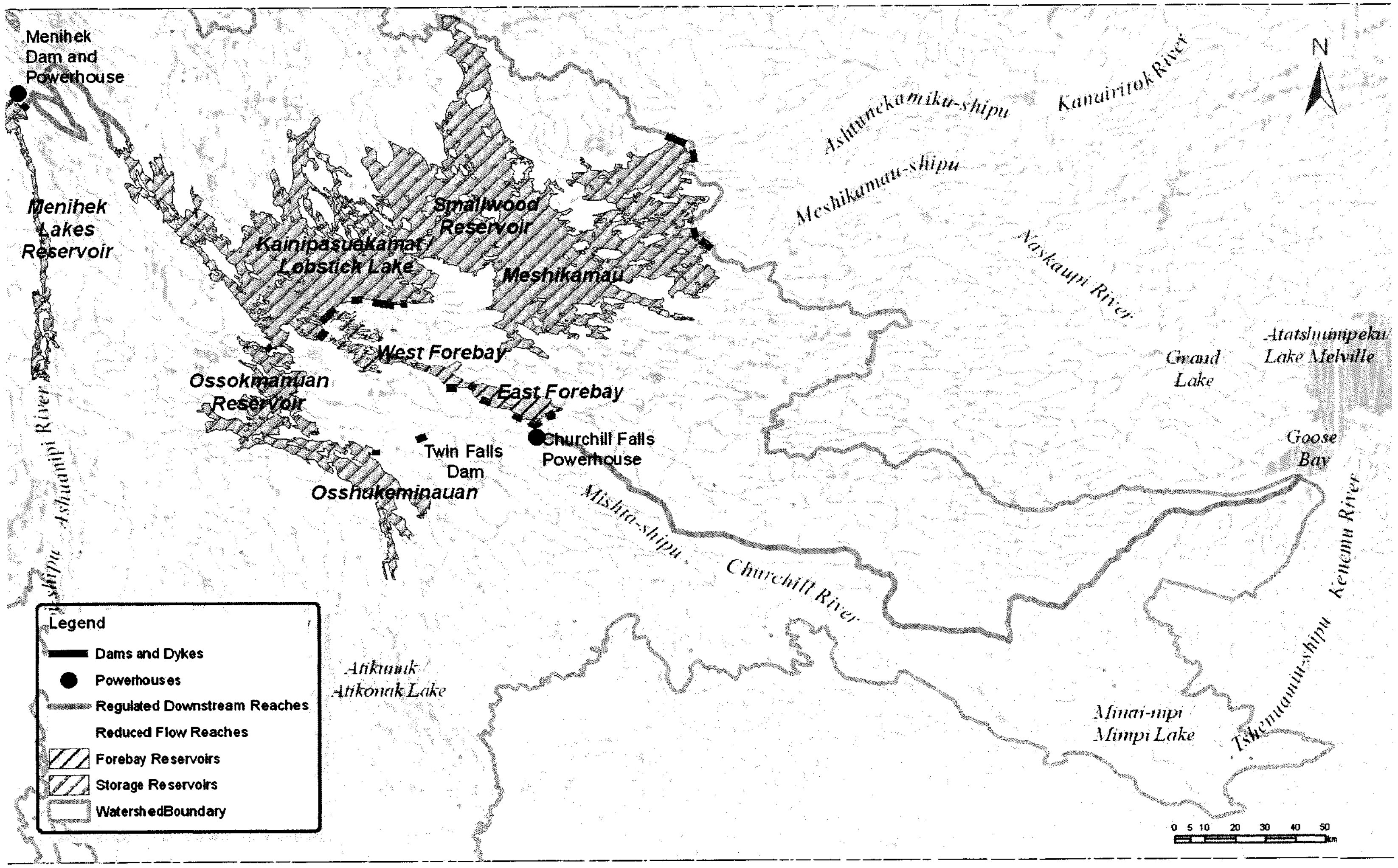

Figure 13. The Menihek and Churchill Falls Hydroelectric Developments. These facilities have created a variety of artificial hydrological regimes throughout the Churchill River watershed and two adjacent rivers. (Map produced on ARC GIS by A.Luttermann. Base map data obtained from: Environmental Systems Research Institute (ESRI); Geogratis; National Topographic Data Base (NTDB), 1:250,000 map sheets)

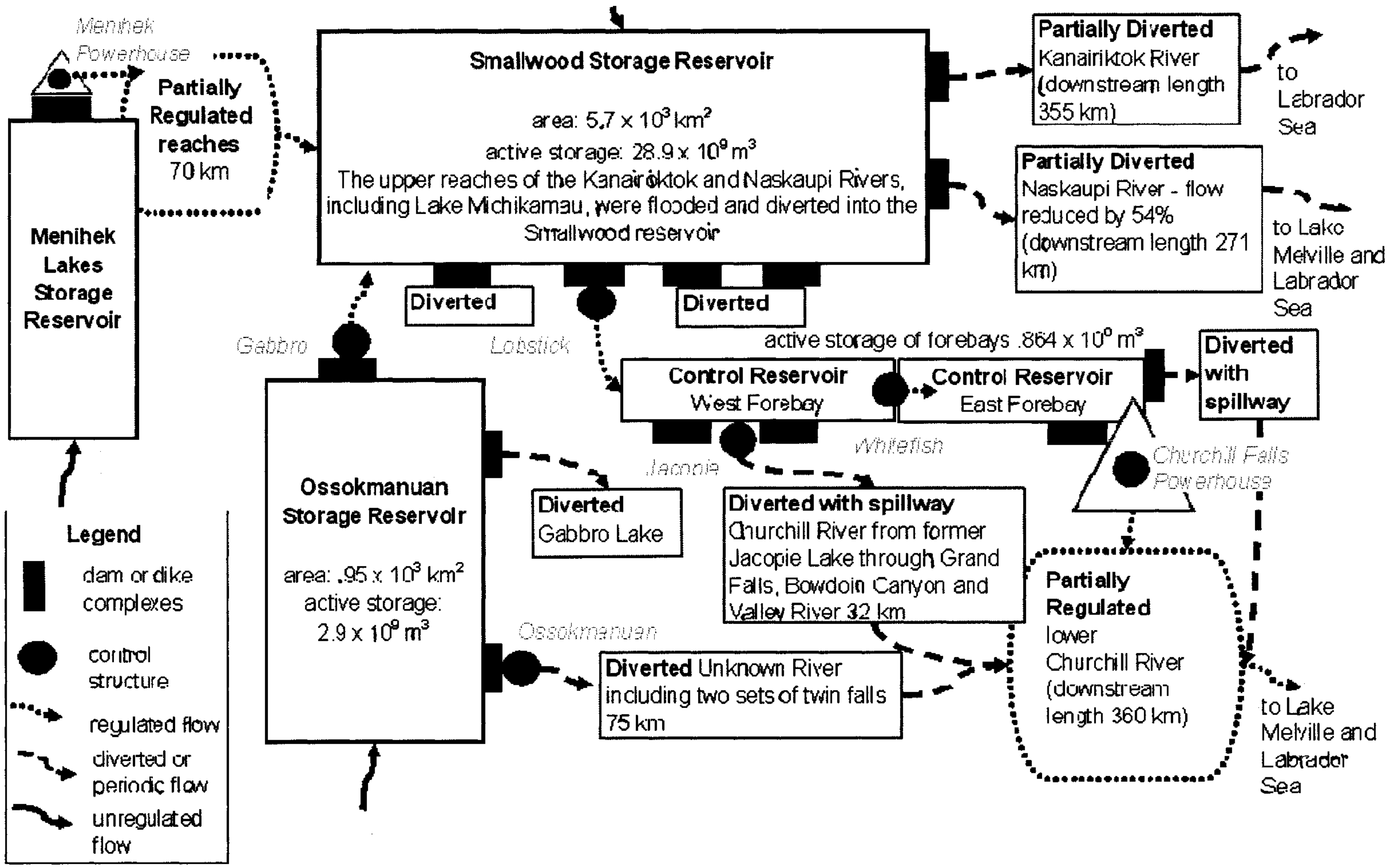

Figure 14. Simplified Diagram of Changes in Flow Regimes Created by Hydroelectric Infrastructure in the Churchill River Watershed (A.Luttermann, 2007).

Although the Churchill Falls development is by far the largest to date in the region, portions of the watershed were regulated prior to that project. The additional effects of the Menihek and Twin Falls generating stations must be considered in any effort to assess the cumulative impacts of hydroelectric development in this drainage basin.

3.3.1 Menihek Power Station

The first hydroelectric power station in Labrador was constructed in 1954 on the Ashuanipi River at the outlet of the Menihek Lakes in the western-most region of the Churchill River watershed (see Figure 13). Menihek Lake was converted to a reservoir storing water behind two dams to supply a 21 MW generating station that controls the drainage from 19.1 x 10^3 km^2 of the upper watershed. The facility was required by the Iron Ore Company of Canada (IOC) to power its mine and town site at Schefferville, Québec. The power station presently only supplies the town site, using less than half of the installed capacity in the winter and approximately 10% in summer (Hilyard pers. comm., 2006). The mine is now powered by the larger electricity grid.

Figure 15 depicts an estimate of the spatial extent of the Menihek Lakes reservoir. An accurate reservoir map is not available at this time as the water level data obtained from the operating company were inconsistent with topographical data.

The Iron Ore Company of Canada conducted an environmental assessment of this facility in the mid-1990s, and has reportedly pursued some remediation measures. The documents related to this work were not made available to me for review. IOC is currently in the process of transferring ownership of this hydroelectric facility to Newfoundland and Labrador Hydro (NLH) and Hydro Québec (Hilyard pers. comm., 2006). NLH plans to operate the facility and sell power to Hydro Québec. The future operating regime of the plant has yet to be determined (Windsor pers. comm., 2006).

I did not make observations of riparian habitat in this portion of the upper Churchill River watershed during my study. Only one site on the Ashuanipi River upstream of the Menihek Lakes reservoir was visited. Field surveys should be conducted in the reservoir and downstream reaches to investigate the structure and species composition of the existing riparian vegetation. Some comments are made in Chapter 5 regarding the potential influence of the Menihek facility on hydrological regimes within the watershed.

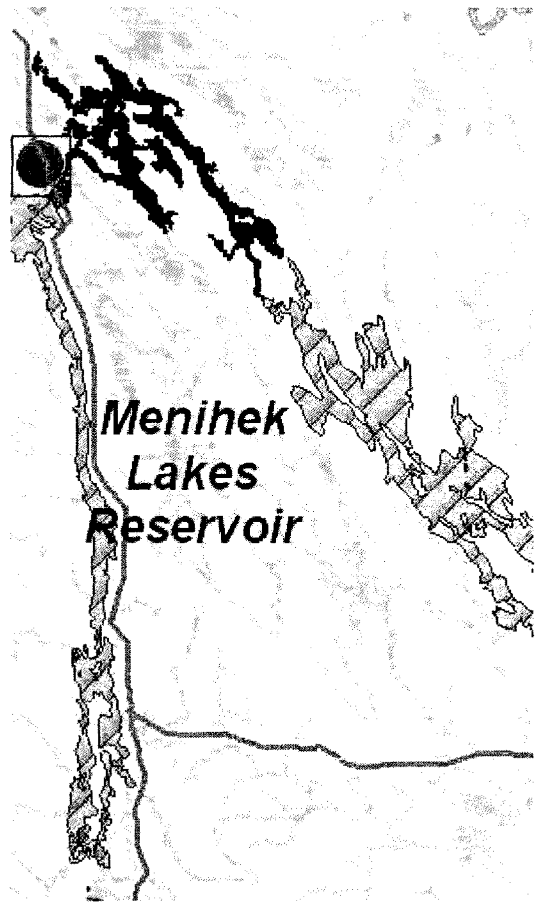

Figure 15. The Menihek Lakes Reservoir. (A detail of the western section of the map in Figure 13). This reservoir controls water levels upstream along the Ashuanipi River, and regulates the flow downstream (dark coloured reaches) until it meets the Smallwood reservoir system. (Map produced in ARC GIS by A.Luttermann. Base map data obtained from: Environmental Systems Research Institute (ESRI); Geogratis; National Topographic Data Base (NTDB), 1:250,000 map sheets).

3.3.2 Twin Falls Power Station

In the early 1960s, the Twin Falls hydroelectric project was constructed to provide power to the developing iron ore mining industry in western Labrador at Labrador City and Wabush. A dam and generating station with a capacity of 225 MW were situated at the upper pair of falls on the Unknown River, a tributary of the Churchill River draining part of the upper watershed (Figure 16 and Figure 17) (Churchill Falls (Labrador) Corporation, 2000).

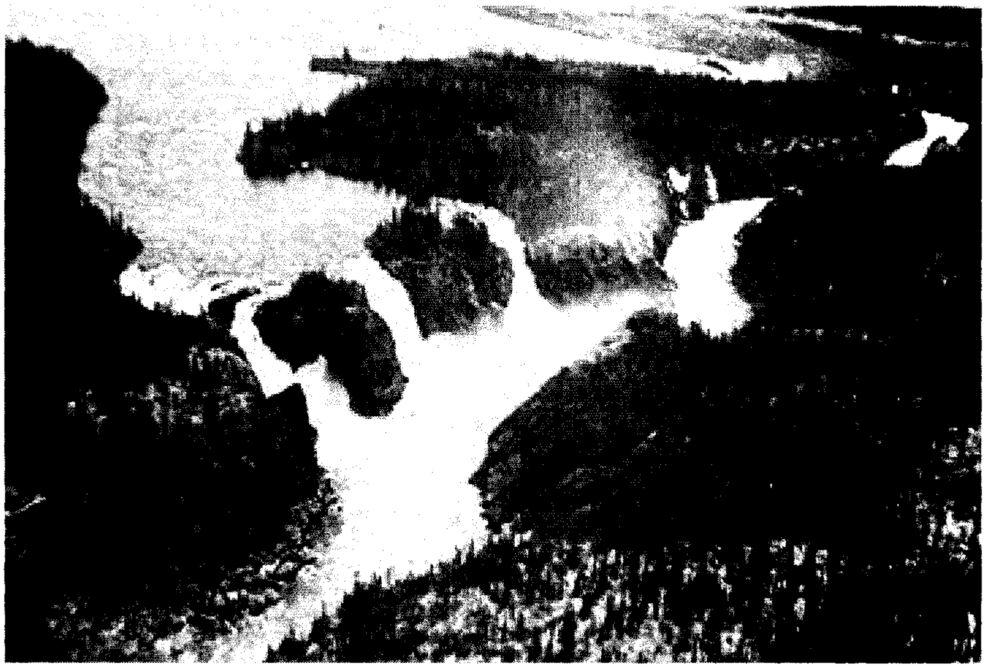

Figure 16. One of Two Sets of Twin Falls on the Unknown River Prior to Damming (Photo: Churchill Falls (Labrador) Corporation, circa 1959).

Figure 17. The Twin Falls Generating Facility on the Unknown River, a Tributary of the Churchill River. This facility is not currently in operation. The entire flow at this junction is diverted into the Ossokmanuan Reservoir (Photo: Churchill Falls (Labrador) Corporation: circa 1964).

Ossokmanuan Lake was flooded to create a large storage reservoir. This impoundment has therefore been in existence about ten years longer than the Smallwood reservoir. Ossokmanuan reservoir has an area of 950 km^2 (Duthie and Ostrofsky, 1975), and an active storage capacity of 2.84 x $10^9 m^3$ (Churchill Falls (Labrador) Corporation, 2000).

In 1974, the hydraulic capacity of the Twin Falls project was incorporated into the Churchill Falls development, as engineers determined that efficiencies in energy production could be attained by diverting the water from Ossokmanuan Reservoir into the Smallwood Reservoir. The flow into the Unknown River was entirely diverted into the Ossokmanuan Reservoir dewatering a reach about 75 km long. The Twin Falls powerhouse was then permanently shut down. However the infrastructure remains in place and there are some outstanding issues regarding contamination of this site (Innu Nation, pers. comm.).

3.3.3 Infrastructure of the Churchill Falls Project

> *When they were talking about damming Churchill Falls, we knew very little about it. There was only very short notice to the* [Innu] *people here about damming the fall.* (Pien Penashue pers. comm., 2001)

Construction of the massive 5,428 MW Churchill Falls hydroelectric project began in 1966. By 1971, the plant was producing its first power and construction was completed in 1974. It was the largest such development in the world at the time, employing 30 thousand people over the course of its construction (McBride, 2001). It now has the second-largest hydroelectric generating capacity in North America, after the Robert Bourassa powerhouse in Québec that was commissioned during the years 1979-1981 with an installed capacity of 5,616 MW. The Churchill Falls project is vast compared with the earlier facilities constructed in Labrador. It resulted in considerable physical alterations to the environment of a large portion of the upper Churchill River basin and the upper watersheds of two adjacent rivers to the north, together comprising much of western and central Labrador.

Many hydroelectric facilities are known by the names of their large dams, for example, the Hoover Dam on the Colorado River, in Nevada, and the W.A.C. Bennett

Dam on the Peace River in British Columbia. Perhaps because there is no single large dam highlighting the centre of the Churchill Falls facility, that project is known by the name of the once thundering falls that were silenced by diversion of their flow for power production. ("Churchill Falls" is in fact a relatively new name given to the falls by governmental proponents of the project just prior to diversion.) The Innu know the falls by two names – *Patshetshunau* (great mist rising), and *Mishta Paushtuk* (big rapids). The former English name, Grand Falls, is still used by many Labradorians.

The town that now exists to operate the hydroelectric facility is also called Churchill Falls. The new town site and several new roads have increased human access to a large portion of central Labrador, which had no roads prior to the advent of this development. A total of 1,538 km of transmission lines delivers the power to local users and to markets to the south in Canada and the U.S.A. (Churchill Falls (Labrador) Corporation, 1991).

3.3.4 Reservoirs

The plateau basin where the reservoirs were formed has been likened to a huge "saucer with a few dents in the edge" where the rivers drained to the east (Gibbons, 1972). The project design involved plugging those notches in the edge of the plateau to allow the collection of water in two large storage reservoirs, and redirecting the flow into two control reservoirs bypassing the main stem of the river, and then on to the generating station (Figure 13). After flowing into the penstocks set into a solid granite cliff, and then passing through the turbines, the water is released back into the main valley of the Churchill River about 32 km downstream of the Jacopie control structure (where the flow of the main stem of the Churchill River was halted). A large portion of the upper reaches of the Churchill River was impounded, along with the drainage from 11.4×10^3 km^2 of the upper watersheds of the Naskaupi River (including Lake Michikamau, which was the largest natural lake in the region) and the Kanairiktok River[14] (Anderson, 1985). These diversions increased the surface area of the drainage from the upper basin by about 14%.

Rather than one large dam, the project design involved building 88 dikes with a total crest length of 64.4 km, an average height of 9 m, and a maximum height of 36 m

[14] The Naskaupi and Kanairiktok rivers are the second and third largest rivers in Labrador.

(Churchill Falls (Labrador) Corporation, 1991). The entire facility should technically be counted as *several* large dams when compiling statistics on the numbers of such structures in the region. The longest dike, at Sail Lake, is 6.04 km in length. A total of 20 x 10^6 m^3 of solid fill was incorporated into these structures. This included glacial till mined from the surrounding area and rock blasted from the solid granite cliff to form the enormous cavern for the powerhouse situated 90 stories down inside the cliff, the tailraces, and the access tunnels.

In total, an area 5.7 x 10^3 km^2 in size was inundated to form the Smallwood Reservoir, which is the largest anthropogenic impoundment in Canada. The area flooded included much of the main stem of the upper Churchill River, hundreds of small lakes and tributary streams, extensive bog and fen wetlands, and spruce forest and tundra. Duthie and Ostrofsky (1975) estimated that about 60% of the area under the Smallwood Reservoir and 75% of the Ossokmanuan Reservoir was formerly comprised of water bodies. The Smallwood Reservoir has an active storage of 28.9 x $10^9 m^3$, which, when combined with the capacity of the Ossokmanuan Reservoir, provides 31.8 x $10^9 m^3$ of active storage capacity. The total area covered by these two large storage reservoirs is about 6.65 x 10^3 km^2.

The watershed of the Naskaupi River, the second largest river in Labrador, was reduced by more than 54% when dikes built for the Churchill Falls project permanently diverted the runoff from 10.6 x 10^3 km^2 of its watershed into the Smallwood Reservoir. This included all of Lake Michikamau, formerly the largest lake in the region. The Naskaupi River now drains an area of 12.7 x 10^3 km^2 (Anderson, 1985). There are no provisions in this system of dikes for spilling water into the Naskaupi River. The river channel is therefore now virtually dry for about 90 km downstream of the dikes as far as Wuchusk Lake (Duthie and Ostrofsky 1975). The Kanairiktok River lost a smaller portion of its drainage area, amounting to about 1.38 x 10^3 km^2. The diversion of these adjacent rivers increased the mean annual flow of the lower Churchill by about 12% (CF(L)Co, 1991).

Figure 18. The Lobstick Control Structure. These gates set into a long dike regulate water releases from the Smallwood reservoir into the forebay reservoirs (Photo: A.Luttermann, 2001).

Six control structures and spillways were constructed to regulate the flow of water through the series of dikes that created the storage and control reservoirs, and through to the intake channel of the power plant. The Lobstick spillway (on what was formerly Lobstick Lake) controls the flow from the Smallwood reservoir into the two forebay reservoirs (Figure 18). The flow there is thus controlled to respond directly to the demand for power generation. The flow of the main stem of the river was diverted at the Jacopie dikes and control structure (Figure 19), about 20 km upstream of the former falls. It therefore no longer flows over the falls or through the canyon. The diverted waters now rejoin the main stem of the original river valley after passing through the turbines of the powerhouse at what is now the town of Churchill Falls.

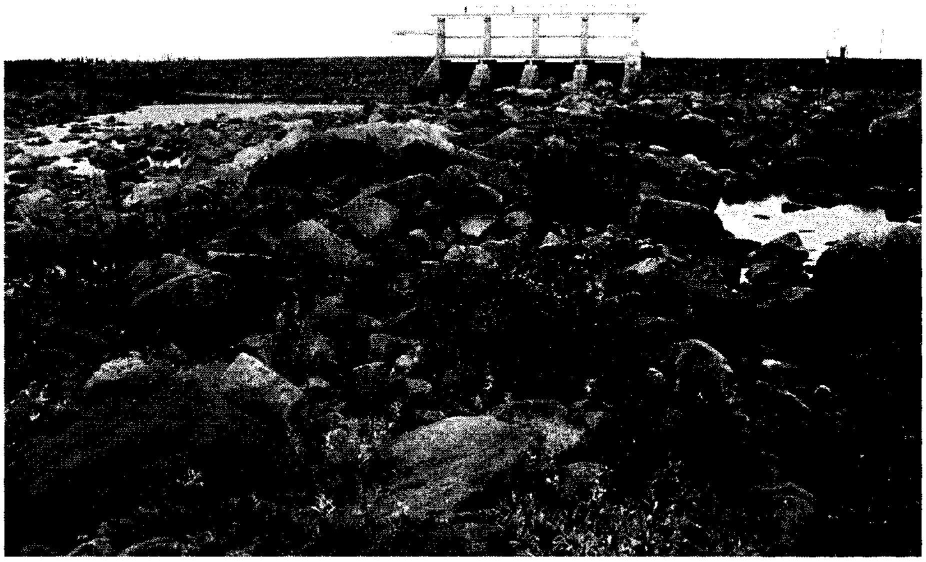

Figure 19. The Jacopie Control Structure. This structure is part of the series of diversion dikes on the main stem of the upper Churchill. It can be used as a spillway to release flow into the main channel and over the falls (Photo: A.Luttermann, 2001).

Figure 20. The Whitefish Control Structure. This spillway and its associated dikes controls flow between the west and east forebay reservoirs (Photo: A.Luttermann, 2001).

The Jacopie structure also acts as a spillway. Should reservoir levels become too high due to extreme precipitation, water can be released into the former river channel above the falls to avoid overtopping the dikes. A similar spillway is situated on the downstream end of the east forebay, where water can be released into the lower river if necessary to protect the dikes and prevent uncontrolled flooding of the town site and surrounding lands.

In addition to illustrating the range of general changes in hydrological patterns throughout the watershed and adjacent affected rivers, my study concentrates some more detailed observations on the characteristics of riparian habitat along various reaches of the main stem of the Churchill River on the upper plateau and in the lower river valley.

Chapter 4. Sources of Information and Research Methods

For this study, several sources of information were used to develop an understanding of the context and scope of past changes in riparian habitats related to flow regulation. Historical documents, hydrometric records, and observations made by knowledgeable local people, supplemented by imagery including ground and aerial photos assisted in constructing a picture of the physical structure and richness of plants in riparian habitats of the main stem of the Churchill River prior to the Churchill Falls development. Field surveys were conducted to investigate the present riparian habitat structure and species richness at specific sites. Interpretations were assisted by the work of others on riparian habitats of the Churchill River (e.g. Beak Hunter, 1978) and other Canadian boreal rivers (FORAMEC, 1992 a,b,c; Church et al., 1997). The results of longer-term research in other boreal regions such as Sweden provided important comparative information (e.g. Nilsson et al., 1997; Jansson et al., 2000; Dynesius et al., 2004). These collective observations can help us to understand some of the changes in riparian vegetation that have occurred in reaches affected by hydrological regulation, and are useful in predicting the effects of additional proposed manipulation of the river.

This study is incomplete in the sense that substantial additional survey work could have been done throughout the watershed of the Churchill River and adjacent rivers to comprehensively describe the floral diversity and ecological functioning of regional riparian habitats. For instance, I was unable to examine changes in riparian habitats in rivers that were subjected to diversions during the construction of the Churchill Falls project (e.g., the Naskaupi, Kanairiktok, Unknown, and Portage Rivers). Many recommendations for further research on this subject are made in section 7.5.

4.1 Riparian Vegetation Response to Flow Regulation in Other Regions

Cumulative effects assessment is often not pursued to any meaningful extent because of a lack of pre-development baseline data in ecosystems with older infrastructure. In addition, substantial resources are required to conduct detailed, long-term studies in all areas affected by large projects. Nevertheless, research conducted in relatively analogous ecosystems can provide valuable information with which to better interpret current observations and make general qualitative predictions regarding changes in habitat structure and species richness.

In my study, relevant research on riparian habitat response to hydrological regulation in other boreal regions was reviewed and discussed in relation to observations of past and current shoreline plants in the main stem of the Churchill River. Dynesius et al. (2004) have shown that riparian plant species richness responds in a similar way to various types of hydrological regulation among river sites surveyed in boreal environments in northern Sweden, Alberta, and British Columbia. These general patterns of change may be comparable to some extent with sites in Labrador along the Churchill River.

4.2 Historical Records of Riparian Habitat

Facing a similar situation with scant pre-development data, studies conducted in the Peace, Athabasca, and Slave River basins for the Northern River Basins Study included a review of archived writings related to environmental change in the region. They examined how these historical documents may enhance physical science study as well as understandings of how the land was viewed in the past by people familiar with it (Crozier, 1996). Likewise, for my study of the Churchill River, historical accounts of travels on the river, Hudson's Bay Company records, and botanical reports available from the decades prior to hydroelectric development were reviewed to determine whether they provide any description of riparian habitat, common or unusual vascular plant species observed along the river banks, or other relevant observations regarding riverine geomorphological processes (i.e. Grenfell et al., 1913; Frissell, 1927; Watkins, 1930; Scott, 1933; Todd, 1939; Tanner, 1947; Gillespie and Wetmore, 1973; Goudie and Whitman, 1987; Goudie, 1991, Meades, 1991). More detailed plant surveys and descriptions of the physical character of the shorelines also exist that were reviewed for information on species presence, distribution, and abundance for general comparison with present conditions (i.e. Low, 1896; Blake, 1953; Abbe, 1955; Brassard et al., 1971).

The earliest written account of the upper portion of the Grand River including the Grand Falls was by John McLean, a factor with the Hudson's Bay Company (Wallace, 1932). Although McLean made detailed notes on his observations of plants in other regions he explored, he did not produce any account of plants along the Grand River. It appears that he and his companions focused their energy on the rigours of the overland journey by foot and canoe in an attempt to establish an overland communications route between trading posts at Hamilton Inlet and Ungava Bay.

Several other travelers visited the region to conduct mapping, document the natural resources, or simply look for adventure (i.e. Frissell, 1927; Watkins, 1930; Scott, 1933). Fewer came specifically to conduct zoological and botanical reconnaissance research, such as the Carnegie Expedition (Abbe, 1955). With the exception of some limited, pre-flooding vegetation surveys in the main storage reservoirs, primarily focused on forest stands (Bajzak and Bruneau, 1987), and an investigation of the spray zone of Churchill Falls prior to the river diversion to document vascular plants and bryophytes (mosses and liverworts)(Brassard et al., 1971; Brassard, 1972), there has been little documentation of the effects of the infrastructure and operation of the existing reservoirs on riparian plant communities. No formal pre- or post-development research or monitoring of the Churchill River has been conducted to describe the specific effects on riparian habitat throughout the watershed.

In the late 1970s, an environmental assessment was conducted for a proposal to build two additional dams – one at Gull Island, and another at Muskrat Falls near the mouth of the Churchill River (Beak and Hunter, 1978). The study area focused only on the main stem of the river flowing through the deep valley downstream of the Churchill Falls generating station. Some work was done to describe riparian habitats in these lower reaches of the river (Lower Churchill Development Corporation Ltd., 1980). The survey was designed to document the species composition and structure of plant communities, including deciduous riparian habitat types, and to make observations about the possible effects of the upstream facilities on the shoreline morphology. Estimates of species richness were limited as the investigation visited only a few and small survey plots.

The larger areas supporting riparian deciduous thickets were mapped using air photos (Beak and Hunter, 1978). Shrub communities were described generally as being present on emerging bars, deltas, banks, or floodplains. Nine field sites in riparian shrub community types were sampled, with six in alder thickets, two in alder/willow, and one in willow. The plot size was approximately 5 square meters and only the commonly occurring species were recorded (Beak and Hunter, 1978). Vascular plants, bryophytes, and lichens were noted. Forty-seven species of vascular plants were documented, along with the percent cover of each using a six-class Braun-Blanquet scale, and a five-class scale of growth habit (Beak and Hunter, 1978). This report acknowledged that the work conducted for the assessment was limited and that not much information was available from earlier reports to characterize riparian habitats. The report concluded that the only terrestrial habitats in danger of local extinction due to project development would be the alder-willow-scrub complexes and poplar groves found in riparian zones. It emphasized that these habitats provide important forage for ungulates, beaver, wintering ptarmigan, and "undoubtedly others" (Beak and Hunter, 1978: 235). The report did not mention fluvial marshes.

No work was done at that time to attempt to characterize changes resulting from the previous hydroelectric development at Churchill Falls on lower reaches of the river or to predict cumulative effects of additional dams.

Until the summer of 2006, when extensive field research was carried out in support of a future environmental assessment of additional dams on the lower river, little work had been done to identify unique habitats that may support rare species along the river course (see Northcott, 1991). The work begun in 2006 is not yet complete, however it will add a great deal to the knowledge of plant diversity in the lower river reaches.

Local residents have described the existence of uncommon plants at certain locations in the river valley (Pien Penashue pers. comm., 2001). Work under the International Biological Program in the early 1970s identified two sites immediately downstream of the proposed dam at Gull Island that hosted the only known occurrence of wood sorrel (*Oxalis acetosella L. subsp. montana (Raf.) Hultén*) in Labrador, and is the northernmost record of this species (Northland Associates, 1979). One of these sites has been destroyed, possibly due to increased ice scour from higher winter flows released from the Churchill Falls power station (author's field observations, August 2001). The 2006 field team observed additional populations of this species in the river valley.

Studies of breeding waterfowl densities in the reservoir areas include relevant observations of the structure of shoreline vegetation, habitat quality, and suggestions regarding the effects of regulation in the reservoirs (i.e. Keast, 1971, 1973, 1975; Gillespie and Whetmore, 1973; Goudie and Whitman, 1987).

In 1939, Margaret T. Doutt collected and identified vascular plants from several riparian sites along the Churchill River, from its mouth to Sandgirt Lake, during a field survey for the Carnegie Museum (Abbe, 1955). Her work was described as the first relatively thorough botanical investigation along the transect formed by the river valley into the interior (Abbe, 1955). Observations were also made by other researchers in Doutt's party on avifauna and mammals (Todd, 1939). There are no other well-documented and relatively comprehensive surveys of riparian vegetation along this river prior to the Churchill Falls hydroelectric development. Doutt's survey was a reconnaissance and did not delineate plots or focus on riparian habitats in particular. However, her field notes do provide detailed descriptions of the geographical locations and habitat types along the river shorelines where she made collections.

Those observations remain some of the most detailed and useful for comparison with present conditions. Publication of Doutt's observations (Abbe, 1955) was accompanied by lists of vascular plants from some limited earlier inventories. These included Wetmore (1923) and Wenner (1947), whose work extended a short distance up the river to Muskrat Falls. Kindle (1924), Abbe (1936), and Hustich and Petersson (1944) published lists of plants from the Lake Melville area and offered descriptions of the general features of the vegetation in the Lake Melville-Hamilton Inlet area. Doutt's observations are reviewed and compared with post-development observations. There are species that were observed frequently in Doutt's survey that were not observed in the survey conducted for my study. However, given that riparian habitats are continually changing due to the dynamic nature of fluvial geomorphology, valid studies of changes in riparian biodiversity must involve surveys of numerous sites along any given river to compile a sufficient sample of a broad range of typical and unique habitat types.

Journals were consulted from Hudson's Bay Company trading posts that operated at Lake Michikamau 1845-1849, Fort Naskaupi 1842-1869, and Lake Winokapau 1863-1874. The managers of the posts were required to keep journals that included certain types of information requested by the Company. This was mainly restricted to information that affected trade such as: numbers of furbearing animals trapped by post employees and brought in by the aboriginal hunters; fish and game captured to provision the men operating the posts; work carried out on a day-to-day basis; and factors affecting travel such as weather conditions and times of freeze-up and break-up of water bodies used as travel routes. Some post managers included more detail than others of observations such as the arrival and departure of migrant songbirds. These journals are available on microfilm from the Hudson's Bay Archives in Manitoba. Unfortunately, some sections are not legible including much of the material from the Michikamau House Post. However, some useful observations can be gleaned from the Winokapau Post journals. This was an outpost of the Northwest River Post located on an island at the upstream end of Lake Winokapau. Observations such as the rising and falling of the river water levels, timing of fall freeze-up and spring break-up, ice flows down the river, and numbers and locations of animals and birds observed or caught in the vicinity of the Post provide some indication of the ecological conditions during those years along river shorelines.

Such information can only be used in a general sense for comparison with post-development conditions along the river, because riparian habitats are dynamic and may change rapidly in any one location due to the influence of the natural disturbance cycles of seasonal and extreme floods, erosion and deposition of sediments. Other potential factors such as climate change can affect water levels and directly influence the character of riparian habitats. In the absence of any specific baseline data for riparian vegetation in the lower reaches of the river, and minimal surveys in the flooded plateau region, any pertinent archival records may provide useful insight into the character of the river in recent history.

4.3 Local Ecological Knowledge and Current Perspectives on Changes in Land Use

4.3.1 Archival Material

Some transcripts exist from the late 1970s of interviews with Innu who had spent time in areas flooded by the Smallwood and Ossokmanuan reservoirs (Innu Nation, unpublished material). Several Innu and Metis participated in the first environmental assessment review process for the lower Churchill development proposals and their comments are documented in the summary of the review panel hearings. Peter Armitage and Pien Gregoire conducted an interview with elder Joe Nuna in 1993. People described generally how the hydroelectric project had affected them and their families through the intrusion on their land base by the construction activities, permanent infrastructure, and extensive flooding for the large reservoirs. The importance of the project to Innu people's use of the entire Churchill River watershed was addressed. Those comments provide important perspectives on how changes in land use, culture, and environmental knowledge were perceived to have been influenced in part by hydroelectric development.

4.3.2 Innu Nation Community Consultations on Hydroelectric Development in Nitassinan

Between 1998 and 2002, while developing the focus for my study and conducting research, I worked on contract with the Innu Nation. Innu Nation is the organization representing the Labrador Innu communities of Sheshatshiu and Utshimassits (now moved to Natuashish) on land rights and resource management issues. Funding was provided by Newfoundland and Labrador Hydro (NLH) to allow Innu Nation to review recent baseline environmental research reports contracted by the company, provide advice on the direction of the environmental research program, and conduct two community-wide consultation programs to gather perspectives and share information related to hydroelectric development on the Churchill River in Nitassinan. My role in this work included working as coordinator for community consultations, along with Camille Fouillard for the first phase, and acting as a representative for the Innu Nation on the review of environmental baseline research. It was understood by all parties that my involvement in the work would contribute to the development and substance of my doctoral thesis.

Community consultations were held in Sheshatshiu and Utshimassits from March to July, 2000, and from November 2000 to November 2001. As coordinator, I worked with eight Innu commissioners conducting personal interviews with community members and assisting community members with the interpretation and discussion of the observed and known potential environmental effects of proposed hydroelectric projects in the context of community planning. We held large and small group workshops, focus group meetings, camp visits, individual interviews, and group trips to hydroelectric sites in Labrador (Churchill Falls Project) and Québec (La Grande Projet, Manic 5 and Sainte

Marguerite).

Together with Innu elders and other community members, we worked on developing ways to translate and illustrate various elements of hydroelectric construction and landscape changes for general comprehension and discussion among community members. In small groups, we visited some potential field sites in the upper watershed, including flooded areas, dewatered sections of the river and forebay reservoirs, and canoed most of the remaining main stem of the river with three Innu families. We visited the Churchill Falls generating station and other infrastructure in the surrounding area. We also traveled as a group to view Hydro-Québec projects in other parts of the region – Sainte Marguerite III and La Grande. During these excursions, we visited and discussed the general issues and proposed study with Innu living in Québec, some of whom spent time on the Churchill River in their younger days. Some Québec Innu still travel to the Churchill River on hunting trips.

During the first phase of the community consultations on the effects of hydroelectric development, a total of 71 people in the communities of Sheshatshiu and Utshimassits participated in personal interviews. Six additional people submitted written responses to a list of questions on their perspectives regarding past and future hydroelectric development in Nitassinan. Participants ranged in age as follows: 17 aged 15-29; 38 aged 30-45; 43 aged 46-65; and 20 over 65. Of these, 57 were men and 61 were women. A total of 238 people from the two communities participated in various consultation activities ranging from kitchen meetings to information sessions, small group workshops and larger community workshops. In the second phase of the consultations, 46 women and 73 men participated in workshops, meetings and interviews. The results of the consultations are presented in two reports (Innu Nation Hydro Community Consultation Team 2000, 2001). The population of the two Labrador Innu communities totals about 2100 with more than 40% under the age of 16.

In the early phases of the broader community consultation processes, we identified topic areas where there is a lack of documentation of ecological and social changes relevant to the assessment of further hydroelectric projects in the region. Community members repeatedly insisted that a better understanding and consideration of the specific effects of the existing Churchill Falls project was necessary before proceeding with planning for any new developments. Changes in riparian habitats were identified by several people, particularly the elders, as a prominent effect of such developments, and an issue that had received insufficient attention in previous research. We therefore arranged to conduct additional discussions focused on riparian habitats.

4.3.3 Discussions with Local Inuit-Metis

Prior to finalizing the focus of this study on changes in riparian habitats, I also discussed some of the questions and the purpose of the planned research with several Metis trappers who know the river well, and inquired if they would be interested in participating in personal interviews. Inuit-Metis trappers and Innu who traveled and lived along various sections of the river prior to the Churchill Falls development have described what the shorelines were like from their memory. Horace Goudie, for example, trapped up to the Height of Land in the northwest corner of Lobstick Lake and on the Mackenzie River as a young man with his father, and later had his own trap line until 1941 when the airbase was being built at Goose Bay (Goudie, 1991). He continued to trap on the lower Grand River up until the 1980's, and has traveled there since then, guiding other people (Goudie, pers. comm., 2002). He has spent a good deal of time on the river over the years as an experienced trapper and paddler, and is a keen observer. He is the only Metis/Inuit elder now left who used to trap up above the height of land years ago prior to the hydroelectric developments. Trappers would usually travel up the river in the fall and back down in the spring before the ice broke up. The length of the lower river would have been observed most often in autumn when water levels were relatively high. However, Horace Goudie has also spent time on the river during other seasons. His observations contribute a great deal to this study.

Following a phone conversation with Horace Goudie in 2002, two interviews were held with him at his home in Happy Valley in April 2002 and March 2005. Also in March 2005, an in-depth interview was held with Horace's younger brother Joe Goudie at his place of work.

4.3.4 Interview Methodology

To explore our focus on historical changes in riparian habitats for this study, additional in-depth interviews were held with a small number of elders who were most familiar with the ecological character of the river shorelines before and after the hydroelectric development. These included Innu and Metis residents from the Innu community of Sheshatshiu, and Metis living in Happy Valley-Goose Bay and Northwest River. Discussions were focused on observations that local people have made of shoreline habitats based on their own time spent in areas now affected by the Churchill Falls hydro development - upstream and downstream of the generating station. We also discussed the significance that changes in the river's landscape and ecology holds for them in general.

Prior to commencing interviews, the research proposal was reviewed and approved by the Innu Nation and the Dalhousie University Social Sciences Research Ethics Board. All participants were asked to sign a consent form, written either in English or Innu-aimun that explained the objectives and methods of the research. (See Appendices A and B). In the case of some participants who were not able to read, the consent forms were read to them. One copy was retained by the principal investigator and one copy was left with each participant. In some cases, participants requested copies in English and Innu-aimun.

The work with Innu elders was conducted with three Innu co-researchers, Pien Nuna, Elizabeth Tshaukuesh Penashue, and Rose Gregoire, all residents of Sheshatshiu. They assisted in coordinating and facilitating meetings, and holding individual interviews and group discussions in Innu-aimun with translation.

Interviews were structured as semi-directive with open-ended questions (Huntington, 2000). (See Appendix C for Interview Guide). The initial questions were quite broad and included the following:

1. What did the shorelines in different parts of the river look like in the past, before the Churchill Falls development?
2. What kinds of plants and animals were found there in the past?
3. What do the shorelines look like now and what changes, if any, you have noticed in the plants and animals live there now?
4. How do you feel about the changes that have happened in the past and those that might happen in the future if more dams are built?

The principal investigator and co-researchers asked many additional exploratory questions based on the responses of the participants. Maps were consulted with those participants who were comfortable with them. As the discussions progressed, we looked at photographs of the river taken in recent years to explore in more detail any comments that individuals may have had about particular areas or phenomena.

Notes were taken during all interviews by hand. With the consent of participants, digital audio-recordings were also made of all individual interviews but one. Following the interviews, transcripts were typed and copies sent to participants. In some cases, copies of the audiotapes were also made for participants.

Many observations were also shared during informal discussions and work together. When traveling the lower river by canoe to conduct the vegetation survey, I was accompanied and assisted by a group of six Innu including Richard and Pien Nuna, Francis and Elizabeth Penashue, and Daniel Ashini, as well as my thesis supervisor Dr. Bill Freedman from Dalhousie University, his daughter Rachael Freedman and Todd Keith. Several visits were made with Innu colleagues and elders to various river and reservoir sites by road. In addition, informal discussions were held with elders from the Québec Innu communities of Uashat and Maliotenam who spent time on the Churchill River in their younger days. These discussions took place during visits to the homes of three elder women along with Elizabeth Penashue from Sheshatshiu.

The work was designed be participatory in nature (see Bill et al., 1996; McDonald et al., 1997; Huntington, 2000). Participants were involved in determining research needs, assisting in collecting botanical data, interpreting results, and planning action based on the findings. The use of a participatory research model is intended to contribute to an ongoing learning process for everyone involved. The philosophy of the research process is that it be "enriching" as opposed to merely "extractive "(Grenier, 1998). In other words, the conduct of the research itself can serve to enhance a dialectical process of inquiry and reflection among researchers and participants. Effort was made to integrate learning opportunities into the work with co-researchers and participants. There was a continual effort to share ideas as we carried on the research, including openness about the ways in which different types of knowledge are generated and interpreted, as well as the various limitations they may have. Discussions about our collective local knowledge of changes in the river, and increased opportunities to spend time on the river, are all important to learning about the ecology of the land and participating in decisions affecting its future.

4.4 Hydrological Records

A network of hydrometric stations in the Churchill River basin and adjacent watersheds has recorded stream flow or water level data for various periods of time (Figure 21). The stations were established primarily to investigate the viability of power developments and to meet the needs of engineering studies and management of the existing hydroelectric facilities. Therefore, the data recorded are not necessarily comprehensive for the purposes of environmental assessment. In addition, the data sets for stream flow at several stations are incomplete and/or possibly inaccurate due to discontinuous collection, equipment failure, ice conditions, or other problems. Nevertheless, they provide a good deal of information that is useful for examining flow patterns pre-and post development, and for interpreting the possible effects of flow regulation on riparian zones.

The flow data are compiled and held by the Water Survey of Canada (WSC), an agency to Environment Canada. Additional water level data for the reservoirs, and discharge data for control structures associated with the Churchill Falls project, are recorded and held by the Churchill Falls (Labrador) Corporation (CF(L)Co). Table 2 lists the data sets that were provided by these organizations and consulted for this study.

In order to compare flow patterns before and after development of the various hydroelectric facilities in the watershed, data that represent daily, seasonal and annual flow patterns in different reaches of the river were extracted for analysis. Hydrographs were produced to illustrate trends in these patterns, including the incidence of extreme flooding events and unusual dry periods. These were then compared with the observations of riparian vegetation, shoreline morphology, and geomorphological processes.

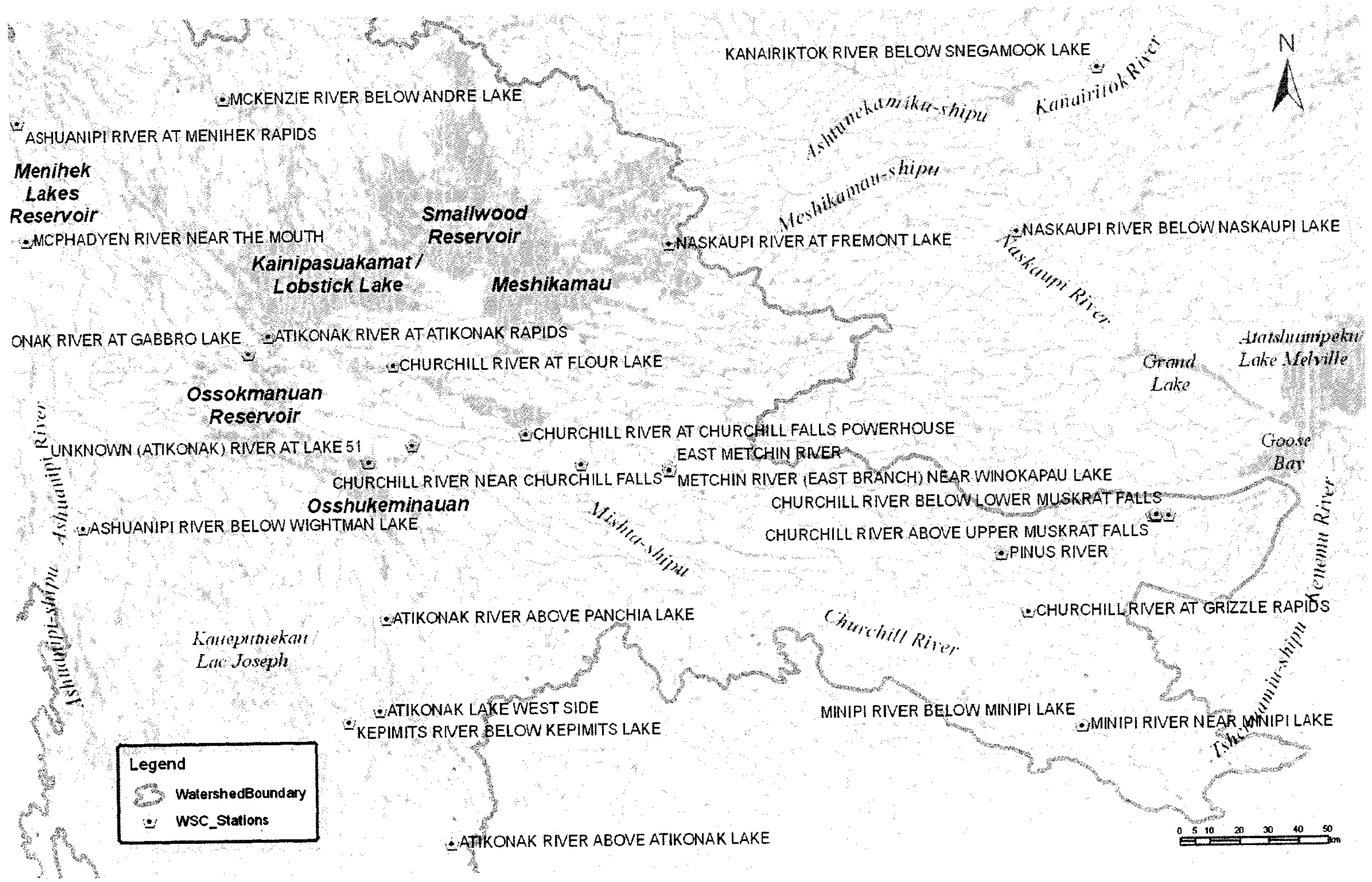

Figure 21. Location of Hydrometric Stations in the Churchill River Watershed and Adjacent Rivers (Map produced on ARC GIS by A.Luttermann. Data obtained from: Environmental Systems Research Institute (ESRI); Geogratis; National Topographic Data Base (NTDB), 1:250,000 map sheets; Water Survey of Canada archives; Churchill Falls (Labrador) Corporation).

Table 2. Hydrometric Stations in the Churchill River Watershed and Adjacent Drainage Basins

Hydrometric Station Name and Number	Latitude and Longitude	Drainage Area	Period of Record (as of 2005)	Gauge Type
ASHUANIPI RIVER AT MENIHEK RAPIDS (03OA001)	54°27'18" N 66°37'30" W	19.0 x 10^3 km^2	1952 – present 53 years	flow
ASHUANIPI RIVER BELOW WIGHTMAN LAKE (03OA004)	53°13'40" N 66°12'24" W	8.3 x 10^3 km^2	1972 – 1983 12 years	flow
ATIKONAK RIVER ABOVE ATIKONAK LAKE (03OC005)	52°17'9" N 64°19'33" W	3.68 x 10^3 km^2	1999 – present 14 years	flow
ATIKONAK LAKE WEST SIDE (03OC007)	52°41'16" N 64°41'22" W	N/A	1998 – 2000 3 years	level
ATIKONAK RIVER ABOVE PANCHIA LAKE (03OC003)	52°58'10" N 64°39'44" W	15.1 x 10^3 km^2	1972 – 1983 1998 – present 19 years	flow
ATIKONAK RIVER AT GABBRO LAKE (03OC006)	53°46'20" N 65°23'47" W	21.4 x 10^3 km^2	1973 – present 32 years	flow
ATIKONAK RIVER AT OSSOKMANUAN LAKE CONTROL STRUCTURE (03OD006)	53°26'53" N 64°46'9" W	No data	1977 – 2004 28 years	flow
CHURCHILL RIVER AT CHURCHILL FALLS POWERHOUSE (03OD005)	53°32'10" N 63°57'51" W	6.92 x 10^3 km^2	1972 – present 33 years	flow
CHURCHILL RIVER AT FLOUR LAKE (03OB002)	53°44'42" N 64°38'24" W	3.39 x 10^3 km^2	1955 – 1971 17 years	flow
KEPIMITS RIVER BELOW KEPIMITS LAKE (03OC004)	52°39'12" N 64°50'45" W	7.07 x 10^3 km^2	1972 – 2000 13 years	flow
MCKENZIE RIVER BELOW ANDRE LAKE (03OB003)	54°32'50" N 65°33'8" W	1.04 x 10^3 km^2	1972 – 1975 4 years	flow
MCPHADYEN RIVER NEAR THE MOUTH (03OA003)	54°5'52" N 66°33'32" W	3.6 x 10^3 km^2	1972 – 1982 10 years	flow
MENIHEK LAKE AT MENIHEK RAPIDS GENERATING STATION (03OA002)	54°27'18" N 66°37'30" W	No data	1955 – 1967 13 years	flow
NASKAUPI RIVER BELOW NASKAUPI LAKE (03PB002)	54°7'54" N 61°25'45" W	4.48 x 10^3 km^2	1978 – 2004 26 years	flow
UNKNOWN (ATIKONAK) RIVER AT TWIN FALLS (03OD002)	53°30'0" N 64°32'7" W	22.8 x 10^3 km^2	1962 - 1976 15 years	flow

4.5 Riparian Vegetation Survey

A survey of riparian vegetation was conducted along the main stem of the Churchill River in 2001 to document patterns of plant species richness and habitat structure. These data can be compared in a general qualitative manner with observations from the pre-development river shores. They can also assist in monitoring riparian habitat into the future. As will be discussed in more detail in the last chapter, additional sites must be surveyed in order to develop a more valid statistical analysis of the relationships between site variables, including several geomorphological characteristics, hydrological regime, and species richness and habitat structure. More comprehensive habitat mapping should also be pursued along this river and adjacent rivers, lakes, and streams.

As mentioned previously, no baseline riparian vegetation data were collected along the main stem of the river prior to the Churchill Falls development. In similar situations in Sweden, it has been shown that adjacent free-flowing rivers can be used as proxies for pre-regulated conditions in rivers with dams (Jansson et al., 2000). However, the rivers compared in those studies were more similar in character to one another than any other rivers in Labrador can compare to the Churchill. There are no other rivers that flow through similar biogeographical areas, or are of the same order of magnitude in size as the Churchill in terms of either flow or catchment area. As will be discussed later in this paper, riparian surveys should be conducted on the larger, unregulated rivers in Labrador such as the Kenemu for general comparison. However, it would not be valid to use these rivers as reference sites for direct qualitative or statistical analysis.

4.5.1 Site Selection

Some of the objectives of this study are similar to those of several studies conducted by the landscape ecology group at the University of Umeå in Sweden. Researchers there have explored changes in vascular plant species richness and structure in the riparian zones of boreal rivers subject to flow regulation for close to three decades (Nilsson, 1983; Nilsson et al., 1989; Nilsson et al., 1991a; Nilsson and Jansson, 1995; Jansson et al., 2000; Dynesius et al., 2004). The sampling strategy employed in my study closely followed the methodology employed by this group (i.e. Nilsson et al., 1989) for determining patterns of plant species richness in different sections of boreal rivers. It was also chosen in order to increase the comparability of the data from this river with long-term studies conducted in similar regions in the future (Dynesius et al., 2004).

The generation of comparable data from other boreal regions can be useful to develop broader analyses of the effects of river regulation on boreal riparian habitats. Some of the data collected during my survey have not been utilized in the current report, but should be useful in the future for analysis along with additional survey work.

In this study, I focused on the active seasonally flooded zones along the main stem of the Churchill River that are clearly structurally distinct from the forest. It has been suggested by Lewis (1996), for example, that the extent of the 100-year recurrence intervals for floods should be used to define riparian zones, especially in larger rivers. Due to the deposition of relatively rich sediment and the introduction of water-dispersed propagules, forested areas bordering the riparian shrub zones may host a greater diversity of plants than upslope areas that are never flooded. To test this idea, further study of the Churchill River riparian habitat should be extended to those areas that may have been historically flooded at infrequent intervals, as well as beyond them to upslope areas for comparison. Furthermore, while some definitions of riparian zones may include aquatic vegetation, this study did not examine submerged aquatic plants, aside from some species that may have been sampled from within the riparian zone at or above the low water level at the time of the survey.

The intent of the 2001 survey was to sample the maximum heterogeneity of the riparian vegetation along the main stem of the river within the constraints of one field season. The sampling strategy involved choosing a 200-meter-long section of riverbank at various places along the length of the river. Scoping for the range of general habitat types was done during a prior canoe trip down the lower river, visits to reservoir sites on the upper plateau, and consultation of recent aerial photography.[15] Some sites surveyed were entire sand bars, or tributary deltas that were approximately 200 meters long. Thirty-four sites were surveyed (Figure 22). The large survey plot size increases the likelihood that most vascular plants growing in the riparian zone will be encountered

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[15] Aerial photograhy of the lower reaches of the Churchill River was flown in 1998, as contracted by Newfoundland and Labrador Hydro. These images are not currently available to the public. The author was able to consult a sample of them during work with the Innu Nation.

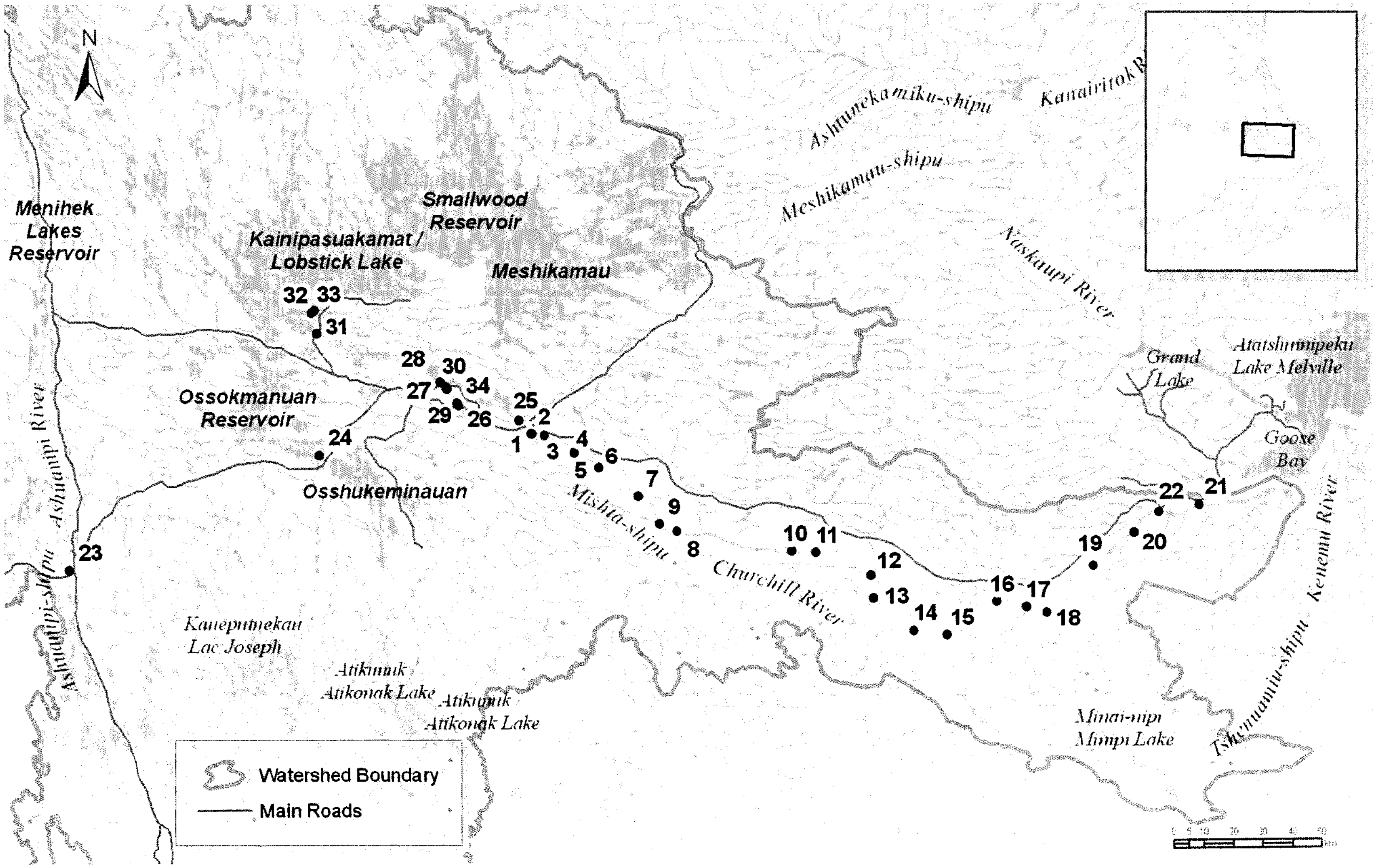

Figure 22. Location of Sites Surveyed in Summer 2001. (Map produced on ARC GIS by A.Luttermann. Data obtained from: Environmental Systems Research Institute (ESRI); Geogratis; National Topographic Data Base (NTDB), 1:250,000).

(Nilsson, 1983). The riparian vegetation survey was carried out in July, August, and early September of 2001. All sites along the lower river reaches downstream of the Churchill Falls tailraces were accessed by canoe. Three of those sites could be easily accessed in future by road followed by a short hike on foot. Some reservoir and dewatered sites were accessed by road near hydroelectric installations. Other sites on the Smallwood reservoir were visited by sea kayak.

A large proportion of the upper reaches of the river on the plateau has been flooded by the storage reservoirs. The previous course of the main stem of the river is more difficult to trace in the upper reaches as it did not follow a single channel, and all that remains of the original topography are hilltops that are now islands. (See description by A.P. Low in Section 5.2). However, study sites chosen in the forebays and reservoirs corresponded roughly to the location of the former main river channel prior to flooding, based on pre-development maps and air photos. This was done in order to ensure a high probability of availability of propagules from the former main stem riparian habitats on the new shorelines in flooded areas.

Sampling locations along various river reaches were not chosen randomly, but rather with the intent of encountering a diversity of vegetation communities present, and adequately sampling a number of reaches with the most typical superficial characteristics. The sites differed in substrate, slope, aspect, river flow, and proximity to tributaries. Choice of sites was also partially opportunistic depending on timing, weather, and where we were able to land in the canoes. In some cases, it was related to sites that were favoured by locals as spots for camping, hunting, fishing, rest stops, or portages. These places would be most likely to have been known and used by travelers prior to the Churchill Falls hydroelectric development. Many of these traditional sites are well used and culturally important to Innu and settlers in the region. A couple of unique sites were surveyed, including "Oxalis or Fred's Island" and the Churchill Falls former spray zone, in order to compare the vegetation with previous botanical surveys.

The Swedish studies primarily chose the south-facing, north banks of rivers for consistency, accessibility, and with the assumption that plant growth on these slopes would be the most productive and species rich (Jansson et al., 2000). However, I did not exclude the south side of the river because I was also looking for potentially rare habitats and species. In addition, in examining geological mapping of the river valley, I noted two small isolated occurrences of dolomitic marble (uncommon in Labrador) on the south side of the river (Wardle et al., 1997). These areas could potentially create microhabitats favorable to less common calcicoles (plants found on or limited to soils with high calcium carbonate).

Jansson et al. (2000) analyzed plant data from riparian zones sampled along eight rivers in the boreal-coniferous zone of northern Sweden. Each site was sampled once. They argued that because >90% of the plant species are perennial, the differences between years in species would be relatively small. However, subsequent studies have reported that species richness along individual river reaches can be reduced following extreme flood events (Renöfält, 2004; Renöfält et al., 2007). Multi-year sampling would therefore be preferable to develop a better understanding of species richness along a river.

Relatively few sites were surveyed in the storage reservoirs, forebays, or diverted reaches. For these reasons and others, the data collected are not adequate for future statistical analysis to examine long-term change or effects after any future dam construction. Additional 200 m-long randomly chosen sites could be surveyed in future along all river sections and particularly in the reservoirs in order to increase knowledge of the floral and riparian habitat diversity and representativeness of the samples. Additional data would also increase the validity of general qualitative comparisons with adjacent rivers and studies from other regions (see below for discussion of future research needs).

Only four sites were sampled in the Ossokmanuan and Smallwood main storage reservoirs, one in each of the forebay reservoirs, three in diverted reaches, and one unregulated site upstream. The lower section of the Churchill River below the tailraces of the generating station is 334 km long[16]. Twenty-two sites were surveyed in the reaches downstream of the Churchill Falls tailraces.

Above the tailraces is Bowdoin Canyon, a 30-km reach stretching to the base of the falls. This cuts through a deep, rocky gorge that is difficult to access. Riparian habitat would have been scarce to non-existent prior to development due to the sheer rock walls

[16] This is the length if you measure down the middle of the channel. The length by meander, which is more relevant to riparian habitat complexity, is about 564 km. The latter measure would be more valid to use in choosing sample sites. However, an even finer scale may be defensible. This question requires further resolution.

and velocity of the water. However, if possible, some sites should be sampled along this diverted reach in the future to investigate vegetation growing on the canyon walls.

One site was also surveyed in the former spray zone of Churchill Falls, corresponding roughly to plots sampled there in 1971, immediately following the initial diversion (Brassard, 1971). Those earlier studies were most interested in bryophytes in the spray zone that would have been affected by the drier conditions after the falls were diverted. However, vascular plants were also inventoried. This is a unique site among the others, and is useful for comparison with pre-development data.

Observations of any additional species made at campsites and other stopping points along the river were recorded to increase understanding of the species richness along the river.

4.5.2 Variables Recorded at Each Site

At each site, a GPS reading was recorded at the low-water mark in the center of the plot using a hand-held Garmin 12. Accuracy of the readings is considered to be within 10 –15 meters. From the central point, 100 meter-long stretches were measured in each direction along the shoreline and marked temporarily.

At least three photographs were taken of each site, a general description of the site was made in relation to landmarks, and adjacent forest cover was recorded (see Table 6). General site variables recorded included: distance from mouth, elevation, type of hydrological regime, channel width, a qualitative value for relative river flow velocity, average riparian zone width and height, aspect, qualitative value for relative slope, and % cover of substrate types, substrate heterogeneity and substrate fineness (See Appendix D for definitions of variables).

To document species richness and vegetation structure, all sites in the lower reaches of the river were searched thoroughly by two, three or more persons. Reservoir sites were searched only by the principal investigator, which may introduce some bias into the data (Nilsson, 1992b). However, the reservoir sites were generally low in cover and species richness and thus much easier to survey. Innu participating in the survey trips assisted in searching the sites, examining and discussing what was found, comparing knowledge of plants and observations of the species along other Labrador rivers or upland areas.

All vascular plant species observed in the sites between the high-water level, and the lowest summer water level were recorded (Nilsson, 1983; Nilsson et al., 1989). This habitat is generally available for plant growth in free-flowing rivers unless the substrate is too coarse (i.e. bedrock). High-water levels were determined by observing the presence of a continuous upland forest floor turf (bryophyte mats), and/or the transition to predominantly forest floor vegetation and soils, evidence of ice scour, upper levels of bank erosion, and deposition of water transported material (drift lines).

As observed by Dynesius et al. (2004), upland vegetation is generally species poor compared to riparian zones, therefore it is not critical to make a precise determination of the limits of the riparian zones. The lower limit of the zones was measured at the current water level at the time of the survey, although any submerged aquatics and emergent species were recorded as observed near the waterline. In the storage and western forebay reservoirs in particular there were often submerged grasses and sedges along the water's edge because the water levels often rise and fall rapidly during the summer months. All species encountered were recorded regardless of their size or life history stage (Dynesius et al., 2004). Vouchers of all species were collected, including multiple specimens of those that could not be positively identified on site. Plant samples and site photographs were also collected and prepared to use in discussions with elders during subsequent interviews.

Following Jansson et al. (2000), variables related to plant species at each site included were documented. These included: the total number of species (species richness), a cover value for each species in each of the three zones: upper, middle and lower; and a percentage cover value for four general categories representing vegetation structure types: trees and large shrubs (individuals of woody species >0.25 m in height), herbs and dwarf shrubs (<0.25 m in height), graminoids, and bare ground.

4.5.3 Taxonomy

As there is no comprehensive descriptive flora yet published for Labrador, several sources were used to aid in plant identification and to provide background information on general distribution and habitat characteristics (Damman, 1964; Gleason, 1974; Rousseau, 1974; Ryan, 1974; Rouleau, 1978; Gleason and Cronquist, 1991; Robertson, 1995; Ringius and Sims, 1997; Cody, 2000; Scott, 2000). External assistance was requested when needed for identification of some difficult species. Specimens of all plants not positively identified were reviewed by Sean Blaney at the Atlantic Conservation Data Centre, and those remaining were sent to the Department of Agriculture Herbarium in Ottawa for identification by various experts including Dr. Paul Catling, Dr. Stephen J. Darbyshire, and Dr. George Argus. Taxonomic nomenclature used in our list follows that of Meades et al. (2000+).

For additional analysis, species were classified by habitat affiliation according to a wetland indicator system developed by the U.S. Fish and Wildlife Service (1996) for a National Wetlands Inventory.

4.6 Aerial Photography and other Remote Sensing Imagery

Aerial photographs were used to compare some reaches of the river at various times before and after regulation. Historical black and white air photos are available for the lower Churchill River at a scale of 1:50,000 from 1968 to 1970, and at 1:30,000 between the years 1949 to 1957 from the National Air Photo Library. Pre-development photography for the reservoir area is available at scales ranging from 1:31,600 to 1:50,000. At this level of resolution, it is possible to differentiate between shorelines that are relatively bare and those that have vegetation cover. However, it is not possible to determine the nature of the substrate in bare areas, e.g., whether it is predominantly sand or boulders. Neither is the structure of the vegetation apparent in areas that appear densely vegetated.

A recent set of aerial photography was flown in 1998 to support planning for further hydroelectric development of the lower Churchill. Colour photos at scales of 1:12,500 or 1:20,000 were produced with coverage including the length of the main stem of the lower Churchill, both forebay reservoirs, a small portion of the Smallwood reservoir adjacent to Lobstick control structure, a southern portion of the Ossokmanuan reservoir, Atikonak Lake south to Lac Brulé, and parts of proposed transmission line corridors. These provide sample views of shorelines in the storage reservoirs and some reduced flow reaches of the Churchill River, and complete imagery of the forebays and the river downstream of the generating facility. These images would allow excellent mapping of the extent of the shrubby riparian zones along all watercourses, although this large exercise was not undertaken for the present study. It is assumed that complete mapping of riparian habitat in the lower Churchill will be completed by the hydro project proponents. A selection of images from this set of photos was consulted for my study in order to make general comparisons with older photography.

Riparian habitats make up a relatively small portion of the vegetation cover across the landscape, especially in relatively contained river systems that do not have large floodplains. Partly due to the limitations of resolution of many types of available satellite imagery, these narrow, linear strips along flowing rivers and lake expansions are not classified on the 1:50,000 Labrador forest inventory maps that include a wide range of vegetation cover types. Aerial photography is still the most accurate data to use to map and classify riparian vegetation communities (Congalton et al., 2002).

Landsat Thematic Mapper ™ data are available for the post-development period, but they are inadequate for mapping riparian vegetation. There are no useful pre-development satellite data from the region that could be used in a GIS system to map changes in riparian habitat since regulation of the river. Development of remote sensing technology is proceeding at a rapid pace. Data from newer sensors such as Ikonos could possibly be used to map existing riparian habitat for future monitoring, although questions remain regarding the expense and utility of such an endeavour. Certain particularly diverse or unique reaches could be mapped using such imagery, rather than flying the whole region, which would be prohibitively expensive. A brief discussion of the use of satellite data and airborne spectral imagery for mapping, classifying and quantifying changes in riparian habitat is found in section 6.4.

Aerial photography could also provide useful information about changes in ice cover over time. However, no winter images were located through the National Air Photo Library for the main stem of the river. Some low-level oblique air photos were taken by the author of the reaches downstream of Muskrat Falls. Ice cover research on the lower river reaches has been pursued by Newfoundland and Labrador Hydro, although to date no results are known to the author.

Table 3. Summary of Research Activities

1. Literature Review

   - Reviewed studies on the effects of flow regulation on riparian habitats in boreal regions (1999 – 2002, 2003 – 2007)

2. Historical Records of Riparian Habitat

   - Reviewed pre-development literature including general observations of riparian habitats in the watershed, species and habitat lists, and photographs (1999 – 2002, 2003 – 2004).
   - Reviewed previous environmental assessment work in the lower river (2000).

3. Documentation of historical and contemporary observations and perspectives of local Innu and Inuit-Metis knowledgeable about pre- and post-development river conditions;

   - Coordinated Innu Nation Community Consultations on Hydroelectric Development – Phase I (March to July, 2000) – Phase II (November 2000 to November 2001)
   - Preliminary discussions with elders (Spring 2003)
   - Additional interviews with nine elders in Sheshatshiu, Northwest River and Happy Valley-Goose Bay (March 23 to April 5, 2005).

4. Hydrological Records

   - Obtained raw data recorded at hydrometric stations from Environment Canada, Churchill Falls (Labrador) Corporation, and Iron Ore Company of Canada. Extracted relevant data and produced hydrographs to analyze and illustrate changes in patterns of flow throughout the watershed (2003 – 2004).

5. Observations of Riparian Habitat

   - Visited La Grande Projet in Québec with Innu representatives from Sheshatshiu and Utshimassits during the community consultation process (September 2000).
   - Riparian plant surveys on the Ashuanipi River, Lower Churchill, Churchill Falls and the reservoirs (July 06 -August 04, 2001, August 20 - September 09, 2001).
   - Identification and analysis of vascular plants specimens (2003 – 2004).

6. Aerial Photography

   - Studied ground and aerial photographs taken before and after commissioning of the Churchill Falls project. To conduct more detailed analysis on selected sites, air photos were chosen from the years 1949, 1951, 1957, 1978, 1979, 1998 (2000).

Chapter 5. Observations of the River Shoreline Vegetation Before and After Regulation

We knew that country. We have been all around that area and visited the falls. We knew all the rivers around there. The young people have not seen it, and do not know how important those places are (Pien Penashue, pers. comm., 2001).

5.1 Patterns of Regulation within the Watershed

The hydrological cycle during the growing season is one of the most important factors directly influencing the structure and composition of the vegetation communities that are able to establish on the shorelines of water bodies. Regulation for electricity production has had profound effects on the shorelines of the greater portion of the Churchill River watershed. The general nature of the changes that have occurred is dependent to a large degree on the specific hydrological patterns and the physical characteristics of the various reaches of river during the pre- and post-regulation periods.

Altered hydrological regimes in turn create changes in sediment transport, river morphology, and ice formation that are essential to understanding the evolution of riparian habitat along the river. Investigation of geomorphological processes is currently being conducted by consultants to the proponents of new dams in the lower reaches of the river. Detailed analysis of these processes is beyond the scope of our study. However, in the course of our discussions, local people shared many observations related to ice conditions and erosion especially in the lower Churchill River valley. Some preliminary observations are presented here as they relate to the available hydrological data, photographic imagery, patterns of riparian vegetation and shoreline physical characteristics documented during our surveys, and findings from relevant research conducted in other regulated boreal rivers.

From its headwaters to its mouth, the Churchill River is now characterized by:

- unregulated headwater rivers, streams, and lakes;
- a storage reservoir in Menihek Lakes along the Ashuanipi River behind Menihek Dam;
- the regulated river downstream of that relatively small generating station;
- two extensive and strongly regulated storage reservoirs – Ossokmanuan and Smallwood;

- diverted reaches with greatly reduced flows;
- two smaller control or forebay reservoirs;
- and partially regulated downstream reaches of the main stem of the river below the powerhouse tailraces (a distance of about 334 km).

The latter reaches are still influenced by many large, unregulated tributaries draining lower portions of the watershed (refer to Figure 13).

Certain unique near shore habitats, such as the spray zones surrounding the former Churchill Falls and three other smaller falls, have experienced dramatic changes with the loss of the constant moisture from mists that once influenced the presence and growth of less common plant species, particularly bryophytes (Kallio, 1969; Brassard et al., 1971; Brassard, 1972; Odland et al., 1991). These areas are not the seasonally flooded riparian zones according to our definition, but they did receive higher levels of moisture and nutrients due to the natural flow patterns of the river and will be discussed briefly in the section on reduced flows.

Trends in regional climate due to factors other than hydroelectric development can also contribute to changes in hydrology and riparian habitats. Horace Goudie observed some of the effects of decreasing regional precipitation during recent years:

> *Our whole land is drying up. You take up here the Lower Brook and Upper Brook, Edwards Brook and all the brooks up through there, small ponds and stuff. They're down that much in my day* [he indicated about 1 meter]. *Lower Brook is now completely dry where the bridge crosses. You used to be able to paddle a canoe up through it, but now a lot of it is all dry rock. And it's just disappeared because we get very little snow in the winter, and we don't get much rain, or very little. We can go five or six weeks here with sunshine every day, and that's too much. It's not right.* (Horace Goudie pers. comm., 2004).

Reductions in annual precipitation can in turn influence the operation of hydroelectric facilities if available water is insufficient to meet generation capacity and demand. In some cases, this may result in increased reservoir drawdown zones, or even lead to the construction of additional diversions from adjacent drainages to supplement water storage capacity.

5.2 Storage Reservoirs

> *To many Innu people, the flooding of Meshikamau was a grave insult. They were not consulted in advance of the construction. No environmental impact assessment was undertaken. No serious archaeological surveys were conducted. No remedial actions were taken to excavate archaeological sites or move cemeteries. Many Innu place names were erased from the maps and replaced with new names marking European conquest of their territory; names like "Smallwood Reservoir" and "Churchill Falls."* (Innu Nation, 1998).

Relatively little survey work was conducted during my study along the reservoir shores compared to the lower river reaches. The Menihek Lakes reservoir was not visited at all. Furthermore, the data are not necessarily representative of the Smallwood and Ossokmanuan reservoirs, because the few sites that were surveyed are all located in southern regions of the reservoirs. The extreme northern and western shores of the reservoirs would have experienced less extensive flooding with the new shorelines somewhat closer to former riparian zones. Additional survey work is required to investigate the quality of riparian habitat throughout these reservoirs. Nevertheless, an examination of the available hydrological data, along with air photos and field observations made over time, can provide some valid indications of the probable changes in structure and species richness of riparian vegetation throughout the reservoirs.

5.2.1 Hydrological Changes in the Areas Flooded by Storage Reservoirs

> *Two, possibly three, cemeteries were flooded; one on an island at Meshikamau-kupitan (outlet of Michikamau Lake), the other at Meshikamass (Michikamats Lake). A third cemetery at Kanekuanikau (Sandgirt Lake) may also have been flooded. The cemetery at Meshikamass was visited by Mina Hubbard in 1905 during her trip to Ungava Bay. It is located on a sand mound and is eroding into the lake as a result of the flooding* (Innu Nation, 1998).

The water levels of the storage reservoirs are subject to large seasonal fluctuations, with hydrological regimes that differ significantly from natural conditions conducive to the development of healthy riparian vegetation and near shore wildlife habitat. In fact, they experience oscillations in water levels that are almost the opposite to that of natural lakes and rivers. Water levels in the storage reservoirs are generally lowest in the early spring after winter power generation draws down the water supply. Throughout the late spring, summer, and fall, water levels gradually rise as the reservoirs capture run-off that previously would have flowed though the lower river system during those months.

Some water level data recorded at the Menihek Lakes reservoir between 1955 and 1967 are available from the Water Survey of Canada. This was a period during which the station was generating more power than it has in recent decades, and so recent reservoir water level patterns may differ to some extent. There are some questions as to the accuracy of these data. Recent data were not available at the time of writing. Nevertheless, this lake expansion along the Ashuanipi River experiences water level fluctuations characteristic of a storage reservoir, with levels increasing throughout the summer and autumn, and falling steadily during winter when power production is highest. The reservoir drawdown is in the range of 1.5 meters over the course of a year.

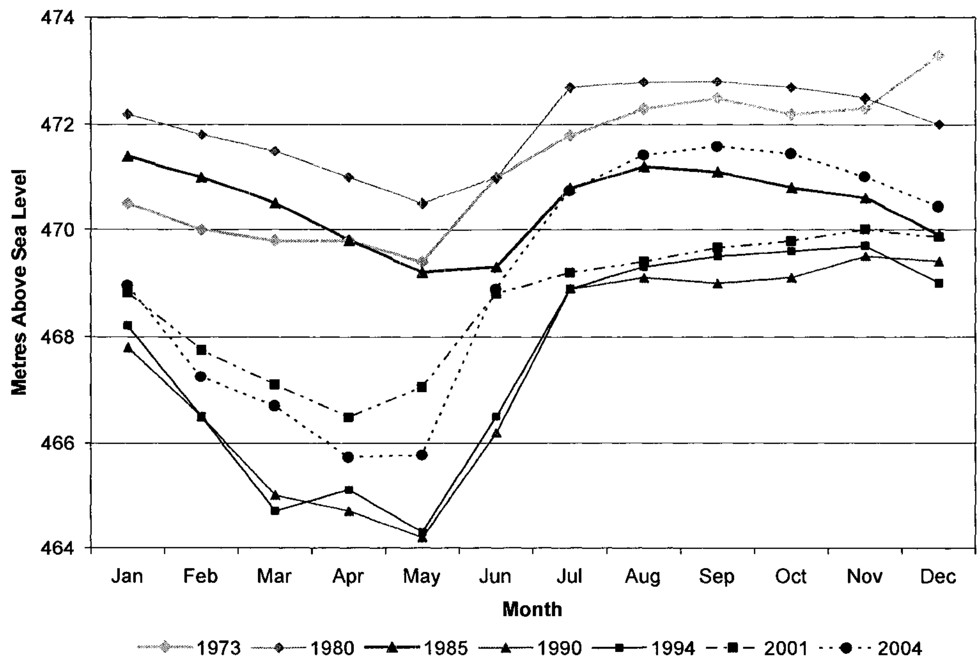

Figure 23. Monthly Mean Water Levels in the Smallwood Reservoir for Selected Years (Data source: Churchill Falls (Labrador) Corporation).

The maximum and minimum operating levels of the Smallwood reservoir are 473 and 464 meters above sea level respectively. Annual drawdown depends upon precipitation patterns that affect runoff received from the upper watershed, and upon rates of power generation. When precipitation is lower than predicted, water levels in the reservoirs, and consequently the total area of exposed shoreline during the growing season, will vary from year to year. Engineers planned average annual drawdown levels for the Smallwood and Ossokmanuan reservoirs of approximately 4 m and 3.5 m, respectively (Duthie and Ostrofsky, 1975). After the initial flooding, reaching full pond in the early 1970s, the water levels in the storage reservoirs have been consistently lower than expected. Particularly in areas of the plateau with low topography, the shoreline within the active drawdown zones can be quite wide (up to about 100 m, as observed in air photos).

Water levels in the Smallwood Reservoir have dropped considerably since the mid-1980s when average precipitation in the region began to fall below previously recorded levels (Figure 23). Thus, the active annual drawdown zone of the Smallwood reservoir has been significantly greater in recent years than predicted – as much as 6 meters in 1994. The annual drawdown of the Ossokmanuan reservoir has also been greater than initially predicted (Figure 24). The normal operating regime for the Ossokmanuan reservoir, which drains into the Smallwood reservoir, is to allow it to fill by the end of September and then maintain it that way until February when the gates are opened and water is discharged into the Smallwood reservoir to prepare for the spring run-off (CF(L)Co pers. comm., 2005). The Smallwood is larger with more storage capacity and is progressively depleted throughout the winter months. Note that the water levels in this reservoir also rise steadily throughout the growing season.

The 2002 Environmental Performance Report for the Newfoundland and Labrador Hydro Group reports that the years 2001 and 2002 were two consecutive years in which reservoirs throughout the province received below average inflows (Newfoundland and Labrador Hydro Group, 2002). Reports show that the years 2003 and 2004 subsequently experienced an increase in total precipitation and in hydroelectric production (Newfoundland and Labrador Hydro Group, 2004). The data for water levels in the Smallwood reservoir show that levels were already dropping below expected operating levels before 1985, and had reached the lowest levels to date throughout the years 1990 to 1994 (Figure 23). Lower than expected reservoir levels had thus been an issue for this facility long before 2001.

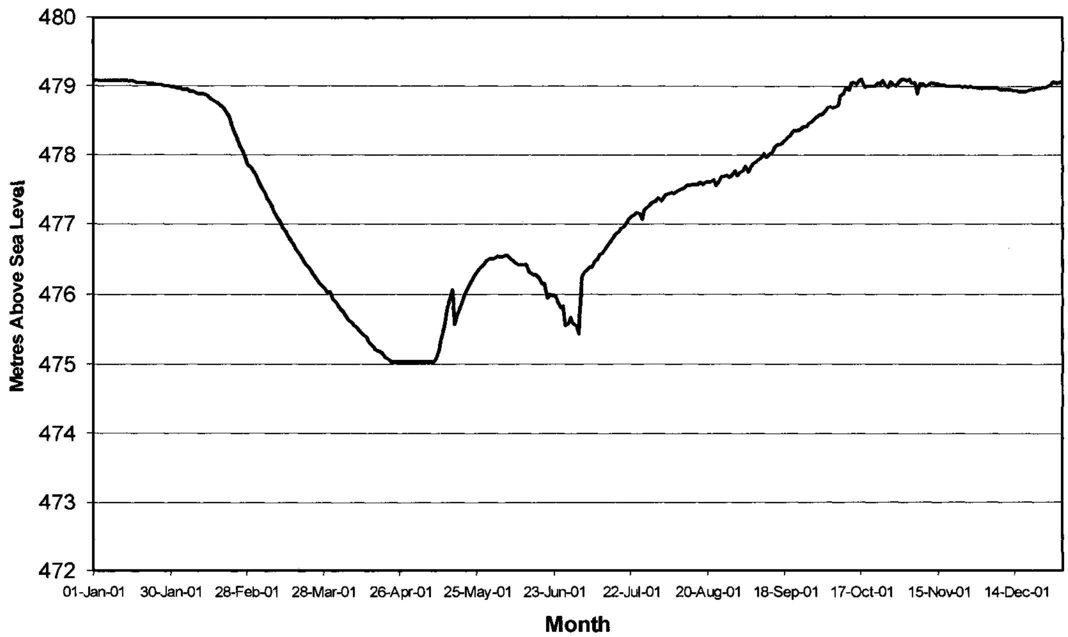

Figure 24. Ossokmanuan Reservoir Water Levels in 2001 (Data source: Churchill Falls (Labrador) Corporation).

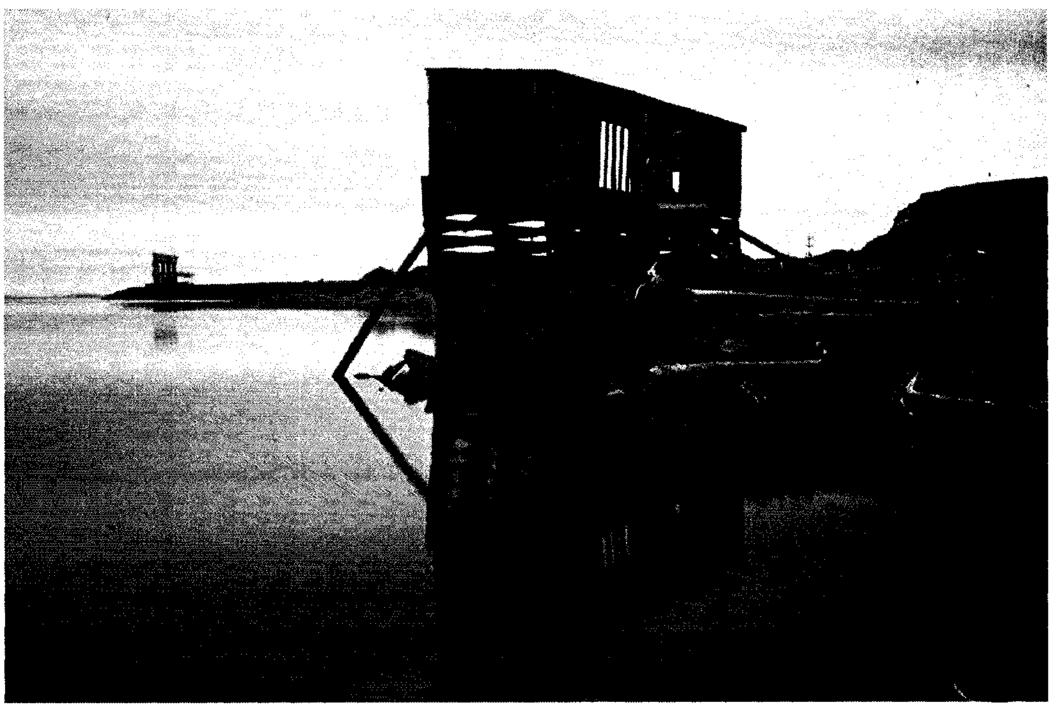

Figure 25. Low Water Levels in the Smallwood Reservoir in August 2001. A supply storage shack erected in the 1970's for an attempted commercial whitefish fishery is well above the water. The Lobstick control structure is in the distance (Photo: A.Luttermann, 2001).

In his observations during a period of low water levels in 1995, Daniel Ashini described an example of a serious consequence of flood-induced erosion in a northern section of the Smallwood reservoir:

> *...my uncle Dominic Pokue and I traveled to Meshikamass with a couple of archaeologists and Peter Armitage on a research project. This was an area where our people had lived before the flooding. When we conducted the research the water level seemed to be at its natural level or at the level, it had been prior to the flooding. We discovered many artifacts, but what was most painful for both my uncle and I was when we discovered an old burial site. We sat overlooking the lake when below us on the side of the bank, we saw a bone sticking out from the sand. We later verified that this bone was human.*
>
> *After having carefully dug out the rest of the bones, we learned that most of them were missing. The water level had risen from the flooding and eroded this hill. The erosion had exposed and washed away the rest of the bones. We gathered the rest of the bones, buried them further ashore and marked the site. To be a part of this personally and to witness this type of impact was certainly very disturbing and will forever live in my memory* (Innu Nation Hydro Community Consultation Team, 2000:24).

In the year of my field survey (2001), the spring high water was about 466.5 m in April and rose throughout the summer growing season to a high of 470.0 m in November. The upper limit of what was considered the active riparian zone measured that year was thus the result of much higher flood levels attained during the 1970s. These levels had not been reached again for over twenty years. Therefore, the shrubs and herbaceous perennials that were becoming established in the upper zones by 2001 had not likely been subjected to any flooding or ice scour disturbance during that period. Most of the terrestrial vegetation observed colonizing the lower and middle zones that year would likely be drowned in future seasons because water-level increases during the growing season would exceed these levels by 2004. If adequate precipitation allowed the Smallwood reservoir to operate to a maximum late summer fill level of 473 m, it is probable that there would be virtually no vegetation cover within the active riparian zone. A range of 7 to 21 percent of the total species observed on the Smallwood reservoir shore sites are classified as obligate wetland plants, although there were no true aquatics observed. However, even most obligate wetland species would not survive if progressively flooded throughout the growing season.

As discussed earlier in section 2.5, erosion of finer soils tends to be observed on the shores of reservoirs with large drawdown zones. Bruneau and Bajzak (1975) reported that already by 1974, one year after the Smallwood reservoir was flooded to its maximum level, there was extensive erosion of finer soils from new shorelines. This was particularly evident on shores where water depth and wind fetch created considerable wave action, but also along relatively protected reaches of shoreline. They predicted that if it became necessary to operate the reservoir at lower elevations in the future, there would be similar erosion of finer substrates lower down on the shores exposed to wave and ice action. This would continue to topple the submerged trees, and also create more extensive shores with predominantly rocky substrates. This is what I have observed in some areas of the reservoirs three decades later.

5.2.2 Daily Fluctuations in Reservoir Water Levels

The water levels in the reservoirs are recorded by CF(L)Co. at midnight daily. I observed large fluctuations in water levels in the forebays and even in the large storage reservoirs close to the control structures over periods of only two or three hours during surveys. Load requirements for the generation facility vary over the course of a day, with electricity demand. Water levels are therefore less stable on a daily basis than is reflected in hydrographs depicting the daily levels recorded at the same time each day.

A graph comparing the daily flows measured at Flour Lake on the plateau pre-development and at the Churchill Falls tailraces post-development indicates the differences in flow patterns throughout the year with regulation (Figure 26). The pre-development flow was characterized by a steady rise in the spring and early summer starting in May, dropping throughout the summer months from late June to August, rising again slowly with the fall rains, falling slightly again before freeze-up in November or December, and then remaining relatively stable until the next spring break-up. In contrast, the flows from the tailraces demonstrate a seasonal pattern almost opposite to the natural cycle, with substantially more daily variation in flow. This daily fluctuation would impede the development of some species of riparian plants in the zones affected during the growing season.

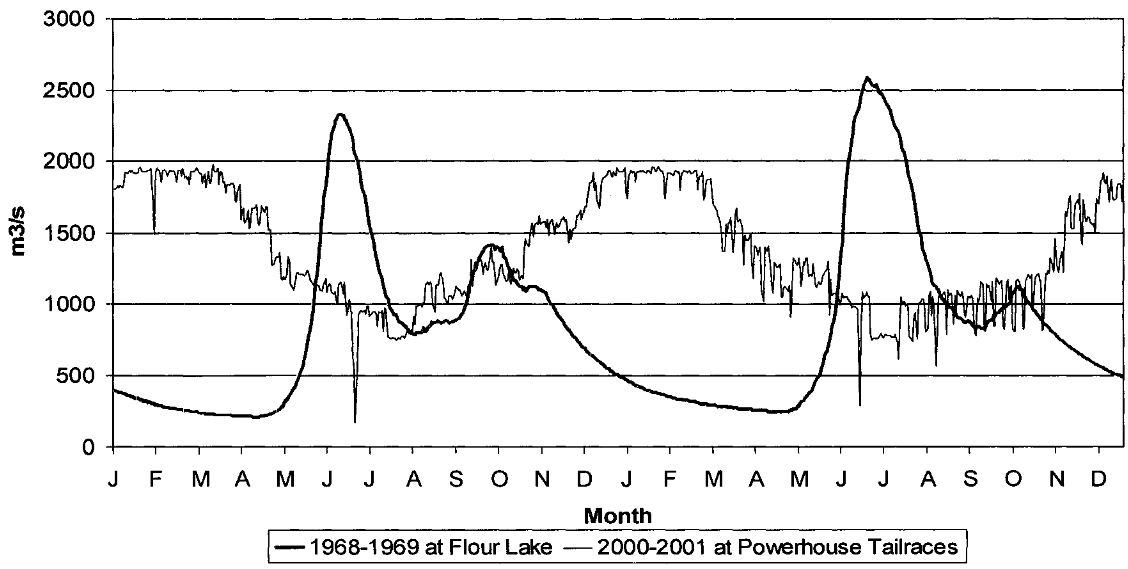

Figure 26. Daily Flow in the Upper Churchill River For Two Years Pre- and Post Regulation (Data sources: Water Survey of Canada, and Churchill Falls (Labrador) Corporation).

Horace Goudie described his view of natural water level patterns compared to the present reservoir conditions, and the effect on plants:

> *They'd come up in the spring a good bit and drop, and usually drop a little bit all summer, you know. A lot of this stuff here can't take too much water* [pointed to shoreline shrubs and herbs on the natural lake]. *It'll take some water but not too much. So if they are going to be raising the water up and down all the time for the control of the electricity, you'll see this probably for all eternity* [points to a photo of a wide, bare reservoir shoreline]. *There will never be any willows or anything growing around, because it would be coming up and down so much they wouldn't get a chance to grow* (Horace Goudie pers. comm., 2005).

He also commented on the effect of reservoir fluctuations on the use of these water bodies for travel:

> *You take Ossok Lake, we used to call it Unknown Lake. I went up there to go to the fish camp where I worked one summer, in a canoe, and I had to carry it a couple of places to get over some rocks and I thought it was normal. But then you see all this dead wood piled up on the beach like that. It took three days to get to the place where I worked, so we camped one evening on a little spot of sand out by the edge of the woods, and the water was a way down like that. So, we had a month back at the camp, and then I left, with my canoe to paddle back down the same way for Joe to pick me up at the Ossok spillway. When we came along by our old campsite, I*

> *was looking down at it down there. They had the water up, and I tried to reach it with my canoe paddle. I pushed straight down with a long paddle, and way up my arm like this* [to shoulder] *and I still didn't touch the bottom where I had my tent a month before that. So they had the water up about eight feet higher than it was when I camped there. Now you just imagine what would have happened if they had started putting the water up the night that I was sleeping there. You've got to be careful* (Horace Goudie pers. comm., 2005).

The reservoirs are not used for travel by many people now partially due to the hazards of unpredictable water levels and ubiquitous floating and submerged large woody debris.

5.2.3 Ice Scour and Wave Action in Reservoirs

Wave action and ice scour have a much stronger influence on the shores of a large reservoir than in a small pond or stream. However, one important question is whether the effects of ice scour are different in reservoirs than in a large natural lake such as Lake Michikamau with shores exposed to wave action. Bruneau and Bajzak (1975), who were primarily concerned with processes affecting the degradation of flooded trees, observed the ice on the newly formed Smallwood reservoir over several seasons. They wrote that:

> *The vertical motion of the ice on the surface of the reservoir as it follows the gradual drawdown from November to May or so, and then the rapid rise during the spring run-off in late May-June, plays a considerable role in the destruction of the inundated trees* (Bruneau and Bajzak, 1975:62).

They explained the mechanisms by which the flooded trees in a reservoir could be felled by ice. In late October and early November during freeze-up, the reservoirs are at their maximum levels for that year. Then the levels begin to decline. The ice that had formed around the trunks of standing trees would gradually slide down the trunks and scrape off bark and small branches in the process. Trees that may be standing in deeper water may become frozen into the ice at crown level. As the ice continues to thicken and drop throughout the winter, these trees are subjected to increasing vertical loads. The forces are enough to break major branches from the trunk and/or cause the entire trunk break off (Bruneau and Bajzak, 1975). Such forces would also affect the persistence of shrubs and herbaceous plants within the active riparian zones of storage reservoirs.

In contrast, the physical effects of ice on shoreline vegetation of a natural lake in spring during break-up, typically would not be nearly as stressful. Water levels generally begin to rise in spring with increased melting, rain, and run-off from surrounding lands. By this time, the solar radiation absorbed by dark tree trunks that may be frozen into the surface ice will have begun to melt the ice that is actually in contact with the plant structures. The spring ice therefore does not tend to exert significant lifting forces on these trees (Bruneau and Bajzak, 1975). This suggests that ice scour during spring break-up may not be nearly as stressful to woody riparian vegetation growing in lentic environments with a natural hydrological regime, compared to the effects in winter reservoir drawdown zones.

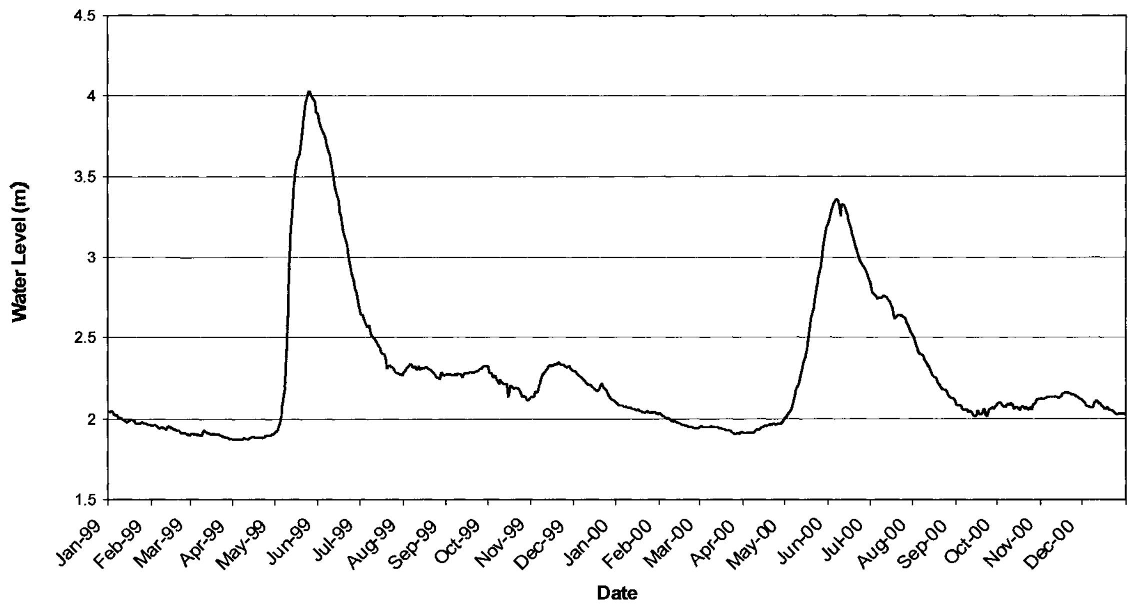

Figure 27. Water Levels on the West Side of Atikonak Lake for Two Years, 1999-2000 (Data source: Water Survey of Canada).

A comparison between the storage reservoirs and an unregulated large lake in the watershed demonstrates the considerable differences in water level regimes. As can be seen if we refer back to Figure 23, the elevation of the Smallwood reservoir typically drops by as much as four meters from January to April or May. All of the shoreline exposed during this period would be subject to severe physical stress from the ice. In contrast, the hydrograph from the unregulated Atikonak Lake, a relatively large lake in the upper watershed (Figure 27), shows that the winter water levels under natural conditions remain relatively stable, dropping less than 30 cm from freeze-up until spring break-up.

Another consequence of falling water levels in the late winter is that the massive ice sheet that has established on the reservoir, over a meter thick by early spring, settles onto the bottom along the shores (Bruneau and Bajzak, 1975). With a winter drawdown in the range of four meters, any plants or other material lying within this zone will be subject to severe crushing and scraping forces. This can further explain why reservoirs have shores that are typically devoid of riparian vegetation. Such processes may also prevent the establishment of aquatic plants in storage reservoirs.

5.2.4 Changes in Riparian Vegetation in the Storage Reservoirs

Prior to reservoir creation, about 20% of the upper plateau drainage basin was covered in water (Lower Churchill Development Corporation, 1980). The areas that are now flooded under the immense storage reservoirs were previously laced with a complex maze of smaller waterways, lakes, ponds, streams and rivers, all bordered with their respective riparian habitats.

A.P. Low's observations in the region provide general indications of the structure of shoreline vegetation in many areas of the watershed. In relation to central Labrador, he wrote that, "Throughout the forest belt, the lowlands fringing the streams and lakes are covered with thickets of willows and alders" (Low, 1896:37). The character of the shores in the river reaches on the plateau above the falls are described in the following passage:

> *The banks are often low, and covered with a dense growth of small willows and alders, that form a wide fringe between the water and the conifers of the higher ground behind* (Low, 1896:145).

Lake Petitsikapau southeast of what was to become Schefferville is translated as "Willow-fringed Lake". Of this area he wrote, "Almost everywhere the shores are low and swampy and bordered with willows" (Low, 1896:152). He noted that in the transition from forest to semi-barrens, shrub communities become more extensive. They are common in open glades and form low thickets on hillsides along with dwarf birches and arctic willows. In some areas such as Lake Michikamau, he described low sandy shores and bouldery points but did not mention vegetation cover on the shores specifically.

Keast described a narrow alder zone along the shores of a large island in Lake Michikamau (Keast, 1971). He also referred to numerous "lush, wet, grassy areas" on the foreshores of islands and sheltered bays in the upper Churchill River watershed (Keast, 1971). It is presumed that these would have been within active riparian zones. My observations suggest that such shorelines are virtually non-existent in the reservoir environments at present.

Studies of the effects of project infrastructure and operations on wildlife in the area were limited to the following: predicting and then observing for one season the behaviour and fate of selected species of mammals in the new reservoir areas (Fenton, 1971a, 1971b); predicting the possible fate of birds and mammals on islands to be flooded (Keast, 1971); some limited surveys of breeding waterfowl during flooding and for two seasons following inundation (Keast, 1973); and calculating the loss of wetland habitat suitable for breeding waterfowl (Gillespie and Whetmore, 1973; Lamoureux and Laperle, 1974; Goudie and Whitman, 1987). Many of these studies report some observations of the general structure of habitats in the areas that were being flooded, including those close to lake and river shores.

Figure 28. Rocky Shoreline of an Island Typical of the Storage Reservoirs (Site 32). Note the woody debris stranded on the upper shore (Photo: A.Luttermann, 2001).

In 1973, a biologist contracted to conduct work on waterfowl populations in the area of the Smallwood reservoir recommended to CF(L)Co that a broad-based study should be pursued to document and monitor the natural history of the area affected by the project, particularly the habitat utilization and relative abundance of major species (Keast, 1973). It appears that this was not carried out. No studies have been published describing the development of riparian vegetation on the new shorelines of the main reservoirs or forebays, the use of those habitats by wildlife, or the potential long-term effects of flooding on the abundance of wildlife populations in the broader region.

Observations indicate that the flooding and operating regimes of the storage reservoirs have resulted in severe degradation of previous riparian habitats within the flooded areas, and an overall simplification of the landscape. The extensive new shorelines that have developed are relatively homogeneous in structure with sparse vegetation and coarse substrates (Figure 28). These shores do not provide the diverse physical attributes of riparian habitats typical of natural lakes and streams in the region, other than being adjacent to open water. This is what would be expected based on research in other boreal regions and the hydrological data from the reservoirs.

In Figure 29, an historical view of a portion of Lobstick Lake shows indented shorelines with myriad islands surrounded by bands of low vegetation, interspersed with areas of exposed rocky or sandy beaches. In contrast, the shorelines of the storage reservoirs, as viewed on air photos (Figure 30), are remarkably homogeneous in terms of vegetation cover, and are distinctly different from the shores of surrounding unregulated water bodies outside of the influence of the reservoirs. If the aerial view of the current reservoir shores is compared with the photo of the area prior to flooding (Figure 29), it is clear that the shorelines are greatly altered. The photo shown in Figure 30 was taken in 1998 when water levels in the storage reservoirs were drawn down quite low due to several years of below average precipitation.

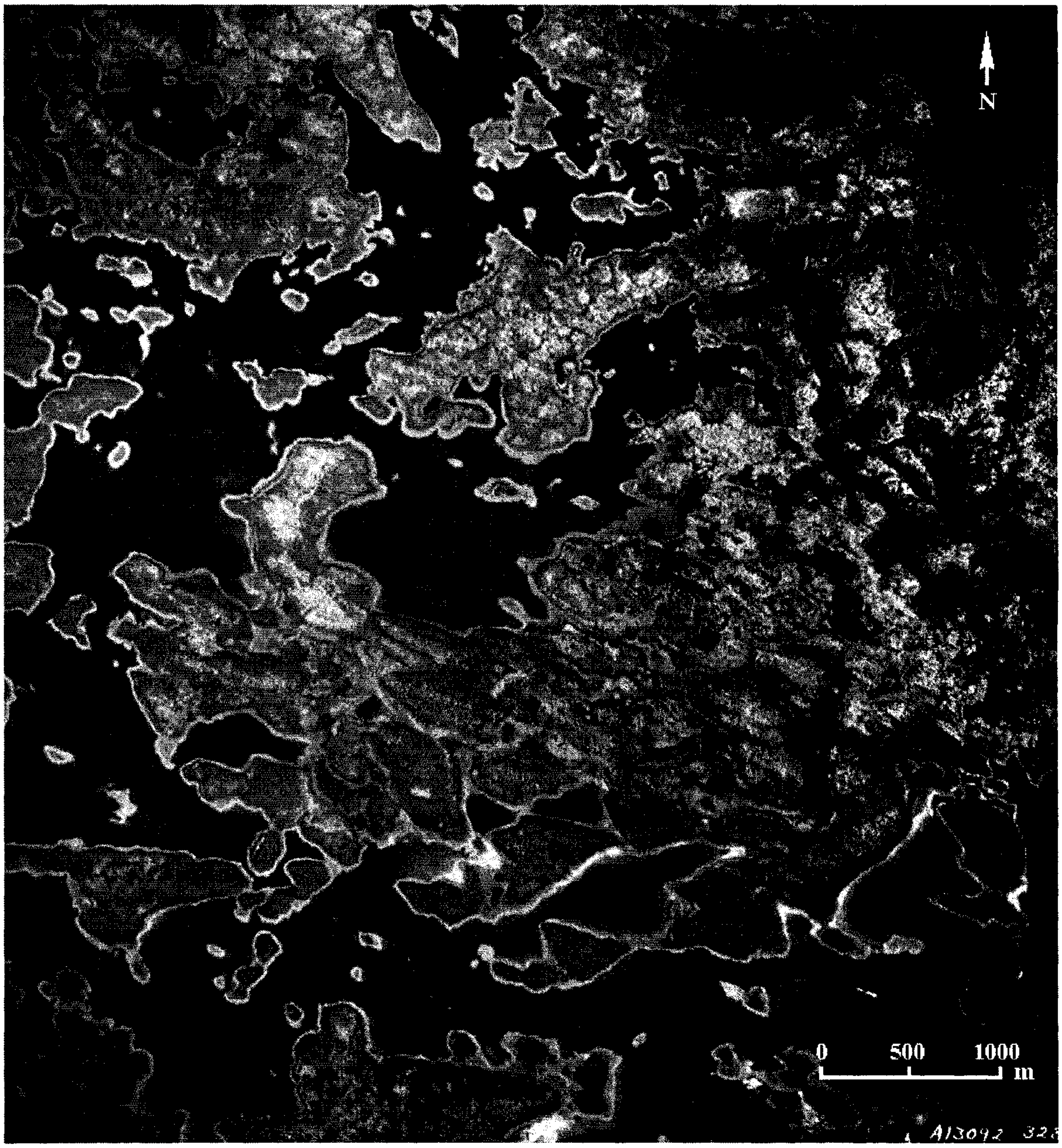

Figure 29. An Aerial View of a Portion of Lobstick Lake in 1949. Shorelines are predominantly bordered with a fringe of shrubby and herbaceous vegetation (Photo: National Air Photo Library). Centre Lat 53° 53'11 Long 64° 59'34.

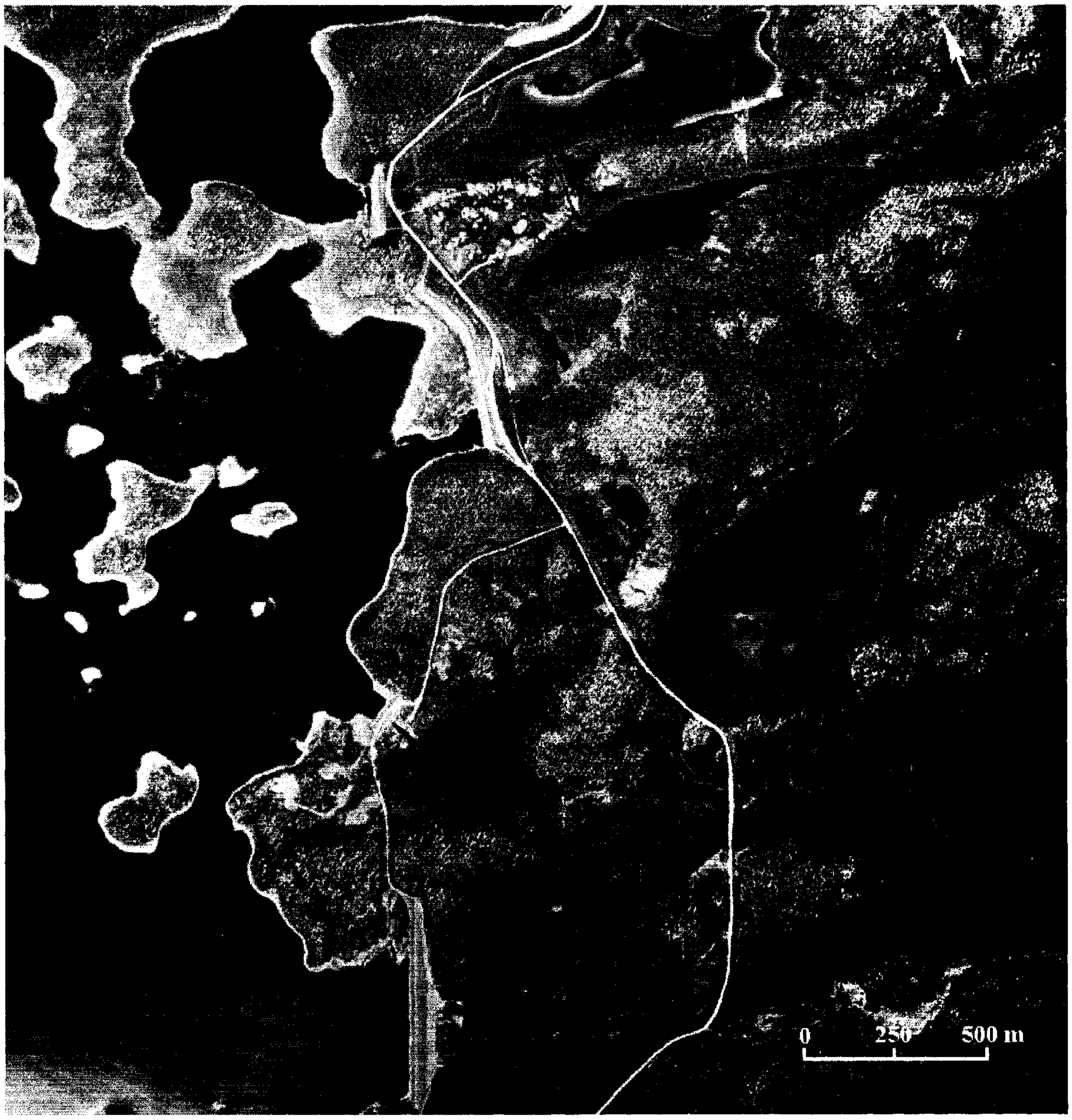

Figure 30. Dikes South of the Lobstick Control Structure. Note the wide, rocky shorelines on the left within the Smallwood reservoir, and the densely vegetated shorelines of the diverted and dewatered reaches downstream on the right (Photo: Newfoundland and Labrador Hydro, 1998). Centre Lat 53° 47' 65 Long 65° 02' 30.

Few people travel extensively on the large storage reservoirs since they were created, especially during the summer. Small areas of shoreline can be viewed from the main road and along the maintenance roads to the control structures and dikes. Field visits were made to some of these areas with groups of Innu elders and youth from

Sheshatshiu and Natuashish. Some of the individuals interviewed for this study have also observed larger portions of the reservoirs from the air. All accounts suggest that the post-flooding appearance of the reservoir shorelines is uniform throughout, with wide, rocky shores, sparse vegetation cover, and substantial quantities of large, woody debris piled adjacent to the high water mark (refer back to Figure 28 on page 115). They appear much like the large storage reservoirs in the La Grande project in Québec and elsewhere.

Figure 31. The Lower Zone of a Relatively Sheltered Site on the Ossokmanuan Reservoir (Site 24). On this sheltered, depositional shore the substrate is fine but there is little vegetation cover. Scattered individuals of 7 vascular plant species were noted in the lower zone, with an estimated 95% bare ground. Water levels were rising at the time and some recently submerged sedges were observed (Photo: A.Luttermann, 2001).

As discussed above, the unnatural pattern of water level fluctuations in association with substantial wave action on exposed shores creates a highly stressed environment for plant growth. In most places, the finer substrate particles are eroded, leaving mostly boulders, cobble and coarse gravel. Within the active drawdown zone, seedlings that germinate on exposed substrates in the spring, or perennials that have survived previous years or newly take root are inundated and exposed repeatedly throughout the growing season, perhaps flooded before they can flower if the reservoir levels continue to rise, and possibly crushed by ice in the late winter.

The width of the shoreline between the high water and low water marks measured in the storage reservoirs ranged from 11 m to 41 m, with an average of 26 m. These shores are uniformly bare of vegetation and piled high with large woody debris. Vegetation cover in the storage reservoir survey sites ranged from 80 to 90% bare ground, with most plants only occurring in the upper areas of the riparian zone. The substrates are generally coarse and rocky, but even where finer sediments had been deposited in sheltered coves, the vegetation cover was low (Figure 31).

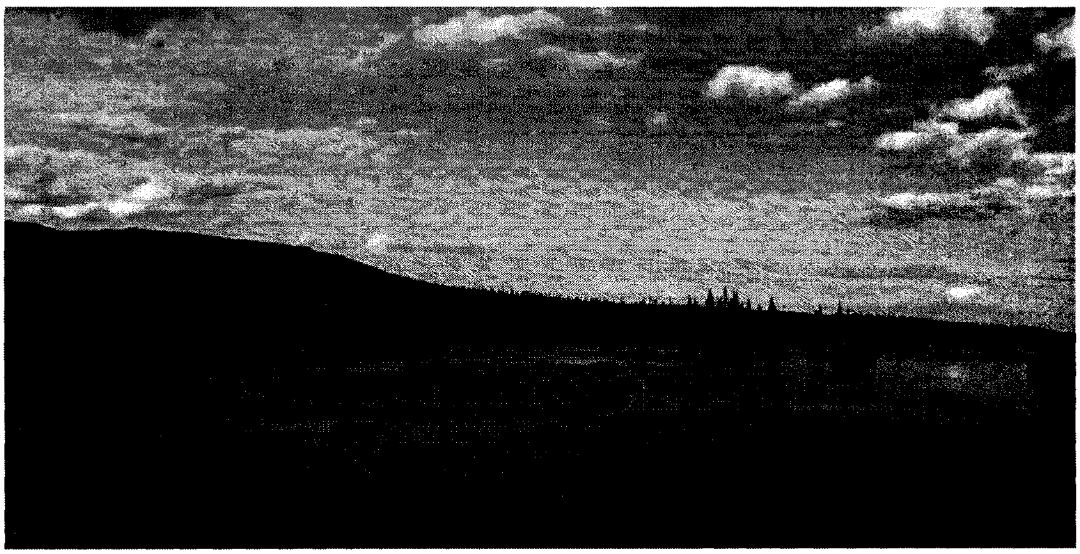

Figure 32. Section of a River in the Upper Plateau of the Watershed Unaffected by Regulation (Photo: Anonymous, 2003).

In comparison, the shorelines of large unregulated river systems in the region are densely vegetated along most reaches (e.g. Figure 32). For example, a canoeing guide warned potential travelers on a lake expansion of the George River, "Good luck finding campsites on the southern half of Indian House Lake. The shore is a disaster of ten foot tall alders and willows" (Munn, 2001). While such shrubs may be difficult to negotiate for human travelers, as several elders have observed, they are home to many small mammals and birds that benefit from dense shrubs close to the water.

Figure 33. Typical Upper Zone of a More Sheltered Shoreline on the Ossokmanuan Reservoir (Site 24). There is a large accumulation of woody debris. Twenty-nine species of vascular plants were observed at this site, but most were scattered individuals. The upper portion of the zone had about 20% plant cover. The lower and middle zones had only about 5% cover of living plants (Photo: A.Luttermann, 2001).

As we were examining photographs of the storage reservoirs (e.g. Figure 33 and Figure 34), Horace Goudie talked about the effect that the large quantities of dead trees stranded on the shorelines may have on the use of these areas by larger mammals:

> *Now a lot of animals, big animals, don't like to be moving if they're going to make a noise. If you put one pound [of weight] on a certain piece, then a whole lot of stuff will move and make a noise. They'd like to walk along a beach like this* [he pointed to a sandy beach photo], *where their paws can touch something solid. They're going cautiously, they're always cautious, and they're going quiet without a sound. Now you take stuff like this* [large woody debris on reservoir shore] *they couldn't get from up in there in the woods through all this, out to here without making noise. So they wouldn't walk over all this loose stuff, you know, like bears and lynx, and even foxes and caribou. They're scared to make a noise, they're scared something else will hear that and come after them. So just everywhere, everywhere up there in that whole area the size of New Brunswick there's nothing but wood like this, everywhere. The wildlife will shy away from stuff like that, definitely* (Horace Goudie pers. comm., 2005).

Mr. Goudie had previously described the upper plateau lakes and rivers as having a narrow bit of shoreline in places, with pockets of sandy beaches here and there, and sparse large woody debris.

With regards to the long-term future of the shoreline habitat, he was hopeful that eventually it would regenerate:

> *I don't think the shrubs have had much time to grow up yet. Some places they might be growing a little bit. But it's not old enough for the willows to be growing up good yet. Eventually all the dead trees will rot, and turn into topsoil, then the willows will grow up through the topsoil then it will be O.K. for the animals again. They'll be able to walk around quietly again. But that will take another hundred years yet, or close to it* (Horace Goudie pers. comm., 2005).

Unfortunately, as long as the operational regime of the reservoir is maintained, there will not be an opportunity for riparian vegetation to reestablish and provide good quality shoreline habitat. As mentioned, the regeneration of shrub growth in the upper zones that has occurred will likely be eliminated in future years if sufficient precipitation allows operators to bring reservoirs up to optimum storage levels (Figure 35).

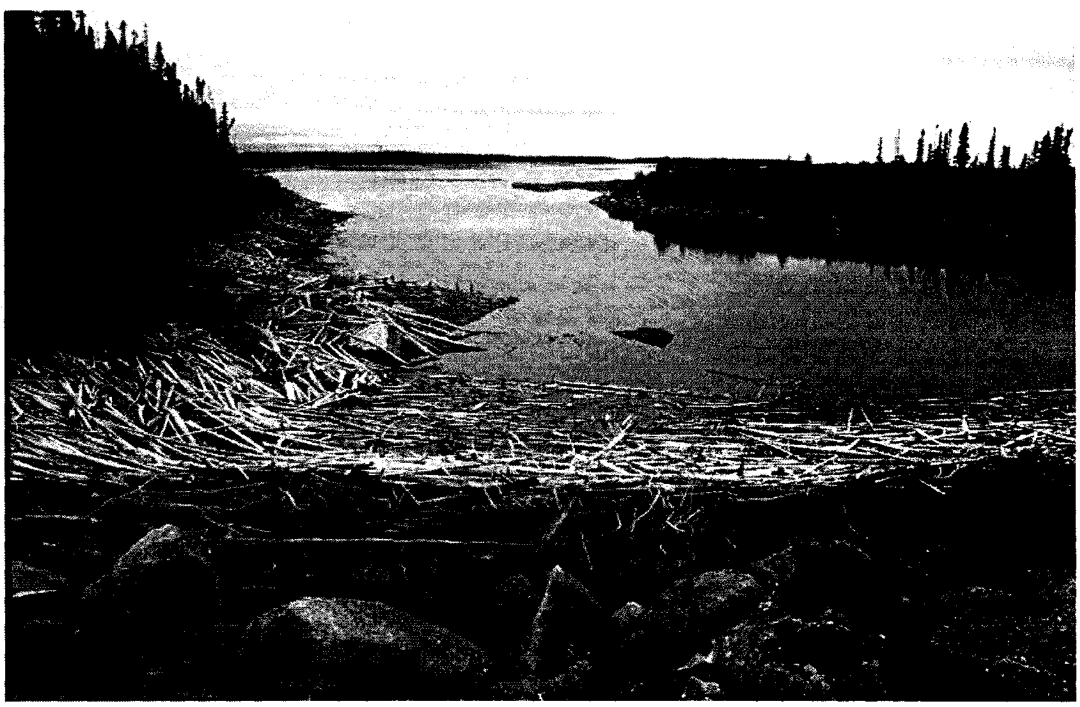

Figure 34. Smallwood Reservoir Shoreline Adjacent to a Dike (Site 31) (Photo: A.Luttermann, 2001).

Figure 35. Shore of an Island in the Smallwood Reservoir near the Lobstick Control Structure (Site 32). This is typical of exposed storage reservoir shorelines – a coarse, rocky substrate with little vegetation cover and substantial large woody debris in the upper zone. Note that there is some regeneration of low shrubs in the upper zone. These are within the predicted operational drawdown zone and would not persist if maximum water storage levels were reached. This has not been possible due to several years of lower than predicted precipitation. A total of 25 vascular plant species was observed here with 99% bare ground in the lower zone and 60% bare ground in the upper zone (Photo: A.Luttermann, 2001).

5.2.5 Species Richness of Vascular Plants on Storage Reservoir Shores

The new shorelines of the reservoirs were established for the most part, in what were previously upland terrestrial environments. A diverse assemblage of riparian habitats was inundated including the shores of all rivers, streams, lakes, and ponds, in addition to bog and fen wetlands. Virtually no former vegetated shorelines within the reservoirs were left unflooded. As discussed earlier, the work of Nilsson and colleagues has demonstrated that if the new shorelines of regulated water bodies are established in areas with vestiges of former riparian habitat, they tend to have higher species richness (Nilsson et al., 1991). The extreme northern and western shores of the main reservoirs where the least flooding would have occurred may have been established in former riparian zones. However, given the operating regimes of the reservoirs, conditions are limited for maintaining riparian vegetation in these areas, except perhaps where unregulated tributary rivers flow into the reservoirs.

As mentioned, botanical data collected from the region prior to flooding of the reservoirs are very limited. A program of research was initiated just prior to the inundation of the Smallwood Reservoir, the objective being to measure, interpret, and evaluate the effects of large-scale flooding on the vegetation and wildlife habitat (Bajzak, 1977). The vegetation studies focused primarily on mapping the "distribution of closed forests and of valueless [sic] areas (barrens, bogs, scrub and open forests) within the reservoir area" (Bajzak, 1971:1). It included more detailed mapping of vegetation cover in a five mile wide (8 km) zone surrounding the reservoir. The primary objective of this research was "…to determine the most appropriate means of dealing with the trees flooded in the process of reservoir filling" (Bruneau and Bajzak, 1973:5). This study was not designed to gain a better understanding of the effects of flooding on the ecological communities, aside from some general observations of rates of erosion along new shorelines. Following inundation, work was done on the effects of flooding on submerged forest vegetation, primarily directed at measuring the rates and processes of death and deterioration of trees (Bruneau and Bajzak, 1975).

Mapping at the 1:50,000 scale was carried out through air photo interpretation (scales ranging from 1:31,600 to 1:50,000), with limited fieldwork. Unfortunately, I was unable to gain access to these maps for consultation. Within the area that was to be flooded by the Smallwood reservoir, the vegetation type described as "alder thickets" was observed to be found on lakeshores where the water level fluctuates greatly and frequently (Bajzak, 1971). Clearly, those surveys were limited in scope. The focus of Bajzak's studies was primarily on mature trees, and therefore ground vegetation received relatively little attention. Only 10 species of plants were listed as present in the alder thicket vegetation class. This low reported species richness was most certainly the result of a very cursory survey. The same data set reported only 15 species for "mixed wood forests" and 8 species for "black spruce forests". Only one species of willow, *Salix pedunculata*, was recorded for the thickets. This species may have been misidentified since it has been otherwise reported only for the Island of Newfoundland (Meades et al., 2000). Likewise, only one sedge was recorded, *Carex mainensis*. It has not been reported elsewhere for Labrador. Abundance of the various species was not estimated. The shrubs were described as typically 6 to 8 feet high. The following vascular plants were identified in this community type: *Alnus rugosa, Athyrium filix-femina, Calamagrostis canadensis, Carex mainensis, Equisetum arvense, Potentilla palustris, Salix pedunculata, Sanguisorba canadensis, Solidago macrophylla* and *Viola pallens* (Bajzak, 1971).

In the 2001 survey conducted for my study, a total of 45 species of vascular plants was observed in the four 200 m-long storage reservoir riparian sites. Seventeen of these were observed at only one of the sites. There was a range of 14 to 31 species per site. Many of the observations consisted of only single individuals.

Of the species reported by Bajzak, only three were observed in the 2001 survey of the storage reservoir sites: *Amelanchier bartramiana*, *Calamagrostis canadensis*, and *Equisetum arvense*. The latter is a common plant found in disturbed sites and waste places. *Calamagrostis canadensis* is a ubiquitous species observed throughout the region in riparian areas as well as wet roadsides and other disturbed sites. The others observed by Bajzak, including *Athyrium filix-femina*, *Potentilla palustris*, *Sanguisorba canadensis*, *Solidago macrophylla*, and *Viola pallens* are all species that were common to riparian sites in the downstream reaches of the river in recent surveys, but were not found by me at the reservoir sites.

Observations of species richness and structure on the storage reservoir shorelines are discussed further in section 5.6, where some comparisons are made with other areas of the watershed.

5.2.6 Potential Effects on Wildlife

> *Innu people lost valuable harvesting territory including the area around Kanekauanikau (Sandgirt Lake), and to the east of Meshikamau. Innu people from Sheshatshit continue to spend a lot of time in the country, and had the Meshikamau area not been destroyed by flooding, they would have continued to establish camps here. Today, camps are established just to the east of the flooded area at lakes such as Keshikashkau (Disappointment Lake) and Katshakutinau-nipi (Red Wine Lake)* (Innu Nation, 1998).

It is sometimes assumed that flooded areas will simply create new lake-like shoreline habitats to replace those lost under the deeper water. Unfortunately, since vegetation development in riparian habitats is so dependent on certain hydrological patterns, and reservoirs rarely operate to create similar natural fluctuations in water levels, the new habitats created are different and generally less biologically rich.

There is no doubt that extensive areas of former terrestrial habitat as well as wetlands including bogs, fens, streams, ponds, lakes and all of their riparian habitats were lost with the flooding of the main storage reservoirs. The regional carrying capacity in Labrador for species that inhabit those areas has certainly decreased. However, since no detailed baseline data exist, and no ongoing monitoring has been conducted, it is impossible to quantify the changes in wildlife populations.

Horace Goudie described some of his wildlife observations on the plateau area where he trapped decades prior to the hydroelectric development:

> *The most plentiful* [species] *around Lobstick Lake area was the muskrat, the water rat. You'd get a lot of mink. You'd get very few marten in my day up there, but then again the whole of Labrador was dead for marten in those days, you'd never get any anywhere. You'd get a lot of coloured foxes, not very many white ones. There were not very many lynx. The lynx would be down around the valleys of the larger rivers where the big trees are. Up there it is all small woods and all black spruce. It's open land. But you'd get a lot of foxes, muskrats, minks and weasels. No wolves at all. There were very few caribou in those days when I used to be up there. You'd see a few tracks here and there. We didn't used to bother them. There were always lots of ptarmigan and spruce grouse and we lived on those* (Horace Goudie pers. comm., 2005).

Species such as muskrat depend upon habitats with submerged vegetation along the shores in water that does not freeze to the bottom in winter (Banfield, 1981). Good vegetation cover adjacent to the shore and stable ice cover are also critical. Reservoirs with large drawdown zones do not provide such habitat.

In Figure 36 we can see the structure of the riparian vegetation in a typical small lake in an unregulated area just south of the Smallwood reservoir. A dense growth of shrubs, forbs and herbs forms a fringe bordering directly on the water's edge. Some emergent sedges and rushes are present. This would be typical of a small lake or pond with slow current in an area of relatively fine glacial till. Spring floods would not be of the same magnitude as would occur along the main courses of the former Churchill River, even on the plateau. There is little to no remaining riparian habitat of this type in the storage reservoirs today. The natural lake in Figure 36 would provide relatively high quality breeding habitat for dabbling ducks, geese, loons, muskrats and beaver.

Figure 36. A Small Unregulated Lake South of the Road to the Lobstick Control Structure (Photo: A. Luttermann, 2001).

A Canadian Wildlife Service report in 1973 stated that, at the time of surveys conducted between 1970 and 1972, the Ossokmanuan reservoir which was created in 1962 did not "support any number of breeding or moulting Canada Geese or any other waterfowl" (Gillespie and Whetmore, 1973:18). More recently, Goudie and Whitman estimated that about 1.4 x 10^3 km^2 of high quality waterfowl nesting habitat, or about 10% of that originally present in the Lake Plateau region, was lost in the flooding of the reservoirs (Goudie and Whitman, 1987). These authors noted that new shorelines in reservoirs with fluctuating water levels would offer low-quality nesting habitat. They also acknowledged other areas of the watershed would experience important effects, including reaches with reduced flows and the river downstream of the generating plant (Goudie and Whitman 1987).

General observations of habitat quality provide a good indication of current and future potential. In referring to the Smallwood reservoir, Horace Goudie stated:

If you go around down by those lakes here you're not going to find any loon's nests. Or any other kind as far as that goes. You know, there are a lot of other kinds of birds like black ducks and mallards, and mergansers and so on, they like to lie *out on those little islands in the lakes. But they are always bordered with willows next to the water. So it's thick for any kind of enemy to get through to them, and they go in through that into the bushes, and then they make their nest and if something tries to get at them, the willows and stuff are so thick they will hear them coming... Anyway, you're not going to see nothing like that on the reservoir. So that's all gone. They can't lay anywhere in there. If they did, they'd get their eggs laid tonight, and they're sitting on them ... tomorrow morning they might be floating away, that far under water* (Horace Goudie pers. comm., 2005).

He also talked about the effect that the loss of riparian vegetation would have on populations of songbirds:

That would make a big difference to small birds...probably the worst of all. You would often go in to set a trap, you would walk in through the willows, now that is in the fall now or in the winter, or just go in through the willows to the bank to make a fire for a cup of tea or something, and lots and lots of times you're just walking through that much willow, about eight feet, and there's a little bird's nest right there. So if you walked the whole beach like that you'd see an awful lot. So, they can't lie in the willows any more, at least not as much away from the water. And they like to be a certain distance from the water, a lot of those little birds do. No, they've got to have a lot of willows, and they've got to have a nice broad beach (Horace Goudie pers. comm., 2005).

What can be assumed is that the existing storage reservoirs provide poor potential for any species that require dense vegetation close to the water's edge during the breeding season, and more or less consistent water levels and ice cover during the winter. This would largely exclude breeding waterfowl, amphibious mammals, and passerine birds that nest preferentially in alder/willow thickets or sedge and grass meadows close to the water. Birds such as ptarmigan are known to frequent low-lying areas in river valleys in winter where there is good forage. Many species make use of the fresh growth of herbs and shrubs along river and lakeshores for part of their territories. Hares require dense ground cover and may not do well in a region if the only habitat available is the open drier upland areas without riparian forest. Porcupines make use of a wide variety of habitats, but local elders state that they do use the herbaceous and shrubby vegetation of riparian areas.

5.2.7 Aesthetic Considerations

A common comment among people who were interviewed and others who have seen the reservoirs is that they are extremely unattractive. Apart from the areas with built infrastructure such as dikes, control structures, quarries, roads, or transmission lines, this view is largely due to the nature of the shorelines. The extensive, wide, rocky shores, bare of vegetation aside from the piles of dead trees, are not part of the natural inland landscape. They appear superficially more like marine cobble beaches. Indeed the daily water level fluctuations in a portion of the riparian zone mimic tidal variations to some extent. Unfortunately, few inland plants are adapted to live under such conditions.

George Gregoire, an Innu living in Utshimassits at the time, recounted his perspective during a community consultation on hydroelectric development:

> *In the '60s and '70s, I was in the Meshikamau area. We paddled from the overflow, Piastepeu, to Kainipassuakamat* [Lobstick], *Kanekuanikau* [Sandgirt], *Nuskuau-shakaikan* [Flour] *Lakes and to the place where the town of Churchill Falls is now. We portaged from Nuskuau-shakaikan to many different ponds, and the last pond where we camped is where the dikes are built near Churchill Falls. Now the place is totally unrecognizable. The beauty of the land and ponds is no longer* (Innu Nation Hydro Community Consultation Team, 2000:25).

Later, while flying over the Robert Bourassa reservoir on the La Grande River system in Québec during a site visit, George Gregoire asked me why I was writing down all of the facts and figures being presented to me by a Hydro Québec biologist. I replied that I was collecting information that community members had requested; information that helped to describe how the land had changed due to the hydroelectric projects in that region. He responded that all the facts and figures were not necessary to understand how the landscape had changed. "Just look at it down there" he exclaimed, "It's a mess!" (George Gregoire pers. comm., 2001).

5.3 Forebay Reservoirs

5.3.1 Hydrological Changes in the Area of the Forebay Reservoirs

The west and east forebays are the two control reservoirs that receive water through the Lobstick control structure and divert them north of the former river channel to the powerhouse intake. These reservoirs flooded most of the former Flour Lake and adjacent Sandgirt Lake to the west, and Jacopie Lake to the east, and serve to maintain appropriate water levels at the intake structure. Stable water levels during the winter months, especially in the east forebay, ensure adequate ice cover to prevent the build up of frazil ice[17] which forms in open water. Frazil ice could potentially obstruct the control and intake structures.

The Churchill Falls (Labrador) Corporation (CF(L)Co) operates the Lobstick control structure to maintain water levels in the west forebay from May to October between 449.6 m and 452.9 m (Figure 37). There is no spring flood and the shorelines within the drawdown zone are subjected to daily water level fluctuations trending upwards slightly throughout the growing season. This pattern is not conducive to the growth of most riparian plants. In the winter months, from November to April, the levels in this reservoir vary only a couple of decimeters between 452.54 m and 452.72 m. This is to keep a steady ice cover upstream of Jacopie Structure. Ice scour is thus probably not an important factor in shaping the shoreline vegetation. However, as water levels drop in late spring, a thick ice cover may settle on the shores and would crush larger shrub stems. Under these conditions, it is unlikely that woody vegetation could become established on these shores.

The east forebay is maintained at between 447.96 m to 448.15 m from May to October, and from 447.60 m to 448.21m between November and April (CF(L)Co pers. comm., 2005) (Figure 37). The east forebay will vary in the winter more than during the summer months as there is a large volume of water coming from Lobstick to maintain the forebay while supplying the turbines with water for the required load. Due to the three-day travel time for the water leaving Lobstick before it reaches the east forebay, the elevation may vary by as much as a half a meter at times due to continual changes in load requirements. Overall, the active riparian zone is narrow in the east forebay.

The control reservoirs function in a manner similar to a run-of the river impoundment, in that water levels throughout the year are largely evened out compared to natural lakes and rivers, and there are continual daily fluctuations (Jansson et al., 2000). The active riparian zones are therefore smaller and more continually disturbed. Following inundation, the new shorelines in these reservoirs were established in former upland habitat of spruce/lichen forest, with few if any remnants of former riparian communities. These conditions would be expected to produce relatively poor riparian

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[17] Frazil ice is the first stage of ice formation in turbulent, supercooled water. It is composed of fine spikes and plates, forming a slushy mass.

habitat. The few observations made in the forebay reservoirs (only two sites were formally surveyed) suggest that this is the case.

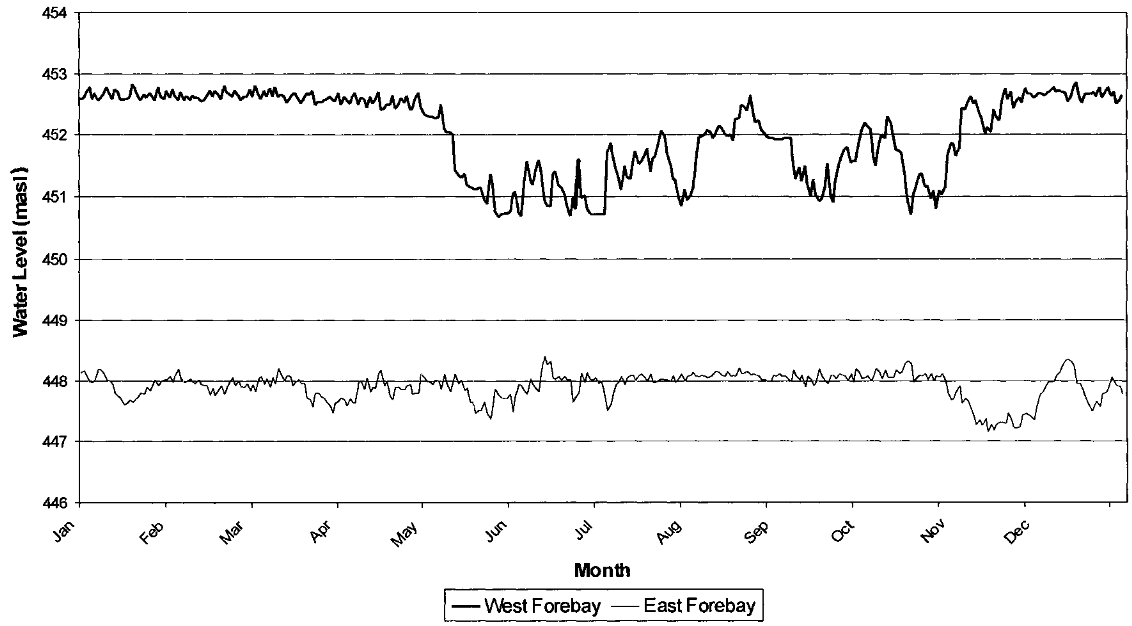


Figure 37. Daily Forebay Water Levels in 2001 (Data source: Churchill Falls (Labrador) Corporation).

5.3.2 Riparian Vegetation Observed in the Control Reservoirs

The individuals consulted identified the forebays as areas that previously had relatively rich wildlife habitat especially for waterfowl, with shrubby shorelines providing plenty of cover. Species richness recorded at the forebay survey sites was 18 to 24, within the range of the storage reservoirs. Vegetation cover was low (<20%), and many species recorded were sparse or single individuals. Substrates were relatively coarse. There was no apparent zonation in the plant cover. Large woody debris was abundant on the shores.

A site was surveyed in the West Forebay control reservoir along the shore of an island in the vicinity of the former meandering river channels of the Churchill River near Jacopie Spillway (Figure 38). The average width of this site was 12 meters. The 200 m-long section of shoreline rounded a sharp point. The portion that was more exposed to stronger winds and wave action was almost bare of vegetation. A total of 24 species was recorded here. Some scattered sedges, Salix spp. and Vaccinium spp. were found in the more sheltered portion. There were no shrubs within the riparian zone and few were observed on the shores in the other parts of this reservoir visited. The majority of plants recorded in the survey plot were upland species growing on small slumps eroded into the riparian zone from the forest in the upper part of the zone. All of the plants that were observed in the middle and lower zones appeared scoured and stunted. Scattered individuals of *Juncus filiformis* and *Equisetum sylvaticum* were the only plants in the lower zone close to the water's edge. Only *Juncus filiformis* appeared to be relatively comfortable here, but it was not thriving.

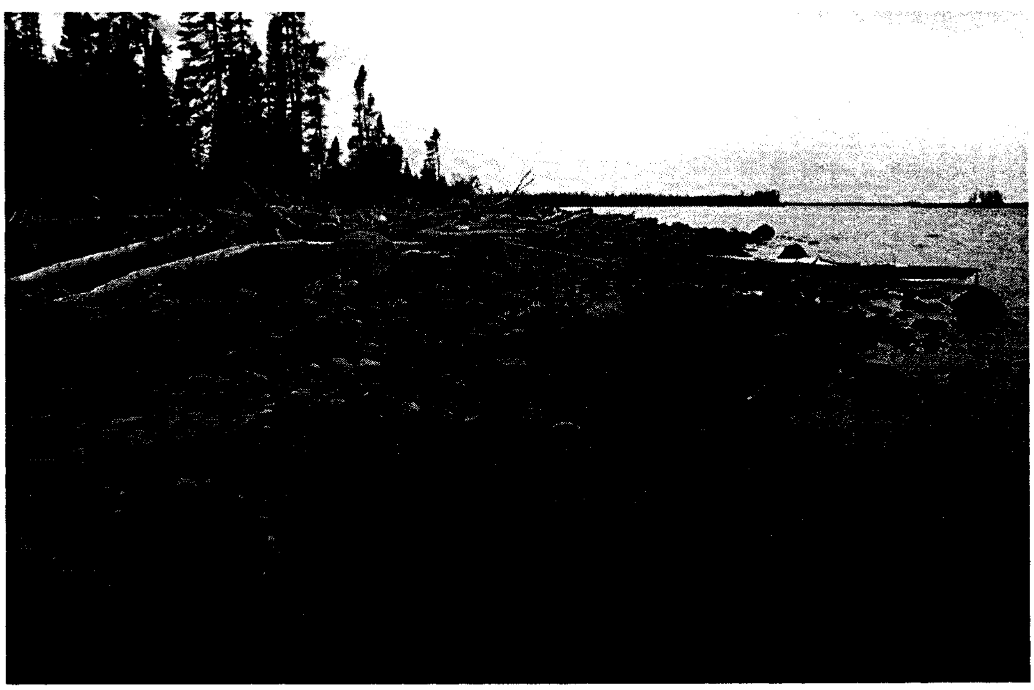


Figure 38. West Forebay Control Reservoir (Site 30). The author's 5 m-long sea kayak on the shore provides scale. Note the clumps of *Juncus filiformis* dislodged and washed up on the rocks (Photo: A.Luttermann, 2001).

Several species that were previously recorded by M.T. Doutt (Abbe, 1955), on the shores of Flour and Sandgirt Lakes, were not observed on any of the reservoir shores in my surveys. In mud along the rocks in shallow water of Flour Lake, she found *Isoetes* *muricata* (syn.*I. echinospora*) and *Ranunculus trichophyllus* var. *eradicatus* (syn. *R. aquatilis* var. *eradicatus*). Doutt described the "usual willow-alder zone along the lakeshore" where she found *Polygonum viviparum* (syn. *Persicaria vivipara*), *Viola adunca* var. *minor* (syn. *V. labradorica*), and *Habenaria dilatata* (syn. *Platanthera dilatata* var. *dilatata*) (Abbe, 1955:25).

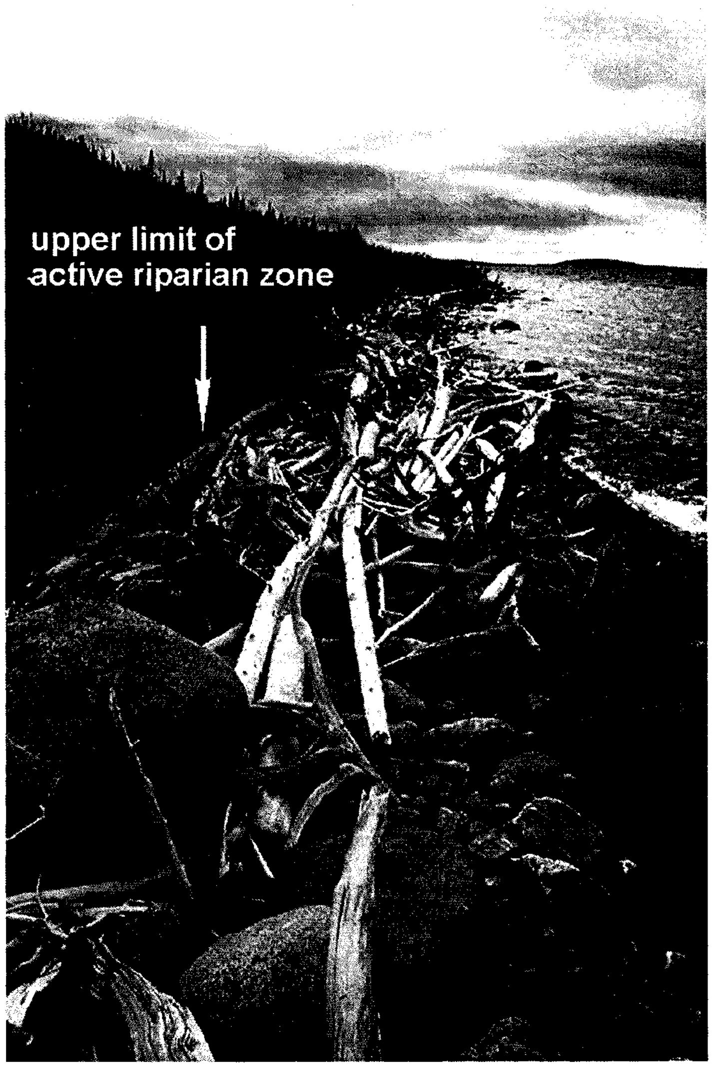


Figure 39. The East Forebay Control Reservoir (Site 25).This reservoir has a narrow active riparian zone with little vegetation cover and low species richness (Photo: A.Luttermann, 2001).

Survey work conducted during my study was limited, and more observations should be recorded in this area before any conclusions can be made about the potential presence of species documented by Doutt. It is probable that they do not persist on the immediate shores of the control reservoirs due to the daily fluctuating water levels. They may be common along streams and ponds in the surrounding area that are not affected by hydrological regulation.

In the east forebay, where there is a narrow active riparian zone, the site surveyed had an average width of only 3 meters over 1.2 meters of elevation (Figure 39). Here some sparse shrubs fringe the upper part of the shore with *Alnus viridis* being the most abundant. All other species recorded were present only as one or several individuals in the plot, including three species of willows, ericaceous shrubs, carices, and a few upland species. A total of 18 species was recorded, all growing on the upper shore just above the stranded woody debris. There were no living plants observed close to the water line. River beauty (*Chamerion latifolium*) did occur at this site. This is a common riparian species, especially on rocky shores adjacent to fast moving water.

Although the focus in my study was on the riparian zone above the low water mark, it was noted that aquatic macrophytes in general were rare in all of the reservoirs and only somewhat less so in the downstream reaches. No aquatic macrophytes were observed in the storage or control reservoirs during the survey work. It may be that they were never common in the faster moving reaches of the main river. However, observations from the past suggest that at least some areas along the main course of the river on the plateau in areas that are now part of the control reservoirs did support submerged aquatic macrophytes that were relatively common. For example, an account of an expedition to the Grand Falls in 1937 by Paul Provencher, a forestry engineer, sportsman, and outdoor columnist along with a trapper Félix Poitras, Emile Sévigny and Donat Picard, an Innu guide from Québec, tells how using the trapper's advice, they regularly checked the "movement of underwater weeds" to determine whether there was a current when trying to find their way in the labyrinth of islands in Jacopie and Flour Lakes (Provencher, 1970).

Sandgirt, Flour, and Lobstick Lakes and the delta of the Mackenzie River tributary were known to have formerly provided good breeding habitat for waterfowl, especially for Black Duck and Canada Goose (Keast, 1973). There was abundant shrub cover close to the water's edge along the shores of islands and the mainland throughout these lakes and rivers on the upper plateau. There were also many low-lying islands and point bars covered with dense grasses and sedges (Keast, 1971). This would have provided goslings and ducklings with good nesting sites and cover from predators close to the water's edge.

Keast (1973) stated that good waterfowl breeding habitat was patchily distributed in the Churchill Falls area and that there was not much of it overall. Flour Lake in particular was observed by Keast and local hunters to host higher breeding density than many of the smaller ponds in the area. The region now centered on the Smallwood reservoir was considered by biologists and local trappers to have some of the most productive waterfowl habitat in all of Labrador (Keast, 1971). After the waterfowl survey work conducted in the early 1970s in the area flooded by the Smallwood reservoir, there have been no long-term follow up monitoring studies to evaluate the trends in waterfowl populations in the large storage reservoirs. With little to no riparian vegetation along the shoreline, it is unlikely that the forebay reservoirs now support productive waterfowl breeding.

5.4 Reduced Flow Reaches

The design of the reservoirs and the nature of the operating regime of the hydroelectric facility results in the diversion of flow from several lake expansions and portions of rivers in the basin and adjacent basins. As mentioned previously, the flow of the upper Naskaupi and Kanairiktok river watersheds has been diverted into the Smallwood reservoir.

The Unknown River, including the flow over two sets of twin falls, was diverted into the Ossokmanuan Reservoir and receives discharge from the plateau only if overflow spill capacity is needed, which has probably not occurred since the plant was constructed. Baikie Lake was entirely dewatered. A portion of Flour Lake between the main south of the Lobstick control structure and the forebay reservoirs is another extensive area subjected to reduced flow. It is now essentially an overflow area which could be flooded in the event of extremely high water levels in the Smallwood reservoir. The exposed beds of these dewatered lakes and rivers will have been colonized by vegetation in the intervening years, but are no longer subject to seasonal flooding. These areas should be investigated to document the vegetation succession taking place.

One recommendation that Keast (1971) made was that the operators of the hydroelectric facility should spill water regularly to try to maintain constant minimum water levels in reduced flow areas such as the Unknown River and portions of Flour Lake that previously provided good waterfowl breeding habitat. However, this is not part of the current operating regime, and even if it were, high quality shoreline habitat with good cover and forage may not be sustainable without substantial and regular spring floods.

During consultations with the Innu Nation community on hydroelectric development, some comments were made regarding observations along the Meshikamau-shipu [Naskaupi River] following regulation. Sebastien Penunsi stated that:

> *When they put up dikes on the Meshikamau-shipu [Naskaupi River], the river flow started to go down lower. I know one place called Utshishk^{u}-nipi [Muskrat Lake] in that area where there used to be plenty of muskrats living in that lake. They seem to be gone now, maybe due to what happened to the flow of water* (Innu Nation Hydro Community Consultation Team, 2000:37).

Joseph Mark added the following:

> *I traveled to Nisukaka [Orma Lake] and was surprised to see some ponds were nearly dried up in that area. I saw some familiar markings of beavers who had lived in those ponds. We never saw any beavers at all that time* (Innu Nation Hydro Community Consultation Team, 2000:37).

The Naskaupi River drains into Grand Lake and then into Lake Melville. The reduction in flow of the Naskaupi River has some effects right down to the mouth of the Northwest River channel entering Lake Melville from Grand Lake. Etienne Andrew of Sheshatshiu observed that:

> *The first thing we felt in Sheshatshiu when they dammed the Meshikamau-shipu* [Naskaupi River] *at Nisukaka* [Orma Lake] *was that we suddenly could not drink the water from the river in Sheshatshiu. The water from that river became salty. The high tide now went up as far as Kakatshu-utshistun* [Grand Lake]. *Before they dammed that river, we drew our drinking water from the river.* (Innu Nation Hydro Community Consultation Team, 2000:37).

The shoreline habitat in that short reach has thus experienced reduced water levels year-round as well as increased salinity. Local people have observed that the vegetation has changed, most specifically with brackish water species being seen further up the river than prior to the Churchill Falls project.

The issue of providing minimal water flows to try to reestablish and/or maintain certain ecological functions such as those that support healthy riparian habitat will be addressed in section 6.2.4.

5.4.1 Reduced Flow Reaches Above and Below Churchill Falls

The reach of the main stem of the Churchill River, 38 km above and 30 km below the vertical drop of the falls, has experienced an almost complete reduction in flow as the entire volume of the main stem of the river was diverted through a series of lakes and streams that have become control reservoirs before entering the intake for the generating station (refer back to Figure 13 on page 67). Two sections of this area above the falls were investigated briefly during the course of my study.

John McLean, a factor with the Hudson's Bay Company traveling through the area in the summer of 1839, provided the first written account of the character of the river at the falls:

> *... one evening, the roar of a mighty cataract burst upon our ears, warning us that danger was at hand. We soon reached the spot, which presented to us one of the grandest spectacles in the world .... About six miles above the fall the river suddenly contracts, from a width of from four hundred to six hundred yards; then rushing along in a continuous foaming rapid, finally contracts to a breadth of about fifty yards, ere it precipitates itself over the rock which forms the fall; when, still roaring and foaming, it continues its maddened course for about a distance of thirty miles, pent up between walls of rock that rise sometimes to the height of three hundred feet on either side. This stupendous fall exceeds in height the Falls of Niagara, but bears no comparison to that sublime object in any other respect, being nearly hidden from the view by the abrupt angle which the rocks form immediately beneath it. If not seen, however, it is felt; such is the extraordinary force with which it tumbles into the abyss underneath, that we felt the solid rock shake under our feet, as we stood two hundred feet above the gulf. A dense cloud of vapour, which can be seen a great distance in clear weather, hangs over the spot. From the fall to the foot of the rapid – a distance of thirty miles—the zigzag course of the river presents such sharp angles, that you see nothing of it until within a few yards of its banks* (Wallace, 1932:75-76).

To the typical road traveler through the region, this section of the river presents some of the most dramatic evidence of changes in the landscape created by the hydroelectric project. The gravel road that is now part of the Trans Labrador Highway (TLH) passes over the dewatered reach just a few hundred meters above the former falls (Figure 40). The only other parts of the river seen from the main road are a couple of sections passing over the Ossokmanuan Reservoir. The main stem of the river is not seen again from the road until the Town of Happy Valley-Goose Bay at the mouth.

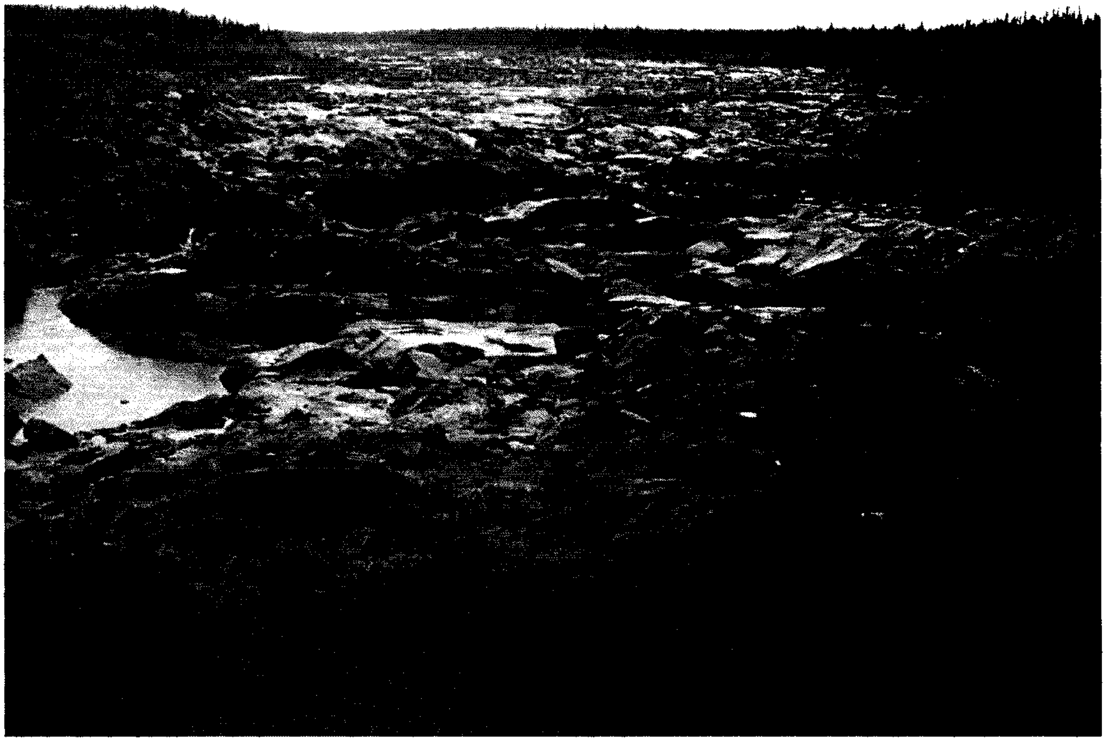


Figure 40. Dewatered Reach of the Main Stem of the Churchill River from the Bridge on the Trans Labrador Highway. Note the shrubby vegetation colonizing from the shores down into the former riverbed wherever sediment is trapped in fissures in the bedrock (Photo: A.Luttermann, 2000).

Most of the exposed riverbed where swift rapids formerly existed consists of coarse substrates including bedrock, boulders, cobbles and gravel. Little vegetation has colonized the middle of the channel, although shrubs are encroaching from the shore in many places. Plants are taking hold in cracks and crevices.

Just west of the bridge, one can walk a few hundred meters along a footpath to view the channel where the river once flowed over the precipice (Figure 41). The 85-m vertical drop into the gorge is spectacular, and one can now view the sculptured granite of the riverbed where it was worn by the passing of tremendous volumes of water at rapid velocity over millennia. However, the influence of the present water flow is trivial compared to that prior to the diversion.

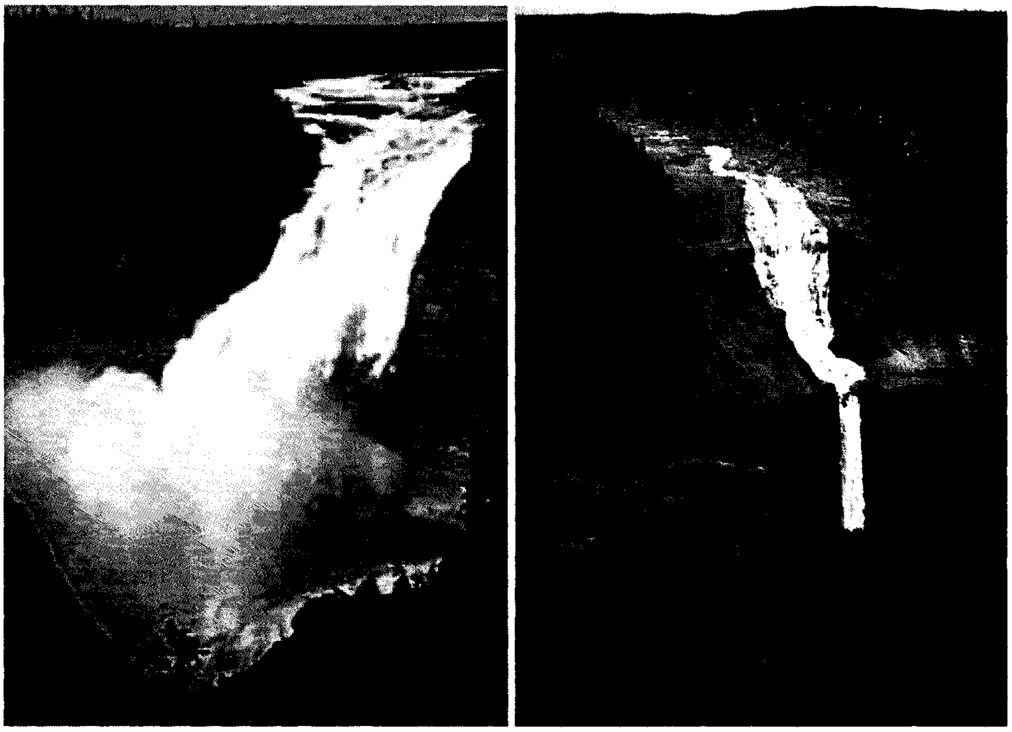


Figure 41. Views of Patsheshunau (Churchill Falls) Before and After Diversion. Note that the photos are taken from different angles (Photos: Newfoundland and Labrador Hydro, date unknown; A.Luttermann, 1998).

A.P. Low surveyed this area in the winter of 1894 while working for the Geological Survey of Canada (Low, 1896). His detailed description of this section of the river offers a sense of the physical conditions that existed prior to the diversion. Two of his passages are included here at length as they leave a graphic and audible impression of the power of the river and how it shaped the surrounding land, carving a great channel into solid granite over millennia.

> *Eight miles in a straight line north-north-west of the mouth of the cañon, the main branch of the Hamilton River issues from a small lake-expansion* [Jacopie Lake], *almost on a level with the surrounding surface of the table-land, and begins one of the greatest and wildest descents of any river in eastern America. ... in twelve miles, the total fall is 760 feet. Such a fall would be nothing extraordinary for a small stream, in a mountainous country, but is phenomenal in a great river like the Hamilton... The descent includes a sheer fall of 302 feet* [Since measured at 245 ft or 76 meters], *the rest being in the form of heavy rapids...*
>
> *The outlet of the lake is dotted over with small rocky islands, capped with dense thickets of evergreens. These islands extend downward for a mile and divide the river into a number of narrow channels with a swift current. The stream, flowing*

southward, then narrows to less than 400 yards, and in the next mile passes over a number of rocky ledges between low wooded banks, falling fifty feet in a continuous heavy rapid. Again it widens out to nearly a mile, and for two miles is obstructed by many small islands, flowing swiftly between them, with short broken rapids. Next, turning south-east, it contracts to less than half its previous width, and rushes along with heavy rapids, in a shallow channel filled with huge boulders, with low rocky shores, capped with thin deposit of coarse gravel and sand, and wooded above with spruce and larch. In this manner the river continues for three miles, gradually narrowing as it descends, with a fall of forty-five feet along the last two courses. The banks and bottom of the river are wholly formed of rock, and as the stream in the next mile has cut a narrow and gradually deepening trough out of the solid rock, at the lower end of the course it flows in a narrow gorge, with sloping rocky walls 110 feet below the level of its upper end. As it descends, its width decreases from 150 to 50 yards, and it hurries along with tremendous rapids (Low, 1896:140-141).

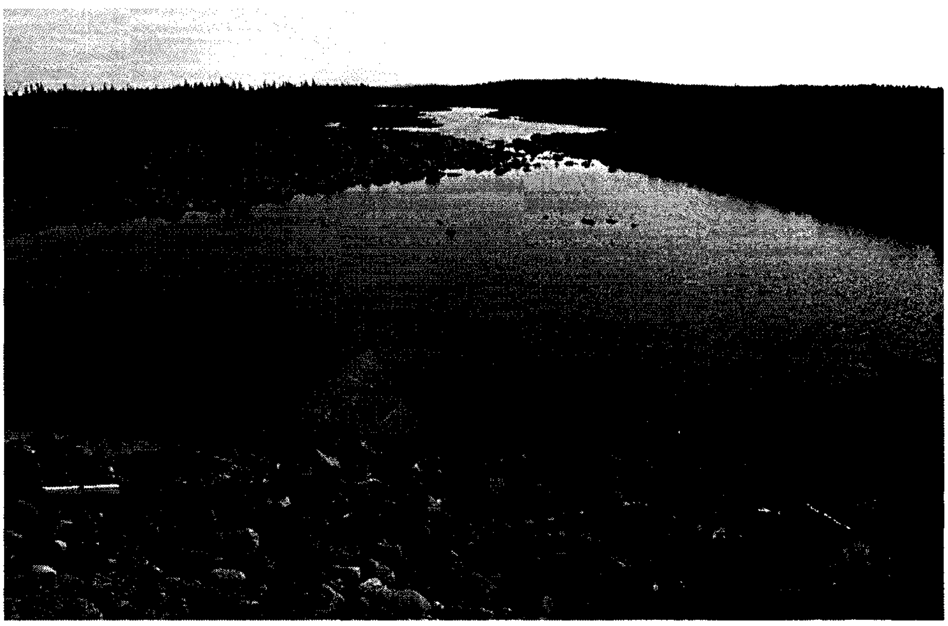


Figure 42. A Reach below the Jacopie Control Structure. The armoured side of a dike and concrete spillway are in the foreground. The former riverbed is largely exposed with some ponded areas in the former channel (Photo: A.Luttermann, 2001).

There is a small amount of lateral runoff from small streams along the diverted reaches, along with some minor leakage from the Jacopie control structure (Figure 42). This maintains some linear ponds connected by a small stream in the middle of the old river channel.

Water may be released into the original river channel through the Jacopie control structure under certain circumstances. For example, if the water levels are too high in the reservoirs, water can be spilled to avoid overtopping the dikes. However, this has not happened since the facility was built, because precipitation has been lower than predicted and the reservoirs have never been overly full.

Water can also be spilled through Jacopie if work needs to be done on the generating facility. This occurred periodically throughout the 1970s and up to 1981, as construction of generating units continued and operations were tested (see Figure 43). The largest releases were most often in the spring, although they were sporadic and did not conform to natural seasonal patterns. Nevertheless, the releases were of sufficient

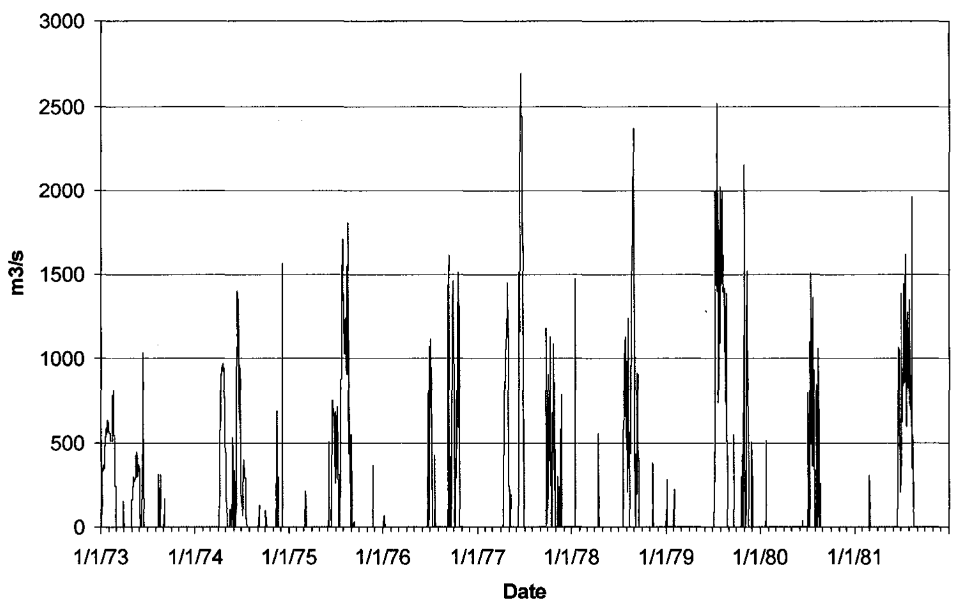


Figure 43. Releases from Jacopie Control Structure between 1973 and 1981. Over the first decade following commissioning of the first turbines at the Churchill Falls facility, water was sporadically released through the Jacopie control structure (Data source: Churchill Falls (Labrador) Corporation).

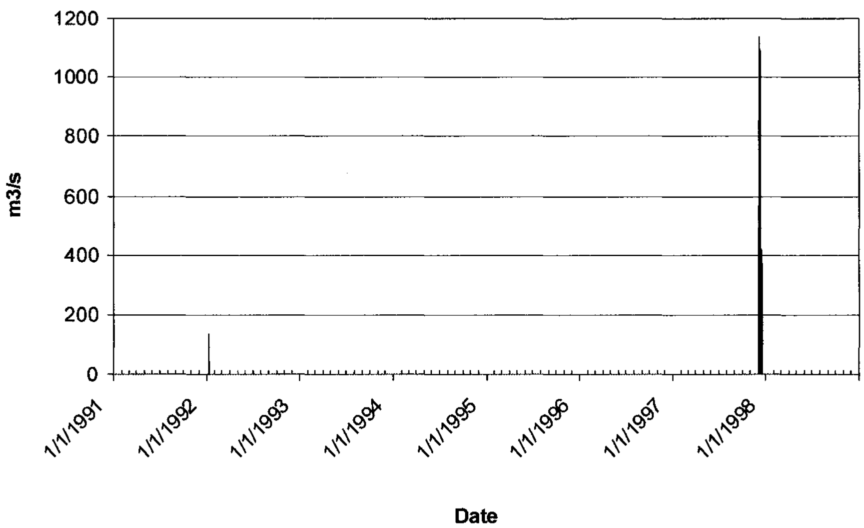


Figure 44. Daily Discharge from the Jacopie Control Structure between 1991 and 1998. During the 1990's almost no flow was released through this spillway except for a brief but substantial flow in December of 1997 shown above (Data source: Churchill Falls (Labrador) Corporation).

magnitude and frequency to keep the shoreline vegetation along the dewatered areas at earlier successional stages.

In subsequent years, there has been little discharge from the control structure (see Figure 44). There was no measured flow between 1982 and 1997 aside from a very small release of <200 m^3/s over two days in early January of 1992. In December of 1997, there were some higher flows released periodically over a total of seven days. On two days, flows exceeded 1000 m^3/s. Although this is less than half the magnitude of the previous typical spring flows over the falls, this sudden winter flow of water and probably ice would have removed many young plants that may have become established in parts of the channel.

Dense alder/willow thickets with a relatively diverse herb community have become established on portions of the former riverbanks which consist of boulders, coarse gravel, and cobbles (Figure 45 and Figure 46). In some areas, finer sediments have been deposited on the lower shorelines. In these finer-grained places, dense, shrubby vegetation has become established close to the shore, and on small islands composed of former riverbed sediment. In combination with the slow flow conditions, these areas provide cover and good breeding and rearing potential for some species of aquatic mammals and waterfowl.

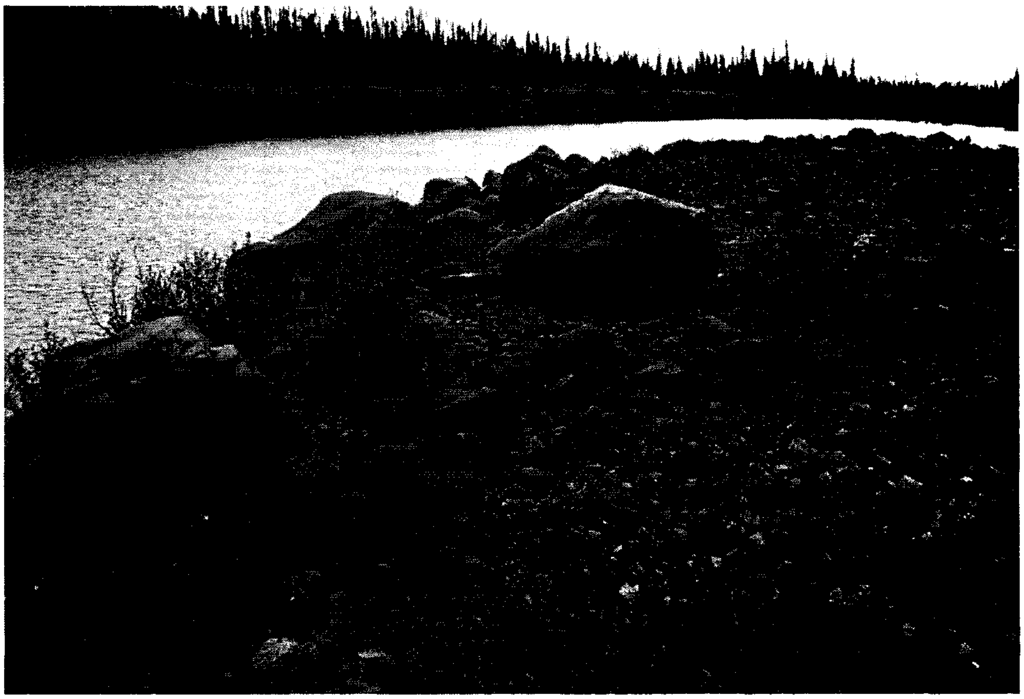


Figure 45. A Reduced Flow Reach Downstream of the Jacopie Diversion Dam and Control Structure (Site 29). Shrubs are colonizing the bouldery banks of former rapids (Photo: A.Luttermann, 2001).

Waterfowl observed incidentally during the surveys of the reduced-flow reaches at sites 27, 28, and 29 included Arctic and Common Loons, Black Duck, Canada Goose, and Common Merganser. The quality of riparian habitat along this reach may be similar to the shores of Jacopie and Flour Lakes just upstream prior to their impoundment as forebay reservoirs. However, the habitat conditions here are not necessarily stable due to the possibility of releases through the Jacopie control structure.

Figure 46. A Reduced Flow Reach Downstream of the Jacopie Control Structure (Site 27). Dense shrubs have colonized riverbed sediments adjacent to a linear pond in the former river channel (Photo: A.Luttermann, 2001).

The substrate of the reach of river just above the brink of the falls is composed of granite bedrock and large boulders (refer to Figure 40). Water flow in these sections is reduced to a small stream in the middle of the old bedrock riverbed. Under natural flow conditions, these areas would have been heavily scoured by the rapid flow above the falls. As with the reaches further upstream, this part of the river will receive any substantial flow only under rare circumstances.

Survey site 34 is located on the west side of the river. In 2001, plants were observed growing primarily in sediment collected in fissures in the bedrock of the former riverbed. A total of 57 species of vascular plants was observed along this reach. These were predominantly herbs and shrub seedlings. Two species of herbs recorded along the shore here in 1939 by M.T. Doutt (Abbe, 1955) were not observed during my survey – *Parnassia palustris* L. var. *neogaca* Fern. and *Sagina nodosa* (L.) Fenzl subsp. *borealis* G.E. Crow. The latter species was recorded only at two downstream sites in 2001, and the former was not observed anywhere on the river shores.

This area was not generally used in the past for hunting or gathering, although people did walk overland from the main travel route through Jacopie Lake to view the falls. Elders who had visited the area prior to the river diversion did not have any specific comments about changes in vegetation here, except to mention the growth of thicker shrub cover directly across from the falls. The reduction of flow through the former river channel and over the falls is so dramatic, that these changes are what tend to be most noted.

5.4.2 The Spray Zone of the Former Churchill Falls

The following description by A.P. Low (1896) makes audible the distinct presence that the falls had on the landscape, now virtually silenced by the diversion of its waters:

> *The last 300 yards are down a very steep grade, where the confined waters rush in a swirling mass, thrown into enormous, long surging waves, at least twenty feet from crest to hollow, the deafening noise of which completely drowns the heavy boom of the great falls immediately below. After a final great wave, the pent up mass of water is shot down a very steep incline of rock for 100 feet, where it breaks into a mass of foam, and plunges into a circular basin below, the momentum acquired during the first part of the fall being sufficient to carry it well out past the perpendicular wall of rock at the bottom, leaving almost a free passage between the foot of the cliff and the falling water.*

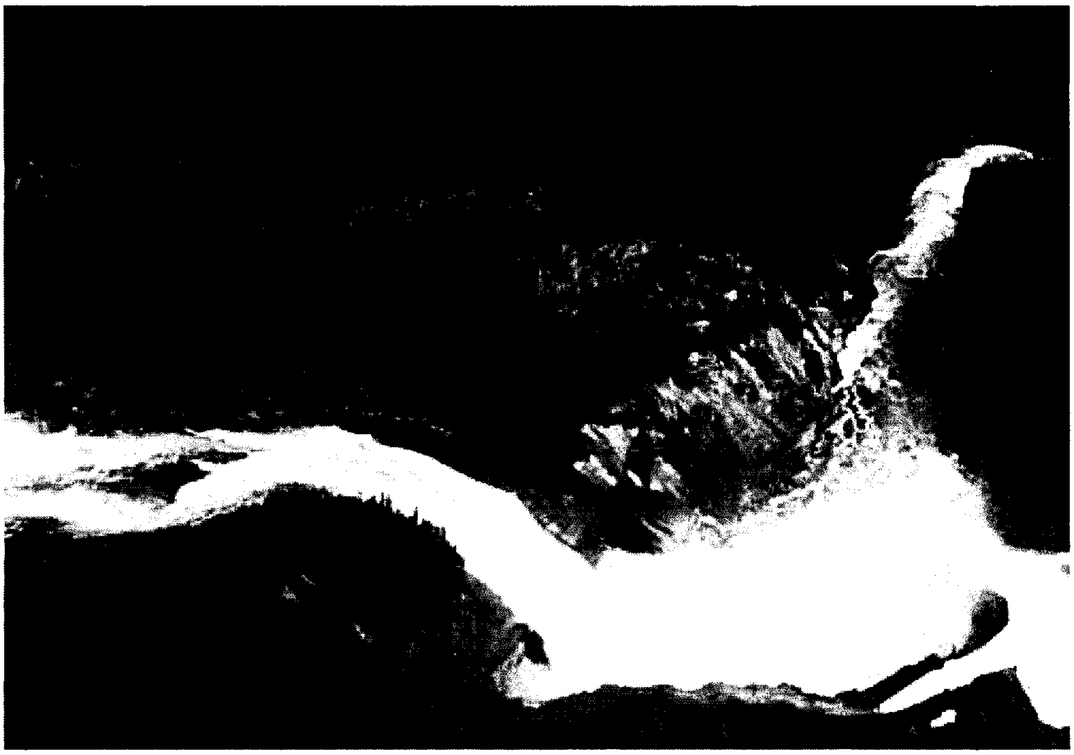


Figure 47. A View of Churchill Falls Prior to Flow Diversion. Note the enduring snow bed in the spray zone directly opposite the falls (Photo: Geological Survey of Canada, date unknown).

The shape and character of this fall resembles closely, though on a gigantic scale that of a small stream flowing down a V-shaped trough, inclined at a high angle, and issuing freely from its lower end. The basin into which the river precipitates itself, is nearly circular and about 200 yards in diameter. It is surrounded on all sides by nearly perpendicular rocky walls 500 feet high, except at the narrow cut at the head of the falls, and where the river issues from the basin. The surface of the basin is violently agitated by the rush of water from above, and its huge lumpy waves break high up the rocky walls. The falls are best seen from the top of the south wall, directly opposite, but the dense columns of vapour that rise out of the basin often interfere with the view, and give a blurred, fogged appearance to photographs taken from that side. The noise of the fall has a stunning effect, and, although deadened because of its enclosed situation, can be heard for more than ten miles away, as a deep, booming sound. The cloud of mist is also visible from any eminence within a radius of twenty miles (Low, 1896:141).

It is clear that the spray from the falls was persistent, given that Low observed it in winter when the flow would have been much lower than other times of the year. Now, as George Gregoire has observed:

The once beautiful and mighty Mishta-Paushtuk is almost dried up. The cold mist that would rise up in the winter is no longer visible. No more rainbows can be seen from the falls (Innu Nation Hydro Community Consultation Team, 2000:25).

The dewatered falls can now be viewed from a platform along a trail, with the highway bridge in the distance upstream (Figure 48). The silencing of this former wonder is a stark example of the capacity of this engineering project to influence this mighty river, and is symbolic to many people of the magnitude of the landscape level changes that have occurred.

The former spray zone of the falls is an area along the top of the cliffs opposite the former falls (Figure 47). This is not a seasonally flooded riparian zone, but it is an area that received an almost constant heavy mist of river water caused by the turbulence of the flow over the falls. It is also one of the few areas in the watershed that received any research attention to investigate the potential effects of flow regulation on vegetation. My brief investigation of the former spray zone provides observations on the general character of the area and indications of how it has changed since the spray was eliminated.

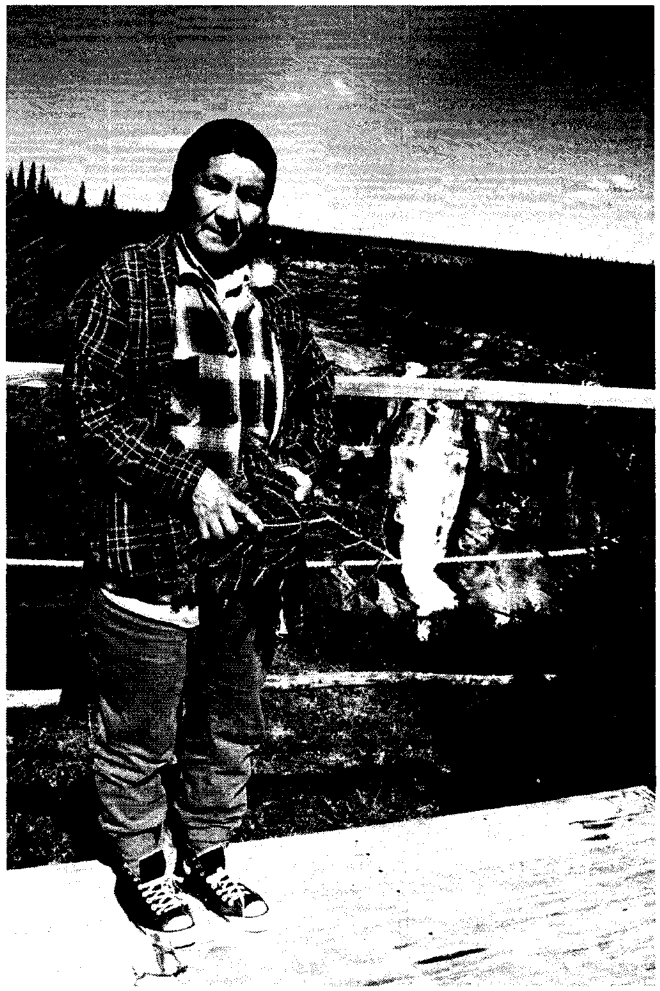


Figure 48. Elizabeth Penashue Overlooking the Precipice of the Mishta Paustuk (Photo: A.Luttermann, 1999).

Spray zones are relatively stable environments in contrast to riparian zones that are periodically disturbed by seasonal cycles of ice scour, flooding, shear stress, and relative desiccation. In areas of intense spray, cooler temperatures coupled with snow and ice that persist late into the summer can delay the phenology of plants and prevent a typical forest cover from developing. The plant communities that develop under these conditions can be unique within a regional context.

Just after the initial partial diversion of the falls in the early 1970s, a survey of vascular plants and bryophytes was conducted in the spray zone of Churchill Falls where a year-round regime of high moisture was suspected of providing a microclimate favourable to hydrophilic plants and potentially endemic mosses (Brassard et al., 1971;

Brassard, 1972).

In 2001, I surveyed roughly the same area covered by Brassard et al. (1971), based on the general description of the survey site in their preliminary report. In addition, vascular plants were recorded along the footpath leading from the road to the spray zone, with forays to the edge of the cliff and pond areas. Because this survey was conducted in early September, it was late in the season to observe diagnostic features of some species.

I observed 68 species of vascular plants in the area of the former spray zone. Only eight species were recorded that were not observed in any of the other riparian sites along the river. These are species typical of mature boreal forest (*Clintonia borealis*, *Schizachne purpurascens* subsp. *purpurascens*), bog habitats (*Andromeda polifolia, Carex limosa, Menyanthes trifoliata, Scheuchzeria palustris* subsp. *americana*), clearings in woods and open slopes (*Fragaria virginiana* subsp. *glauca),* or that have an arctic affiliation (*Salix arctophila*).

The forest around the tops of the cliffs opposite the former falls consists of tall stands of large *Abies balsamea* (this species is not abundant in the surrounding upland forest), *Picea mariana,* and *Picea glauca.* Individuals of all of these species have grown relatively large in the area formerly affected by the river spray compared to adjacent forest stands. This is consistent with previous observations (Brassard et al., 1971). A rocky, north-facing slope on the upper edge of the cliff directly opposite the falls was previously kept free of trees and shrubs by the constant moisture and build up of ice and snow (see Figure 41 and Figure 49). This was the area that was most directly influenced by intense spray throughout the year.

The dominant species contributing to the plant cover in that area documented by Brassard et al. (1971) were *Carex stylosa*, *C. atratiformis*, *Calamagrostis canadensis,* and *Poa alpina*, while the prostrate *Salix arctophila*, *Streptopus amplexifolius* var. *americanus*, and *Rubus pubescens* were also prominent components. Dense thickets of tall alders and willows including *Salix humilis* var. *humilis*, *S. pellita* and *S. planifolia* are now colonizing this area (Figure 50). Moose droppings were noted along the top of the cliff.

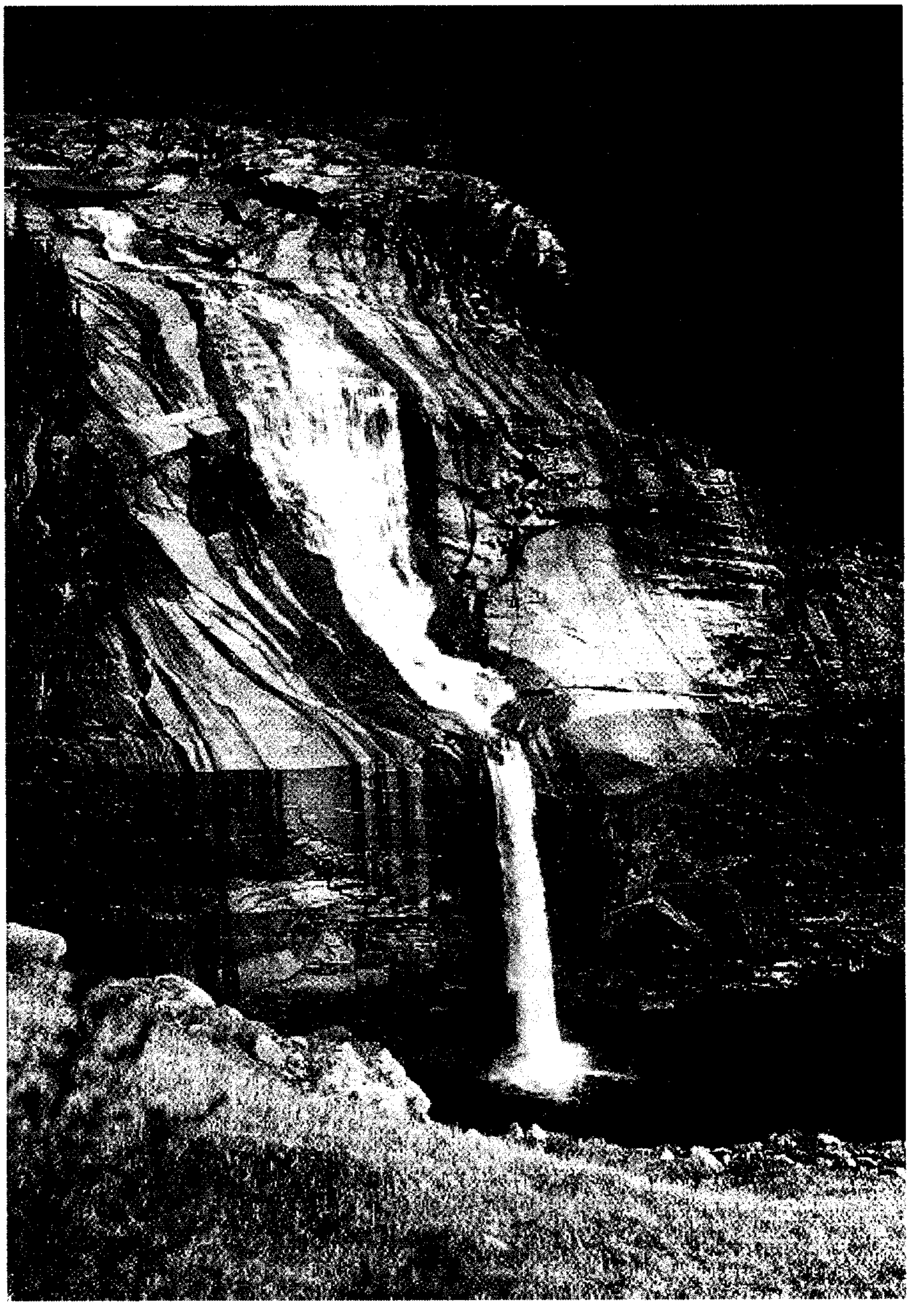


Figure 49. An Image of the Dewatered Falls Shortly after Diversion of the River. In the foreground is the zone of low herbs in the former spray zone (Photo: Newfoundland Tourism, circa 1974).

Figure 50. Dense Shrubs Colonizing an area of the Former Spray Zone. This area was previously dominated by herbs and graminoids. (Photo: A.Luttermann, 2000)

A former pond on the west side (described in Brassard et al., 1971) was dry in 2001. The largest middle pond is still wet in its middle and there is seepage over the cliff. The edges of the pond formerly blanketed with thick mosses are growing up with young spruce (Figure 51).

The following species were recorded in the spray zone by Brassard et al. (1971) and by M.J. Doutt (Abbe, 1955) but were not observed during my 2001 survey either in the former spray zone or at any other sites along the river:

- *Carex stylosa* var. *nigritella*
- *Platanthera dilatata* var. *dilatata* syn. *Habenaria dilatata* [white bog orchid]
- *Poa alpina* [alpine blue grass]
- *Arabis alpina* subsp. *alpina*
- *Persicaria vivipara* syn. *Polygonum viviparum* [alpine bistort]

Parnassia kotzebuei was recorded by Brassard et al. (1971) but not by M.J. Doutt. *Epilobium ciliatum* subsp. *glandulosum* was recorded by Brassard et al. (1971) in the spray zone, and by M. J. Doutt (Abbe, 1955). It was not observed in the 2001 survey of the former spray zone, but was observed at other riparian sites along the river.

Figure 51. A Previously Open Wet Meadow in the Former Spray Zone Growing up in Spruce (Photo: A.Luttermann, 2001).

The understory vegetation of the surrounding forest consists of many species typical of rich boreal forest in the region, including abundant: *Cornus canadensis*, *Clintonia borealis*, *Coptis groenlandicum*, *Trientalis borealis*, *Linnaea borealis*, *Lycopodium annotinum, and Athyrium filix-femina* var. *angustum;* scattered *Alnus crispa*, *Rubus pubescens*, *Senecio* c.f. *congestus*, *Ribes glandulosum*, *Betula papyrifera*, *B. cordifolia*, *Salix* cf. *planifolia*, *Viburnum edule*, *Streptopus amplexifolius*, *Equisetum sylvaticum*, *Calamagrostis canadensis*, *Carex* cf. *atratiformis*, and *Rhododendron groenlandicum*. A small fen along the footpath had abundant bakeapples (*Rubus chamaemorus*) in deep mats of *Spaghnum* spp.. The forest understory flora included several species of gilled fungi and boletes, and lush foliose ground lichens.

As expected, the former spray zone is drier than at the time Brassard et al.

conducted their surveys. Without the constant spray, the late snow beds no longer persist across from the former fall. Areas that were previously dominated by herbs are now succeeding to shrubs and young forest.

5.4.3 Bryophytes in Spray Zones

Brassard (1972) conducted a study of the bryophyte flora of the spray zones of Churchill Falls, two waterfalls on the Unknown River, and a falls on the Portage River, a small tributary joining the Churchill just downstream of the tailraces. The flows over all of these falls have been diverted. Those on the Unknown River had already been diverted by the Twin Falls power plant several years prior to Brassard's work. He reported a total of 130 species of bryophytes for the four sites. The Churchill Falls spray zone was the largest with the most diverse habitat and hosted 92 species. Brassard suggested that this site had some of the best-developed bryophyte flora in Labrador. This is in contrast to much of the landscape across central Labrador where bryophytic vegetation is widely out- competed by lichens. The other spray zones all had between 41 and 46 species. There were 23 species that Brassard suggested may be mostly restricted to the spray zones of waterfalls. Certainly, the constant moisture in spray zones allows many species to thrive particularly well. However, he surmised that more likely, these species would be found more widely in central Labrador particularly in other moist, relatively nutrient rich sites, such as the shores of large lakes and rivers.

Indeed when Brassard surveyed the shores of the river from one to five miles upstream of Churchill Falls, he found seven of the species that occurred in the spray zone but were not found elsewhere in the surrounding area. This investigation also revealed five additional bryophyte species close to the high-water mark of the river that were not observed in the spray zones or anywhere else in the area. Prior to diversion, this reach of the river had high flow and fast, wild rapids which may have also created an exceptionally moist environment similar to a spray zone.

The species identified in the spray zone were mostly wide-ranging and sub-arctic (boreal) in geographical affiliation (Brassard, 1972). There were also several taxa with a more southerly range and some arctic species. Brassard observed that the bryophytes found in central Labrador in general are predominantly acidophilic, but that in the spray zones of the waterfalls calciphilic species are regularly found. As with the surrounding landscape, the bedrock in these areas is composed of non-calcareous Precambrian rocks such as granites, gneisses and schists. He suggested that the additional moisture and nutrients from the river probably helps to temper the influence of the acidic substrates and allow calciphiles to become established. Thus, there may be some similarities in growing conditions between spray zones and the high riparian zones along the main rivers that favour more calciphilic species.

Certain of the rarer species would be expected to decrease or disappear from the spray zones that have been dried up by river diversion. Brassard postulated that some local extirpations may result but did not predict a decrease in the bryophyte species richness of the area as a whole. As far as I am aware, the biogeography of the bryophyte flora along the rivers or throughout the region as a whole has not been well studied. Given the widespread summer drawdown of extensive areas of shoreline in the region, one wonders whether the bryophyte flora may have been degraded by river regulation. It is also not known what the function of large river corridors and lakeshores may be for the dispersal of these species.

Brassard referred to the low fog cover frequently observed lying in the Churchill River valley, and generally extending only marginally beyond the banks. He suggested that this would undoubtedly increase the precipitation along the river shores, adding to the favourable microclimate for plants requiring higher moisture and nutrients (Brassard, 1972). It is not known whether the frequency of summer fog in the river valley has changed since river regulation.

A re-survey should be conducted to compare the bryophytes and vascular plants in the extinct spray zones with the observations made by Brassard in the early 1970s. Future surveys of the riparian zones of the rivers should include bryophyte flora.

5.4.4 Bowdoin Canyon and Below

A.P. Low (1896) described the gorge, since named Bowdoin Canyon, through which the river flowed for several kilometers below the falls, before it widened out into the main valley of the lower river:

The cañon is cut sharply into the surface of the table-land without any appreciable *dip of the ground towards it, and there is so little indication of its presence from above, that the gorge is seen only within a few yards of its edge; and its walls are so steep, and the bushes along the top so thick, that in most places it is necessary to hold on to an overhanging tree and lean far out in order to see the narrow white line of broken foaming water that rushes along 500 feet below. As the country slopes gently towards the main valley, the cañon does not deepen with the descent of the river in it, and the walls are everywhere from 500 to 600 feet high, varying with the undulating surface of the table-land* (Low, 1896:2598).

The canyon now has virtually no river flow aside from a small amount of local runoff (Figure 52). Due to the difficulty of surveying this deep gorge, nothing is known of the vegetation that may have colonized its vertical walls, nor whether any changes have occurred due to the reduced flow. There would have been little to no willow/alder riparian habitat along this reach of steep rock walls and turbulent water. It may be worthwhile to investigate this unique environment. Any survey party would need to be on contact with CF(L)Co to ensure that no releases of water were planned through the Jacopie control structure during a field visit.

Figure 52. The Largely Dewatered Bowdoin Canyon Looking Downstream from the Brink of the Waterfall (Photo: A.Luttermann, 2001).

In the reduced-flow reach of the river below Bowdoin Canyon, before the tailraces of the Churchill Falls power plant, quantities of finer sediment have been deposited where the river widens out and slows beyond the former rapids of the gorge. The bulk of the flow of the Unknown River that joins the main stem of the Churchill along this reach has also been diverted into the Ossokmanuan reservoir, reducing the flushing rate of sediment into the lower river reaches. Exposed sand bars are being colonized with herbaceous and shrubby vegetation. These areas may experience some minimal seasonal flooding from the flow of the Valley River that joins the main stem of the Churchill below the gorge. No riparian surveys were conducted in this reach, but it should be investigated along with several other reduced-flow river reaches in the region.

5.5 Downstream Reaches

5.5.1 General Hydrological Changes Downstream of Menihek Dam

Some portions of the Churchill River watershed, upstream of the main reservoir, are subject to downstream changes in flow patterns from the Menihek dam and powerhouse. Although this area was not surveyed for my study, hydrological data can provide an indication of some of the potential changes. The Ashuanipi River in the upper Churchill River watershed flows into Astray, Dyke, and Pettiskapau Lakes before continuing to Birch Lake and Sandgirt Lake, now part of the Smallwood Reservoir. Figure 53 shows the discharge hydrograph at the Menihek Dam in 2001.
Because there were no available pre-regulation data for this site, a comparison is made with the flow in 1976 at a site about 120 km upstream on the Ashuanipi River, just below the Wightman Lake expansion. Data collection at this hydrometric station was discontinued in 1983. (The mean flow is,greater at the downstream site at Menihek.)

The flow at the relatively small generating station follows a somewhat natural general curve, although daily fluctuations are much greater, especially during the growing season. Winter flows are also more variable. This comparison indicates that the daily flow below the dam assumes a much more erratic pattern than that of the unregulated river. This likely has some effects on downstream riparian vegetation before the river flows into the Smallwood Reservoir. Periodic flooding of seedlings during the growing season and increased ice scour mid-winter would be hard on many species. Vegetation cover close to the shores, and species richness of the riparian zone are likely to be reduced.

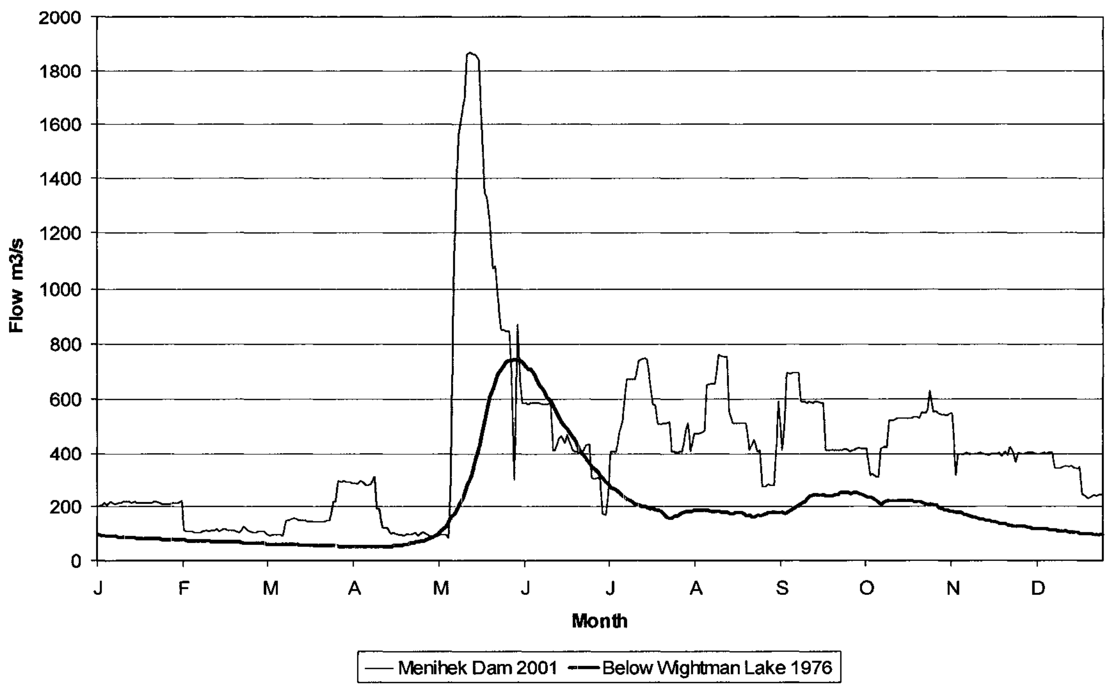


Figure 53. Daily Discharge on the Ashuanipi River at Menihek Dam, and Below Wightman Lake. The hydrograph shows the increased fluctuations in flow related to the operation of the hydroelectric facility (Data source: Water Survey of Canada).

5.5.2 Downstream Influence of the Twin Falls Generating Station

The Twin Falls power station operated between 1962 and 1974. The regulation of flow from the Ossokmanuan reservoir down through the Unknown River and into the main stem of the Churchill River would have created large changes in the downstream hydrology. Therefore, some of the discussion in following sections concerning "pre-and post-regulation" conditions in the lower Churchill refers to patterns of change specifically due to the Churchill Falls project. The ten-year period prior to 1971 cannot be strictly considered to be wholly unregulated in the lower river valley. This fact has not been acknowledged in previous environmental assessment reports. However, the influence of the much smaller Twin Falls facility was probably not significant as far downriver as Muskrat Falls.

The hydrograph in Figure 54 shows the erratic pattern of flow through the Twin

Falls power station. This would have been partially due to variation in power requirements for the developing iron ore mines, but also due to the influence of the construction phase of the Churchill Falls project. Even though the power station was decommissioned in 1974, there was still some periodic discharge over the following few years, indicating use of the structure as a spillway as construction continued on the Churchill Falls generating station. Data recording at this hydrometric station was discontinued after 1976.

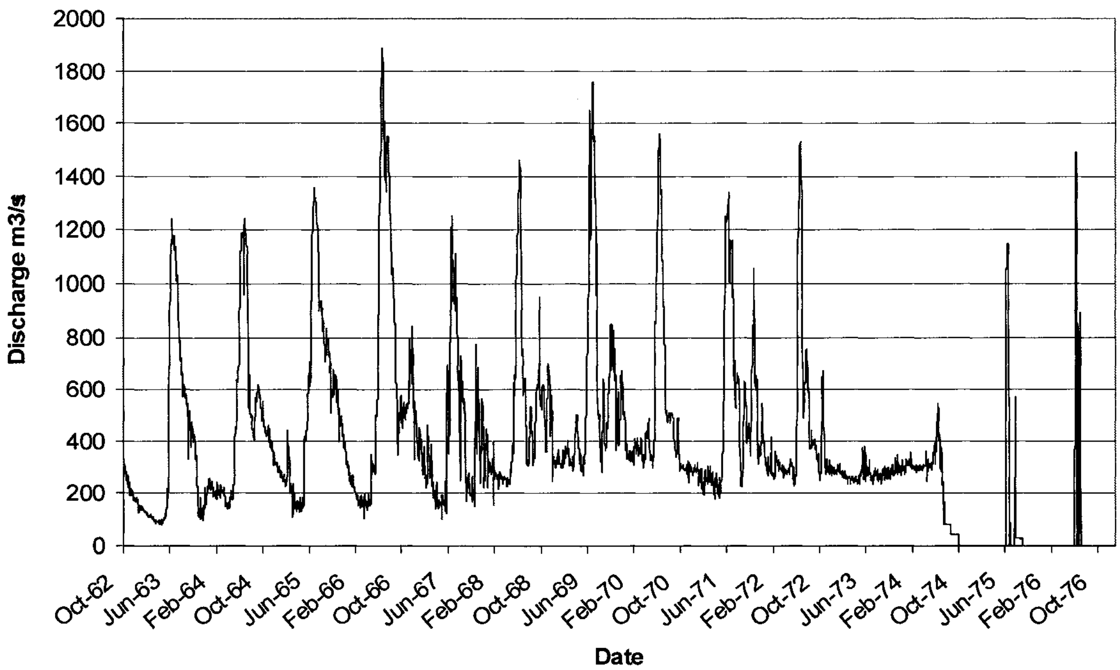


Figure 54. Daily Discharge from the Twin Falls Power Station between 1962 and 1976. Flow is reported as measured daily at the same time each day. (Data source: Water Survey of Canada).

A closer look at the pattern of discharge for one year, 1967 (Figure 55), shows continual fluctuations from one day to the next, typical of a power plant. There was still a high discharge in the spring that remained relatively elevated throughout the growing season. Discharge dropped dramatically in September and October, but then rose in November and December. This pattern of flow may have maintained more open-water in winter, and produced a more stressful environment for plants and wildlife living close to the shoreline.

Far downstream at Muskrat Falls, a hydrograph comparing an 8-year period prior to the Twin Falls development, and a 7-year period during which it operated, shows little variation in monthly mean flow (Figure 56). This indicates that the hydroelectric operation did not change the seasonal patterns of flow at this point in the river.

However, if we look at daily flow data and compare three-year periods before the Twin Falls development and during its operation in the 1960s, some changes in patterns are apparent (Figure 57). The mean annual flow from the Twin Falls power station was about 35% of the flow at Muskrat Falls, so some effect would be expected. However, downstream tributaries would exert a moderating effect on flow patterns, in addition to the relatively long travel time for the discharge waters to reach the lower reaches of the main river.

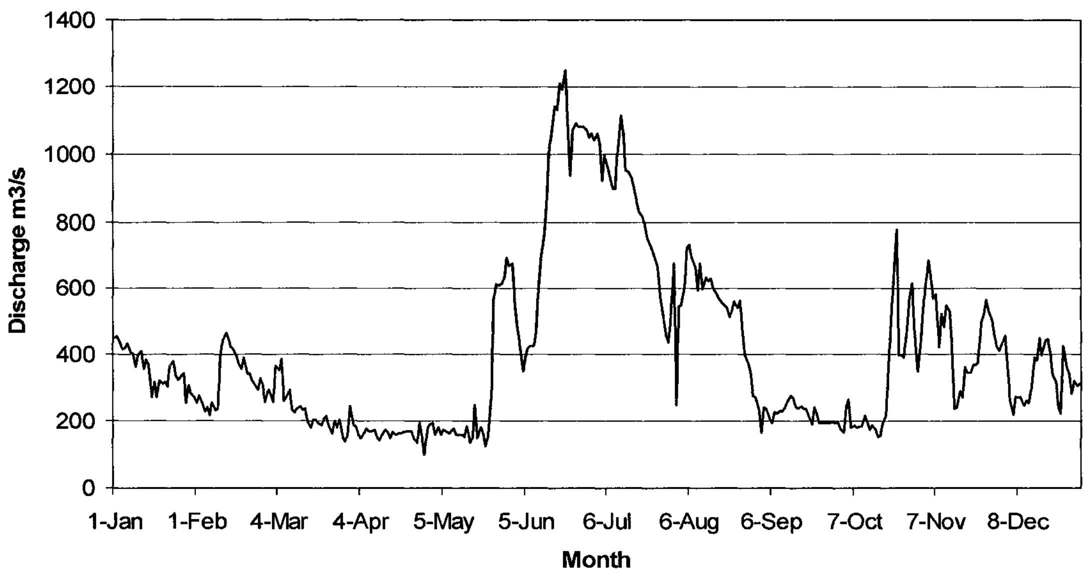


Figure 55. Daily Flow from the Twin Falls Power Station in 1967. Flow was measured once each day at the same time. (Data source: Water Survey of Canada).

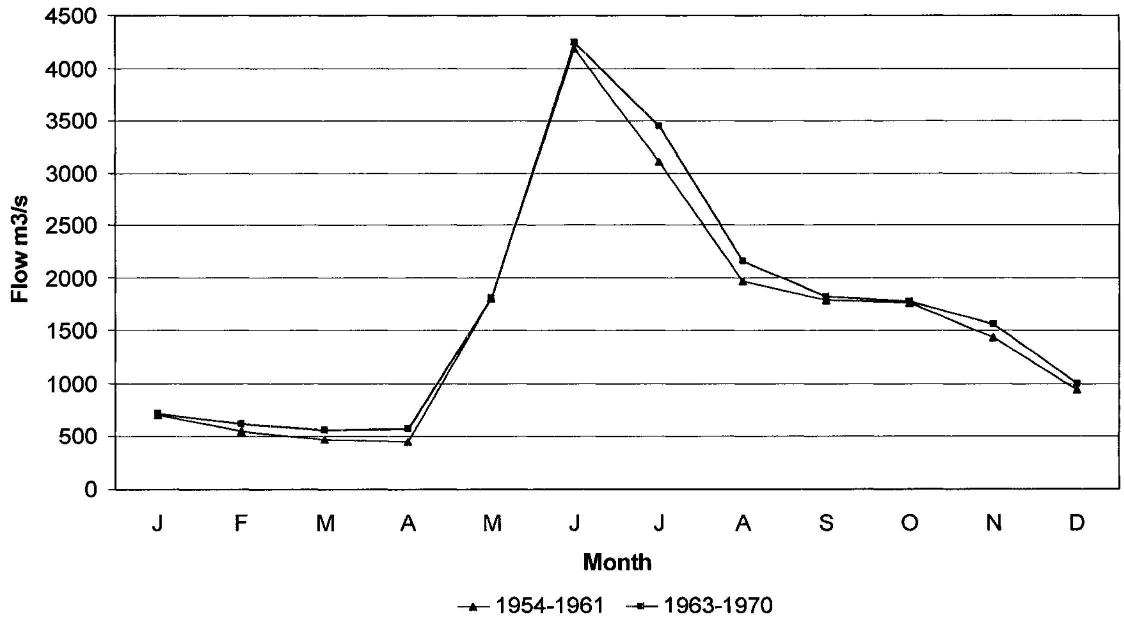


Figure 56. Monthly Mean Flows at Muskrat Falls for Two Periods Pre- and Post-Twin Falls Development (Data source: Water Survey of Canada).

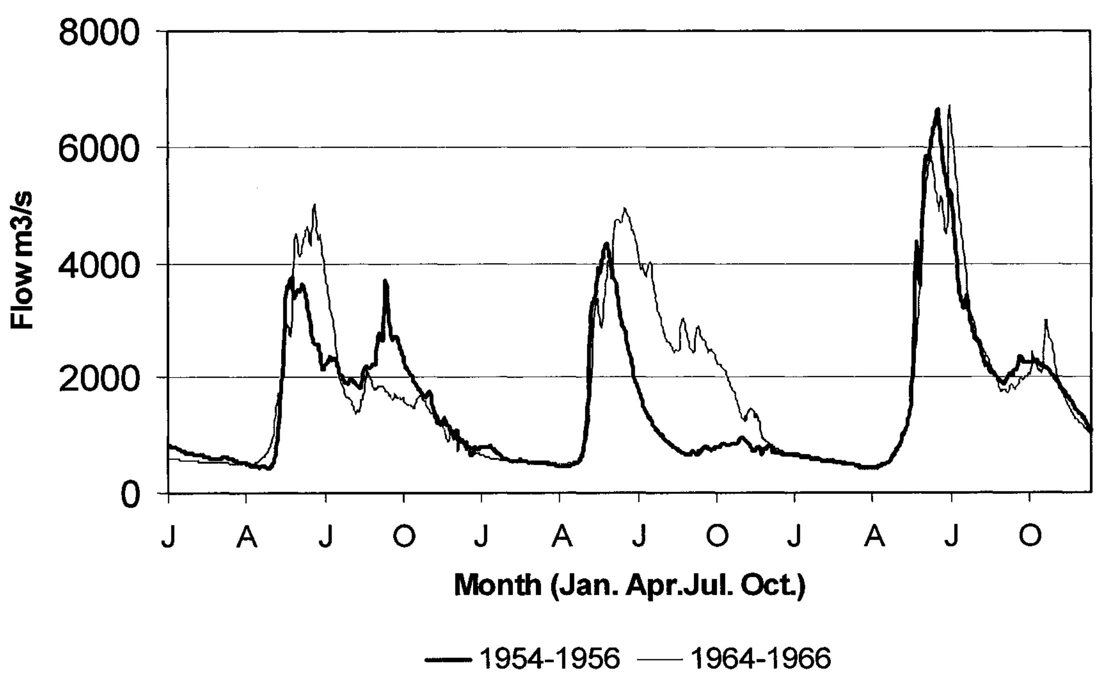


Figure 57. Daily Flows at Muskrat Falls for Two Periods Pre- and Post-Twin Falls Development (Data source: Water Survey of Canada).

The hydrograph (Figure 57) shows winter flows for all years pre- and post-development as being consistently low and stable. There are important differences in spring and summer flow patterns for the first two-year periods compared. However, the third year comparing 1956 and 1966 indicates a similar seasonal pattern.

The major difference that is most likely attributable to the Twin Falls development is the more variable fluctuations in flow over periods of a few days at Muskrat Falls during the operational period of the generating station. This may have contributed to some degree of decreased vegetation cover in more exposed reaches of the lower riparian zones as far downstream as Muskrat Falls, and possibly increased rates of bank erosion as well. These effects would have been more important in the upper reaches of the lower Churchill and most pronounced along the Unknown River before it met the main stem of the Churchill.

5.5.3 Hydrological Changes Downstream of the Churchill Falls Power Station

The river flow downstream of the Churchill Falls generating plant has been altered to a great extent, with numerous possible consequences to riverine processes throughout the 360 kilometres of the lower main stem. Elders interviewed during this study referred to increased bank erosion far downstream of the power plant that uprooted mature stands of trees as an effect of the Churchill Falls project. Ice conditions on the river throughout the winter are reported to be much less stable, making travel more dangerous. Lower summer water levels are always mentioned, with larger exposed bare shores and changes in habitat at the mouth of tributaries. In some reaches, these effects could serve to increase the size of the riparian zone. Overall, the implications of the changing physical conditions for particular species of plants or animals may be positive, negative, or neutral.

Under natural conditions, the river flow in this region would typically increase dramatically in May and June with the spring run-off, recede throughout July and August, rise again slightly in September and October with autumn rains, and then fall gradually with freeze-up, often stabilizing in late winter until the spring break-up in May when the cycle began again.

The hydrograph in Figure 58 compares two years of pre-regulation flow at Flour

Lake on the main stem of the river upstream of the former falls with the more recent patterns measured at the tailraces of the power plant. The mean annual flow measured at the tailraces is greater due to diversions for the facility, and the fact that it is slightly further downstream.

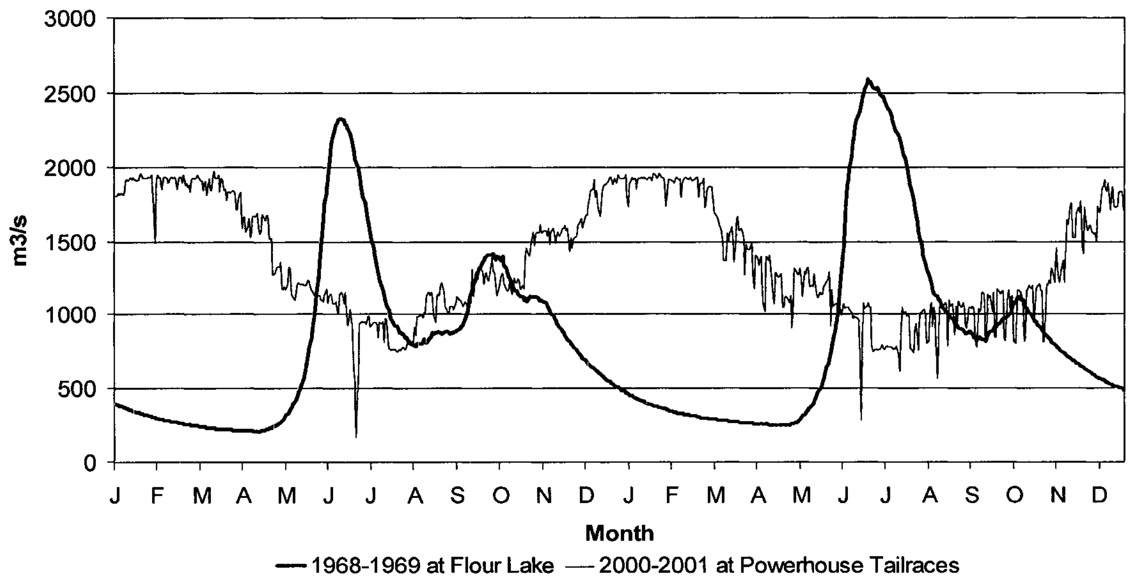


Figure 58. Daily Flow from the Upper Churchill River for Two Years Pre- and Post-Regulation (Data Sources: Water Survey of Canada, and Churchill Falls (Labrador) Corporation).

Over the course of a year, the monthly discharge from the tailraces is somewhat more uniform than the pre-regulated flow in the main stem of the upper river (Procter and Redfern, 1980). Pre-regulation flows varied by about 2330 m^3/s over the course of a typical year, whereas under regulated conditions the fluctuation in flow within a year is generally no more than 1230 m^3/s. This is primarily due to the capture of peak spring flows in the reservoir and the maintenance of higher flows in winter. Flows from the upper river now do not exceed 2000 m^3/s at any one time, while formerly they exceeded 2500 m^3/s during the spring freshet in many years. As will be discussed later, in years of extreme floods, the spring flow could be more than twice that magnitude. In addition, pre-regulation low flows under 500 m^3/s previously occurred in winter, but now tend to drop that low only briefly in summer when production may be temporarily slowed due to maintenance requirements in the turbines.

Daily fluctuations in flow are much more erratic now due to variable power demand during the week. Discharge to the lower river through the tailraces is much less stable from one day to the next, experiencing fluctuations of 500-800 m^3/s over the course of a few days. Large hourly fluctuations in flow also occur as power demand changes within any 24-hour period. These diurnal variations are not reflected in the hydrograph because the data represent flow measured at the same hour each day.

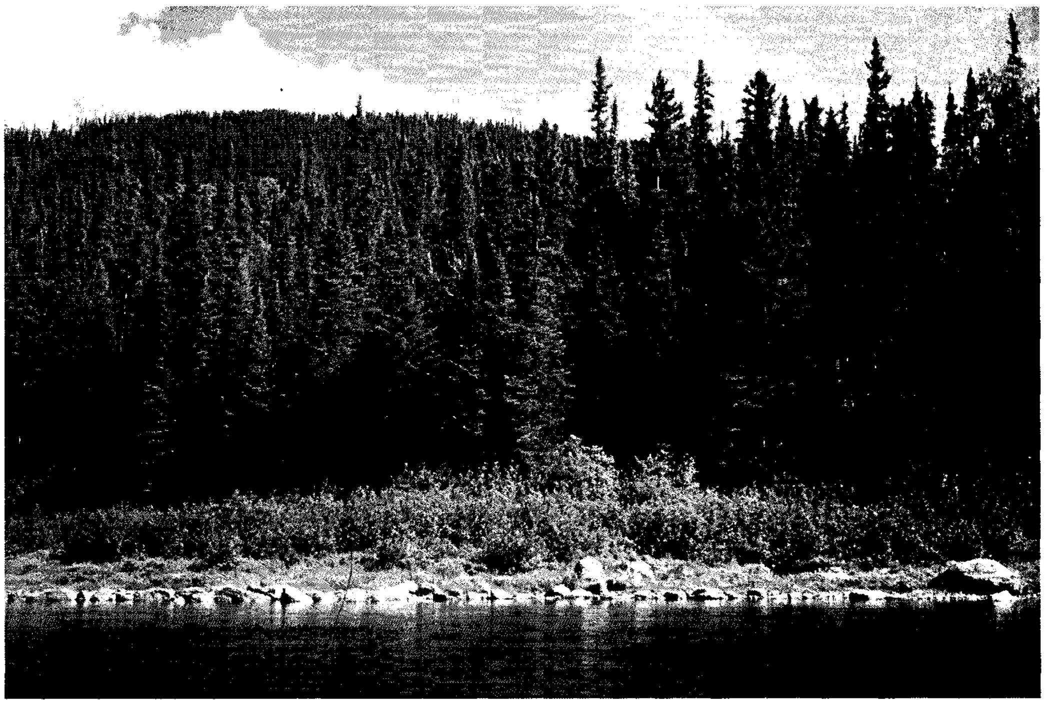


Figure 59. A Typical Shoreline in the Lower River Valley Characteristic of Fast-Flowing, Straight Reaches with Coarse Cobble and Boulder Substrates (Photo: A.Luttermann, 2001).

The pre-regulated environment in the lower river was conducive to the development and maintenance of rich riparian vegetation and wildlife habitat. The more frequent post-regulation daily fluctuations in water levels may impede the development of some species of riparian plants in summer and contribute to increased rates of erosion. Nevertheless, the lower reaches of the river downstream of the power plant continue to support relatively rich and complex riparian habitats compared to reservoir shorelines, and even compared to smaller rivers in the region. It is possible that some sheltered areas with finer sediment in the downstream reaches may even be improved for certain hydrophilic species, because of frequent short floods compared with original conditions.

Figure 59 depicts a typical reach along the lower river in sections with a rapid flow, moderate to steep slope, and coarse substrate. There is a clear zonation in vegetation growth right down to the water in July.

Figure 60. A Young Black Bear in the Herb and Shrub Zone on the Shore of the Lower Churchill River in July (Photo: Jonathan Cumming, 1998).

Signs of wildlife along the shores were abundant during the 2001 survey, especially tracks of moose, wolf, red fox, and black bear. However, habitat for some species of aquatic mammals such as muskrat and beaver has certainly been reduced in quality due to more severe winter ice conditions. Furthermore, lower summer water levels may make waterfowl nesting habitat close to the water's edge much less abundant in these river reaches.

5.5.4 Moderating Effect of Tributaries in the Lower River

The effects of flow regulation would be expected to be most pronounced closest to the tailraces of the facility, where discharge patterns are dependent entirely upon the operation of the plant. These effects, observed below all dams, include increased bed scouring and shoreline erosion. There are ten large, and more than 230 smaller tributaries draining into the river between the plant and the river's mouth. These unregulated streams progressively moderate the effects of regulation to some extent further downstream.

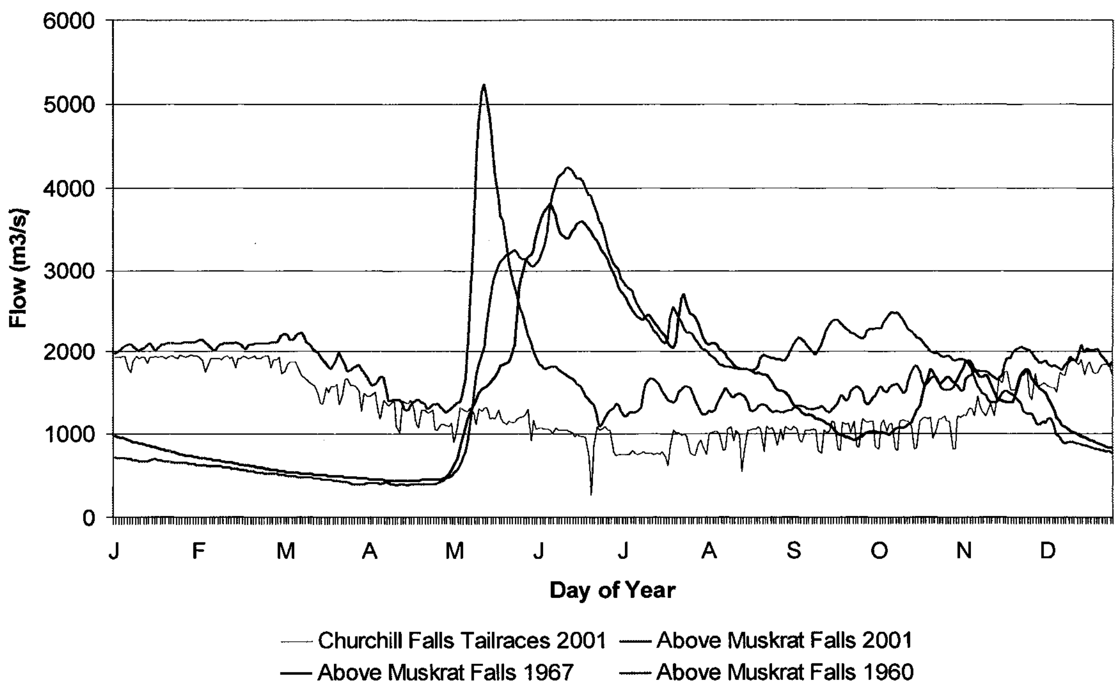


Figure 61. Flow at the Powerhouse Tailraces and above Muskrat Falls in 2001, and Two Pre-Regulation Years at Muskrat Falls (Data Sources: Churchill Falls (Labrador Corporation, and Water Survey of Canada).

The mean annual flow from the tailraces between 1976 and 1998 was 1.37×10^3 m^3/s. The total mean discharge was 478×10^3 dam^3 from a watershed of 69×10^3 km^2. This mean annual flow is approximately 12% higher than prior to regulation due to the diversions. There is also some run-off into the lower river from the plateau through the Jacopie and Ossokmanuan control structures and from the Unknown River. This brings the total average annual rate of flow from the plateau to 1.47×10^3 m^3/s.

The mean annual flow just above Muskrat Falls is 1.85×10^3 m^3/s. The 23.3×10^3 km^2 watershed between the tailraces and Muskrat Falls contributes on average an additional 385 m^3/s to the river flow. Thus, approximately 73.6% of the flow that reaches Muskrat Falls is regulated by the Churchill Falls powerhouse. The mean annual flow at the mouth of the river 43 km further downstream is 1.9 x 10^3 m^3/s, making the regulated portion of the total flow of the river about 71.8%. Seasonal flow data at the mouth of the river are not available for analysis.

The hydrograph in Figure **61** comparing daily flow in sample years, demonstrates that the daily fluctuations in flow from the tailraces are somewhat moderated 291 km downstream at Muskrat Falls, due to the distance and the influence of many free-flowing tributaries throughout the downstream reaches. The patterns of flow are smoothed to some extent, although they remain erratic compared to unregulated conditions, particularly in winter. During the growing season under natural conditions, it was common for water levels to rise in the lower river with rains in late July and early August and then continue to drop further until the autumn rains. Daily discharge above Muskrat Falls indicates that water levels now fluctuate more frequently from a lower baseline level throughout the growing season.

A large spring flood is still experienced in reaches further downstream due to run-off from the unregulated tributaries; however it subsides much more quickly than under pre-regulated conditions. This is because the watershed drained by the tributaries is much smaller than the upper plateau, the streams drain steep slopes, and the natural storage capacity is small (Lower Churchill Development Corporation, 1980). In addition, the onset of the spring melt occurs later in the upper plateau, which under natural conditions would release run-off over a longer period of time to the lower river. The spring freshet from the plateau is now captured in the reservoir.

5.5.5 Changes in Peak Flood Periods

Flows from the plateau to the lower river reaches during the spring and summer are lower on average than prior to regulation. Previously, the maximum mean spring flow at Muskrat Falls was over 4000 m^3/s (Figure 62). The flow typically peaked during June and then gradually receded to 1700 m^3/s in late August and continued to decrease slowly until the following April. Under regulated conditions, the flow generally peaks at about 2500 m^3/s in late April, recedes to 1600 m^3/s in late August, and begins to rise again in

September.

However, the monthly mean flow data do not tell a complete whole story. Peak high flows during sporadic extreme events may have long-term influences on riparian vegetation. For example, overbank flooding delivers sediment, nutrients, and propagules to higher levels on the floodplain and to back channels that may be flooded only on an inter-annual basis (Trémolières et al., 1998; Naiman et al., 2005).

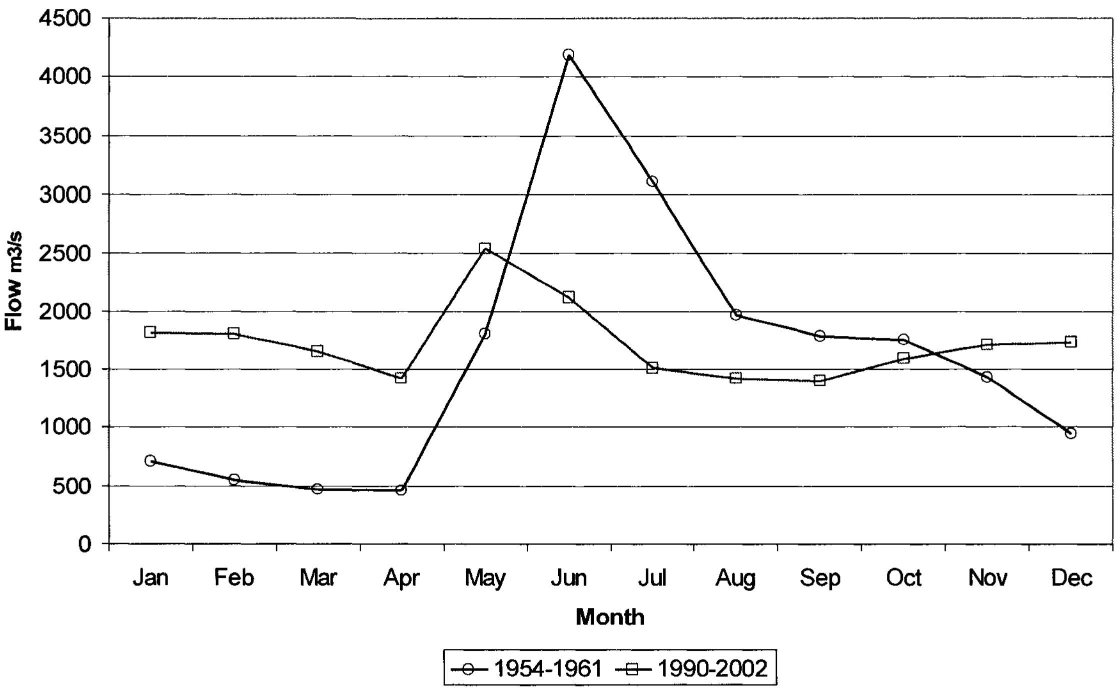


Figure 62. Mean Monthly Discharge above Muskrat Falls during Two Periods, Pre- and Post-Regulation (Data Source: Water Survey of Canada).

In general, extreme floods are considered to have a beneficial effect on the biodiversity of river systems, since they essentially 'reset' the system allowing the maintenance of range of communities at various stages of succession (Petts, 2000). In boreal rivers with natural flow patterns, extreme flooding of long duration can reduce plant species richness in reaches with tranquil flows, probably due to anoxic soil conditions. However, species richness in these reaches recovers over time. This recovery is likely assisted by propagules from turbulent reaches with well-oxygenated soils, where species richness is maintained through extreme floods (Renöfält et al., 2007).

Peak spring flows in the lower river reaches now occur somewhat earlier and are of a smaller magnitude than prior to regulation by the Churchill Falls project. As there are fewer extreme flood events now, the floodplain is smaller than it was prior to hydroelectric development. The magnitude of peak annual flows has trended downwards since regulation (Figure 63), however relatively high floods have occurred in recent years, for example in 1999 and 2001.

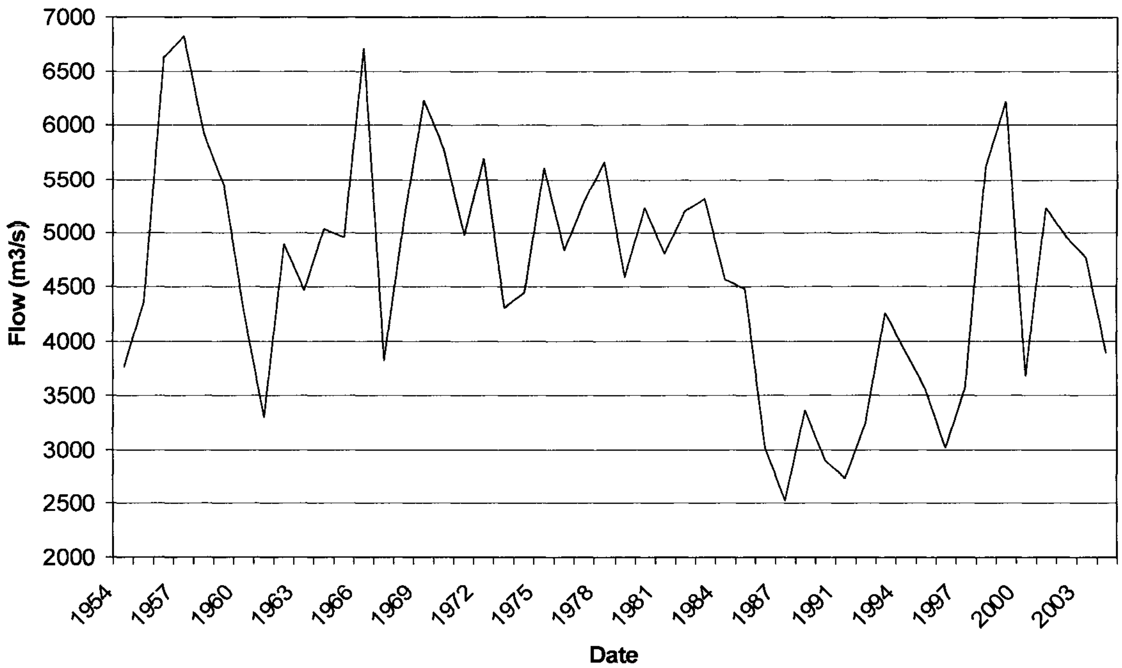


Figure 63. Peak Annual Flows above Muskrat Falls 1955-2004 (Data source: Water Survey of Canada).

In the past, there was substantial variability in the timing and magnitude of spring floods (Figure 64). Figure 65 gives a specific indication of differences in extreme lows and highs recorded on individual days at Muskrat Falls during the pre- and post-regulation periods. It appears that the 20-30 year floodplain was only slightly larger prior to regulation, having been influenced by a maximum additional flow of about 600 m^3/s during extreme events in June. Flows in winter were consistently lower in the past. Extreme high flows have been recorded up to 1240 m^3/s higher in May during the post-regulation period. However, May is early spring in Labrador where the mean date of river break-up at Goose Bay during 1947 to 1979 was May 26 (Procter and Redfern, 1980).

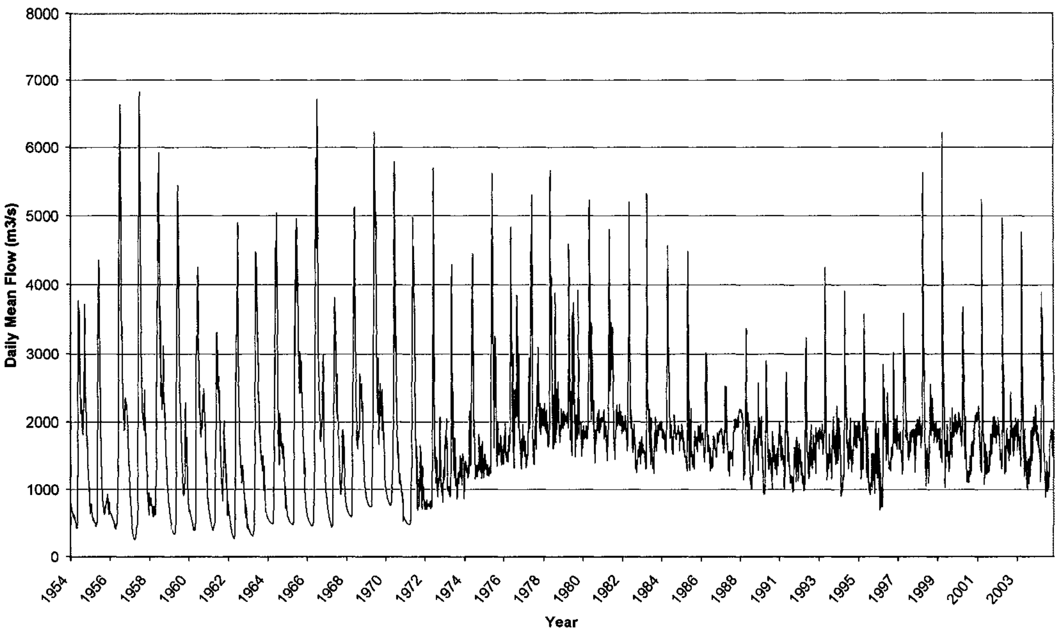
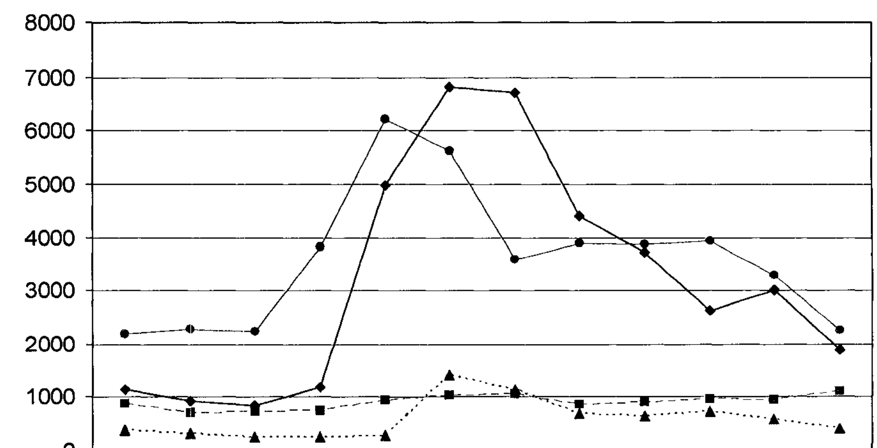


Figure 64. Daily Mean Flows at Muskrat Falls 1954-2004 (Data source: Water Survey of Canada).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1954-1972Max Daily	1140	932	838	1170	4980	6820	6710	4390	3710	2610	3000	1880
1973-2002 Max Daily	2190	2270	2230	3820	6220	5610	3590	3880	3850	3920	3280	2260
1954-1972 Min Daily	396	328	253	253	270	1420	1140	691	634	719	586	411
1973-2002 Min Daily	875	700	730	750	938	1030	1050	867	895	961	934	1120

Month

Figure 65. Monthly Extremes of Daily Discharges above Muskrat Falls Pre- and Post-Regulation (Data Source: Water Survey of Canada).

Since regulation, periodic extreme floods have not been nearly as high during the growing season, the time when newly exposed moist and nutrient rich substrates are more likely to support the rapid germination and establishment of species of riparian plants as flood waters recede.

High spring floods have occurred more recently during periods of intense precipitation, for example, in 1999 (Figure 66). However, they have again occurred earlier in spring when there may be more ice in the river, causing more intense ice scouring. Recent peak floods have been of shorter duration, and have receded much earlier in the growing season than peak floods have in the pre-regulation past, such as that which occurred in 1957. Further investigation is required to consider the potential effects that such changes in extreme floods may have on the river's floodplain and vegetation communities.

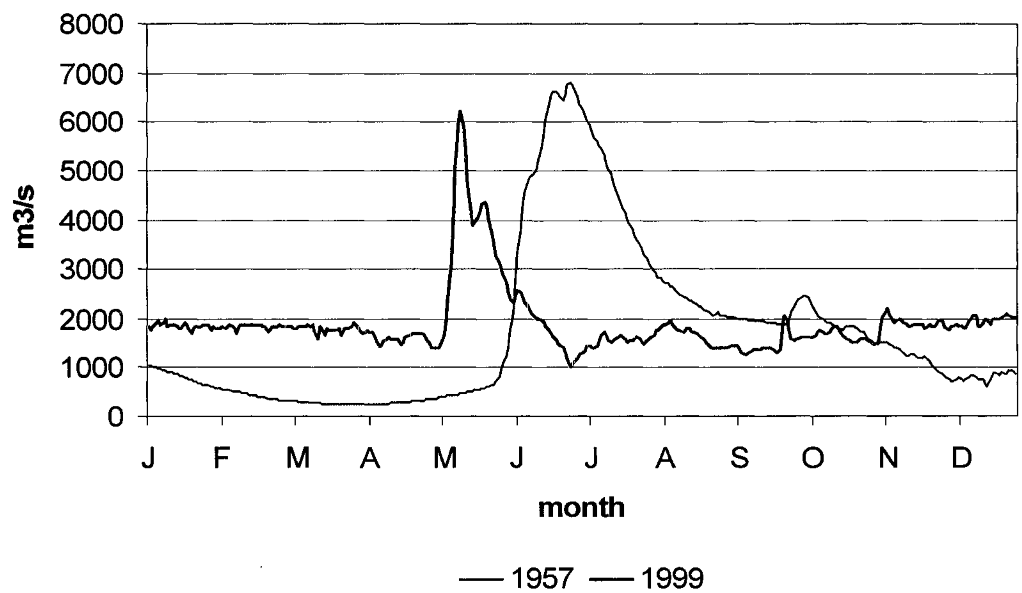


Figure 66. Daily Mean Flows at Muskrat Falls During Two Years of Extreme Spring Floods Pre- And Post-Regulation (Data source: Water Survey of Canada).

5.5.6 Lower Average Summer Flows

As noted in Figure 62 (page 165), the mean monthly discharge downstream of the power plant during the growing season has decreased substantially since regulation, creating lower average summer water levels.

According to the hydrological records, extremely low summer flows occurred periodically prior to regulation. Summer water levels in some years could be lower than they are now, making wide shores available for plant colonization. Some of the lowest flows were recorded in August during some years in the pre-development period (Figure 65). However, flows lower than previously seen are now consistently recorded from June to September.

The hydrograph in Figure 67 indicates that water levels dropped extremely low after the spring freshet in the summer of 2001, when we conducted the field surveys for this study, but no lower than they had been in the previous three summers.

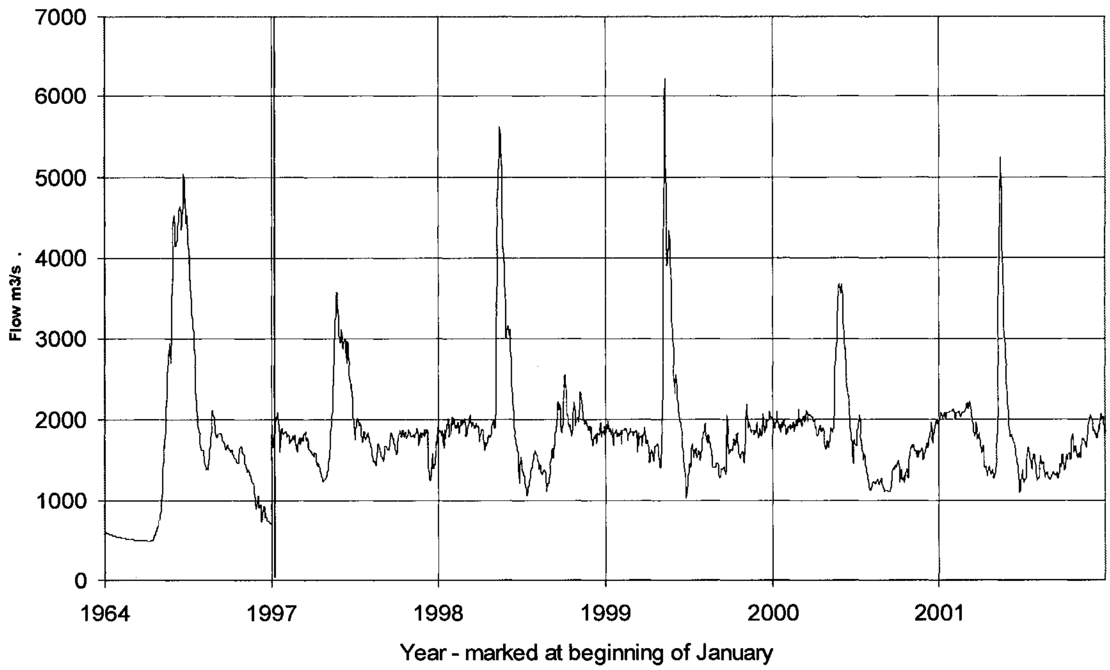


Figure 67. Daily Flow above Muskrat Falls in a Post-Regulation Period 1997-2001 Compared With Pre-Regulation 1964 (Data source: Water Survey of Canada).

With the consistently lower summer water levels in reaches downstream of the power plant, wider shorelines are exposed during the growing season. This may provide additional opportunities for some riparian species that can cope with the increased disturbance and drier conditions, e.g., *Calamagrostis canadensis*. However, with the greater daily fluctuations in discharge, it is likely that there has been an increase in reaches with wide shorelines lacking vegetation cover compared to what was typical prior to regulation. Historical documentation of shoreline vegetation during the height of the growing season are rare, as this is also the height of the black-fly season and most people stay close to the coast at that time.

Figure 68. Francis and Elizabeth Penashue Viewing a Grassy Slope in a Sheltered Riparian Zone Downstream of Churchill Falls. *Calamagrostis canadensis* dominates the vegetation in the middle and lower zones. Elizabeth is holding a branch of the shrub *Viburnum edule* found in the upper zone (Photo: A. Luttermann, 2001).

People who made observations in the fall season in the past described a dense shrub zone close to the water's edge as the typical shoreline habitat along much of the river. Many older campsites used by travelers are in the forest above the current summer water levels. Lionel Leslie wrote about the rigours of traveling into the interior of Labrador prior to roads and gave a general description of the vegetation in the Hamilton (Churchill) River valley:

The country itself consists of ranges of hills covered with spruce trees and *occasional birch, and carpeted with luxuriant mosses, while the banks of the rivers are overgrown with thickets of willow and alder* (Leslie, 1931:200).

Figure 69. Shoreline along the Upstream Side of the Saddle at Manitu-Utshu. This is just upstream from Muskrat Falls. Note the low water levels in early August (Photo: A.Luttermann, 2001).

People now say that it is much easier to find campsites along the river in recent years due to the exposure of wide sandy beaches that were previously under water (Joe Goudie pers. comm., 2005).

However, reaches with wide expanses of sparsely vegetated shoreline are apparent in historical photographs taken along the river prior to the Churchill Falls development. An image from a monograph published by Horace Goudie shows a canoe party on the shore of the Churchill River in 1964 (Figure 70). There is a wide, bare shoreline in this reach with a mixed substrate of cobble and fine sediment, and some woody debris on a slumping upper shoreline. The extreme low flows on record in September and October at Muskrat Falls both occurred in years prior to regulation (Figure 65), so low river water levels in autumn were not uncommon. In fact, the minimum extreme lows from August to May all occurred in the pre-regulation period. Extreme lows for June and July, however, have both occurred under regulation. Much higher extreme maximum daily flows were experienced in June, July and August in pre-regulation times.

Figure 70. A Canoe Party on the Lower Churchill River in October, 1964 (Photo: from Goudie, 1991).

Exposed areas of shoreline during the much lower water levels of summer post-regulation times have provided opportunities for the colonization of grasses. Local elders have observed that dense grassy areas are now much more common along the shores of the lower Churchill than prior to river regulation. Horace Goudie commented:

> *... before, the water used to be up so close to the woods that there wasn't very much grass there, there was a band of willow along close to the water and then the trees. In some places there was a bit of grass. But you take a lot of these places that were bare mud and sand and you get a bit of top soil into it from dead leaves or something, and it's all grown up in nice grass... Those new grassy areas might be very attractive to certain kinds of animals. It would change the pattern and routes that certain animals travel. Like porcupine and rabbit in the summertime, they would love this stuff and they would live in it. There's even a lot of stuff in that grass that would be good for ruffed grouse and spruce grouse and so on. And there didn't use to be so much of that along the river when I was going up there first before the Churchill Falls development* (Horace Goudie pers. comm., 2005).

Blue-joint grass (*Calamagrostis canadensis*) has undoubtedly long been a common species in the region in moist, disturbed areas. It is a hardy colonizing species. It was observed at all sites in our survey except for one in a storage reservoir. However, it may be much more abundant along downstream reaches than it was prior to regulation.

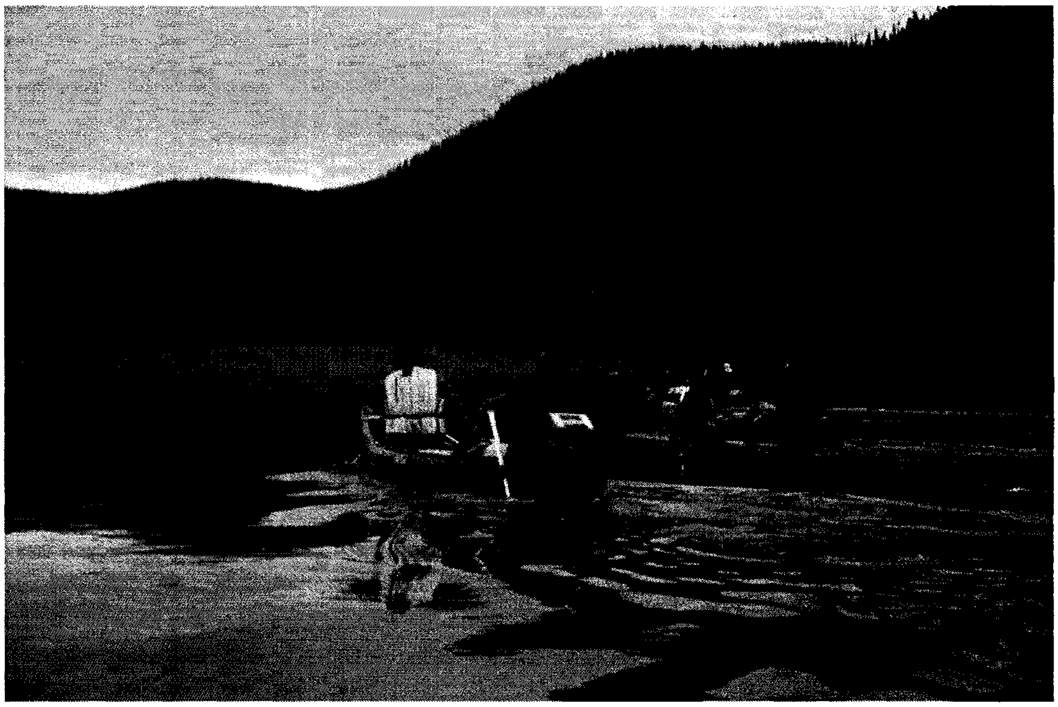


Figure 71. Mouni's Island. The island, on the left, is now connected to the south shore of the river by a dry channel during low summer water levels on the lower Churchill. (Photo: A.Luttermann, 2001).

Adams and Viereck (1992) noted differences in successional sequences on riparian sites downstream from a flood control structure that has dampened the major spring floods on the Tanana River in Alaska. They observed that *Calamagrostis canadensis* was replacing thin-leaf alder (*Alnus tenuifolia*) in intermediate successional stages in the riparian zone of flood-controlled reaches. This grass was described as being a minor species on the floodplain of this river under the natural-flow conditions prior to regulation.

In many reaches of the lower Churchill, distinct bands of older and younger shrubs can be seen. The larger shrubs in the upper zone are older, pre-regulation communities, while those lower on the banks have become established since regulation.

The photograph in Figure 71 shows an example of a dewatered channel around a former island. This is a common feature along the river with the lower summer water levels in the post- regulation period. These channels are becoming colonized by diverse herbaceous and shrubby vegetation.

Lower summer water levels in the main river channel may also reduce the water table in adjacent terrestrial habitats. Jerome Pone commented:

> *I know that the water is very shallow in some places near Mud Lake ever since the dam was built at Churchill Falls. The Mishta-shipu [Churchill River] is very shallow nowadays. In the past, big motor boats used to travel up the Mishta-shipu as far as Manitutshu [Muskrat Falls]. Now you would only see* [small] *speedboats going up the river. The Mishta-shipu used to be deeper back then. I used to go to a marshland near our community to look for bakeapples* [*Rubus chamaemorus*]. *The marshland water seeps into the river. I think the bakeapples don't grow as well in the marshland these days because there is not as much water available now in those places. I don't think that our children know that these things are happening now* (Innu Nation Hydro Community Consultation Team, 2000:37).

As mentioned previously, the region has also experienced lower than average annual precipitation in recent years. This may be the primary influence on moisture levels in bogs adjacent to the river, or it may act in concert with lower post-regulation water tables to create a cumulative effect.

5.5.7 Increased Erosion of the River Bed and Banks

Erosion is a natural process in all river systems and indeed for all landforms over various scales of time. As described in Chapter 2, the entire Churchill River valley may have been filled with glacial till during the most recent glaciation. Since then, flowing water has gradually eroded much of this material. The finer sand-silt-clay marine sediment that settled in the lower valley flooded by the marine incursion up to about 8 km below the confluence with the Minipi River have been gradually moved out through the estuary since sea level began to recede (Jacques Whitford Environment, 2000). The gradual and the more abrupt movements of substrates during high floods continually change the morphology of the banks. Riparian zones are formed, destroyed, and reformed as the forces of flowing water and ice scour contribute to the maintenance of a dynamic mosaic of successional riparian vegetation. Erosion and ice scour also assist in downstream and lateral dispersal of riparian plants, and the colonization of new sites for aquatic macrophytes (Fox, 1992).

Increased erosion downstream of a dam can occur as the suspended sediment load of the water settles behind the dams or dikes. The clear water released from the power plant is thus capable of picking up increased sediment loads for some distance downstream. This process may be responsible for some degree of increased shoreline erosion and riverbed scouring downstream of the Churchill Falls tailraces. Sediment load analysis would have to be conducted to determine how far downstream this is likely to be a factor.

Lake-like expansions in a river can have a similar effect on sediment loads. For example, at 60-km long Lake Winokapau, sediment is deposited at the head of the lake where the velocity of the river slows as it flows into the deep, wide basin. Extensive, silty sand bars have developed there. Some of the most species rich and dense riparian vegetation occurs in this reach of the river. This has certainly been a depositional site throughout the current inter-glacial period. Downstream of Lake Winokapau, the flow velocity increases greatly as the river narrows and flows through a confined bedrock channel. These faster reaches are naturally well scoured and have coarse substrates.

Several large tributaries contribute to the sediment load in the main stem of the river. Those flowing in from the north side of the river may be carrying heavier sediment loads to the main stem since the construction of the nearby Trans-Labrador highway. There are numerous open cuts, and gravel pits along this gravel-surface corridor that runs parallel to the river, crossing all tributaries.

Certain downstream reaches of the Churchill River are naturally subject to high rates of erosion and bank slumping. Bank failure in many reaches of the lower main stem of the river was not uncommon prior to regulation. These are reaches with high marine terraces through which the river has been down cutting since deglaciation, followed by concurrent isostatic rebound and retreat of the marine limit. In 1939, M.J. Doutt described a reach of the river called Sandy Banks between Porcupine Rapids and Muskrat Falls, where the river is bordered by high terraces of interbedded sand and clay marine sediment:

> *The riverbanks have been much eroded by the river, which undercuts them so that great masses of trees and vegetation tumble and slide down into the river. In the faces of the exposed river banks the bank swallows have built nests extending inward 3 to 5 ft.* (Abbe, 1955:19).

One of her companions on that excursion also wrote that, "...many slips and landslides have uprooted the trees and piled them in utter confusion" (Todd, 1963:48).

Another such area is the shore of an immense eddy just downstream of Muskrat Falls which flows around a large granite hill, on the north shore of the river, known as *Manitu Utshu* in the Innu language. It has been suggested that the main stem of the river probably flowed around the north side of the hill prior to the most recent glaciation (Jacques Whitford Environment Limited, 2000). However, that saddle was apparently filled with glacial drift and the present river course flows to the south of the hill. The drift-filled saddle is vulnerable to erosion and bank slumping. Older revegetated slumps and a newer one can be seen on an air photo taken in 1951 prior to hydroelectric developments (Figure 72).

A major slide occurred in the 1970s following logging along the top of the bank in the saddle (Beak Consultants and Hunter and Associates, 1978) (Figure 73). This disturbance may have been the primary trigger of the slide, as opposed to erosion from the base of the slope, or the two factors may have acted together. Several other smaller slides are apparent in the photo from 1979. Note also the erosion of some formerly wooded islands and a large alder/willow flat that could be seen in the 1951 photo but was missing in 1979. These changes will be discussed in the following section on ice-scour effects.

A study of early-successional communities colonizing a large slide feature in marine sediment on the lower river (e.g. Figure 74) would be worthwhile to compare with riparian habitats along the river.

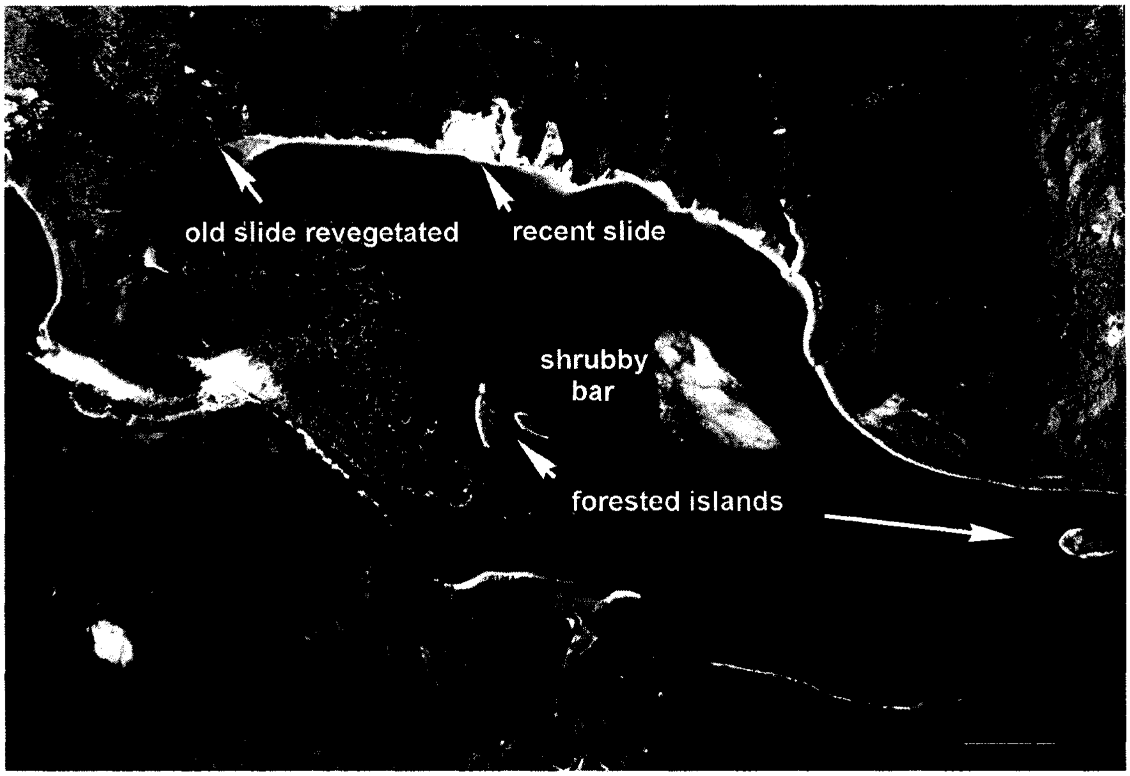


Figure 72. The Churchill River Just Below Muskrat Falls on June 29, 1951 (Photo: National Air Photo Library). (Text added).

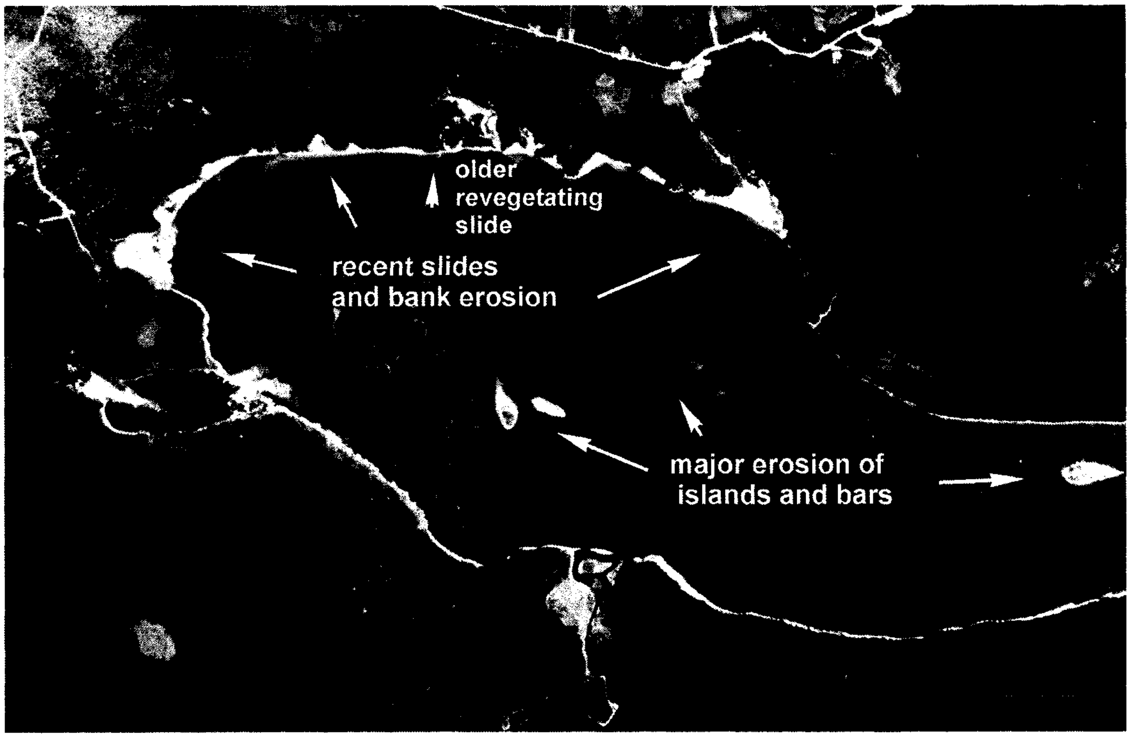


Figure 73. The Churchill River at Muskrat Falls on July 21, 1979 (Photo: National Air Photo Library). (Text added)

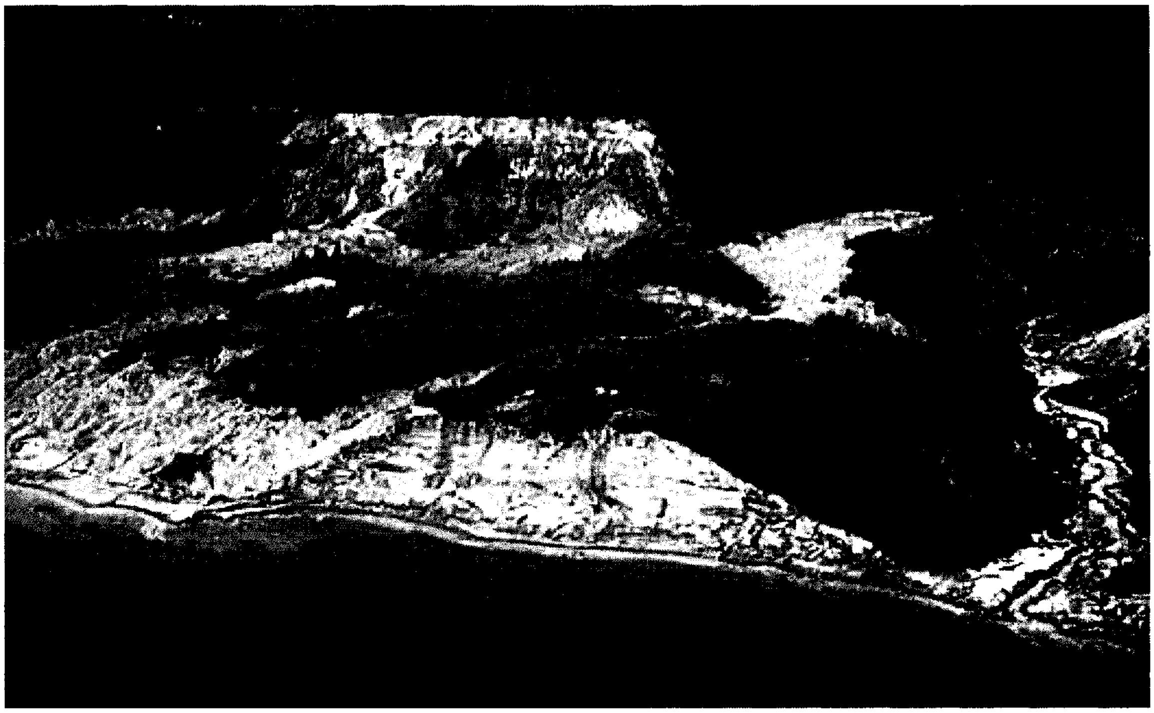


Figure 74. A Large Slide on the North Shore of the Lower River. This massive slumped bank located just upstream of Lower Brook has been partially stabilized by shrubby vegetation. (Photo: Environment Canada, 1998?).

5.5.8 Increased Winter Flows and Ice Scour

In the lower Churchill River, the changes in water levels and flow in the winter due to increased hydroelectric generation have likely exerted the largest influence on rates of erosion. Certain reaches are subject to increased ice scour, especially in areas prone to ice jamming, and this effect is extending higher into the riparian zone than was typical in the past.

Some ice jamming certainly occurred in the past, especially in areas downstream of open fast water where the production of frazil ice may build up thicker ice cover. These events could cause major erosion along the riverbanks as Horace Goudie commented:

> *If you have a big ice jam just below Gull Island Lake, the next place along is the porcupine rapid. So if you've got a big ice jam in the spring when the ice is coming out, jammed up into porcupine rapids it would back up and come up onto the sides of these banks everywhere, and then when it starts going again it would just tear through like a bulldozer* (Horace Goudie pers. comm.).

Prowse and Culp (2003b) state that late-spring ice jamming and resulting flooding are most likely to occur in rivers flowing north in which a period of warming weather initiates snow melt, so that run-off and ice break-up begin earlier in upstream areas and then push against downstream ice cover that is still intact. In contrast, in rivers flowing from colder to warmer regions the downstream ice cover would typically thin and lose much of its mechanical resistance before major run-off arrives from the upper watershed. Large floods from ice jams and major ice scouring would thus be less likely to occur. This is the most probable scenario for the Churchill River in the past, when break-up would occur earlier in the lower valley with warmer temperatures than on the plateau. Other factors, such as the temperature of reservoir releases could also influence erosion and ice scour. Slope migration or failure along the river valley shores is unlikely to be related to solifluction (seasonal melting of permafrost causing the upper soil layers to slide downhill over the lower layers) since permafrost is known to occur in the region only in isolated patches primarily under bogs.

Open water even in mid-winter was common in the past in several reaches of the river, particularly below the larger falls and through rapids. For example, an account of the H.G. Watkins Expedition to Labrador in 1928-1929 describes several reaches with open water during their winter journey up the river (Scott, 1933) (Figure 75 and Figure 76). Many of the rapids were open in mid-February, in some cases right up to the banks. The winter began somewhat late in 1928, with no snow by mid-November (Scott, 1933). Temperatures also rose to "well above zero" on some days in mid-February, 1929. Nevertheless, even in that year they were able to travel on the ice below Muskrat Falls. They stated that when starting out,

> *...we hurried on to Muskrat and drove right up to the foot of the falls. They were an impressive sight: great paving-stones of ice stuck up at drunken angles among furry pillars of frozen spray and loud tongues of angry water that had defied the frost* (Scott, 1933:181-182).

Between the rapids, the river was frozen over, permitting relatively easy travel. That year they were still able to cross the river ice from Big Hill, where the tailraces of the power plant are now located.

Figure 75. Open Water on the Unknown River in February 1929 (Photo: Scott, 1933).

Figure 76. Open Water through the Minipi Rapids in February 1929 (Photo: Scott, 1933)

With consistently low water flows throughout the winter, ice along the edges of open rapids was likely to have remained fast to the shore and be less likely to scour the banks or crush vegetation, as occurs when water levels repeatedly rise and fall.

Many people who discussed their observations with me mentioned the phenomena of more open water in winter and increased severity of ice scouring along the river since the power developments. Horace Goudie emphasized increased ice scouring as one of the most important changes since the construction of the Churchill Falls project:

> *There's enough water coming down to keep the water from making ice right across the river. There's an open strip down the middle of the river all the time, ever since the Churchill Falls development. It was never before like that. It used to freeze up in late November, early December, all over. And you could go across and check your traps and do whatever you like. Today you'd need a canoe to get across the Churchill River beyond the Muskrat Falls, anytime, any winter.*
>
> *The problem is that it changed the nature of the river. The river used to freeze up in the winter and stay frozen all winter. But in the spring, the ice would just come right on out through. But now it stays open, and piles up with this new ice* [frazil ice] *that is made with the frosty weather every night. Every night there is thin ice made in the water then it gets into big lumps, and gathers up down at the Muskrat Falls, goes down over the falls and fills up that great big area* [a huge eddy downstream of the hill] *enough to tear away those islands. And there's islands up beyond the Muskrat Falls that have been torn away too from that ice. So the beaver that used to like to put houses along the river, and some places at the entrances to the little brooks and so on, they had to give that up. They had to get the hell out of there. There's too much destruction from the ice. It would tear away all their food, and lodges, and everything* (Horace Goudie, pers. comm., 2005).

Mr. Goudie further explained his observations about how changing ice conditions on the river downstream of Muskrat Falls have increased erosion:

> *The water temperature was changed an awful lot after the Churchill Falls development. Like now up here below Muskrat Falls, you should look at that sometime, you'd need somebody who knows the river from away back, and you'd need to do it in the summer time with a speedboat. There used to be four woody islands close to Muskrat Falls below it. Since the Churchill Falls development, the water temperature was changed enough for some reason or another that the river never freezes over. You couldn't go across from the south side to the north side like you used to before that. It's now open, wide open all winter long. You take December, January, February, even now, March, there's a lot of ice floating around out in the water, and after months like that, steady floating around, it tore away all those islands up here below the Muskrat Falls. I know why they're gone, it's because of all this ice coming out in the winter that's making it into open water, and it's constantly drifting. It's constantly coming down, drifting over the Muskrat*

Falls. Muskrat Falls was always open, but everywhere else around there, it would freeze over.

And since the Churchill Falls now, you go up to Muskrat Falls up here in late June, early July and there's still big blocks of ice left. That's where it would flow all winter long, accumulating with the cold weather and drifting down and lodging below the Muskrat Falls, and building up. You see cracks up there in the winter time, if you went up there now, if you had the nerve to you could look down a crack maybe fifty feet down to the water, it just piles up. Comes out and just piles up on top of each other all the time. Everything around there all fills up with ice (Horace Goudie, pers. comm. 2005).

Figure 77. Elizabeth Penashue at Manitu-Utshu. She is looking down at the massive build-up of ice in the huge eddy below Muskrat Falls. The ice is laden with sediment and woody debris from scoured banks (Photo: A. Luttermann, 2000).

Goudie attributes the almost total loss of several islands to erosion from increased ice scouring throughout the winter. While looking at some older topographic maps of the river below Muskrat Falls, he indicated a few islands as examples:

This one here is a little tiny bit of sand and rock with a few willows on it. And these two up here, they're gone... well they are there enough for a gull to lay eggs on, and that's all. They used to be big islands, you know. This one here used to be a big *willow island, probably half a kilometer long. And those two were fairly big. And the ice just took them away. There's so much ice that piles down there all winter long, drifting down through the water, and it just keeps piling up. It happens from the Churchill Falls development* (Horace Goudie, pers. comm., 2005).

The islands he refers to can be seen in air photos comparing years in the pre- and post-regulation periods (Figures 72 and 73, page 179).

Figure 78. Uprooted Trees on a Small Island Downstream of Gull Lake (Photo: A.Luttermann, 2001).

Several local people reported that they do not remember seeing many large trees toppled by ice along the tops of the banks in the past. Mathew Penashue stated , "There are dead trees near Gull Island caused by the hydro people" (pers. comm., 2001). It is likely that mature trees were felled along the banks in the past as a result of ice jams, or gradually due to natural undercutting of outside bends in the river. However, recent observations show there is also now extensive uprooting of mature trees on islands and along straighter reaches of the lower river (Figure 78 and Figure 79). This was noted in the 1980 environmental assessment of the proposed dams at Gull Island and Muskrat Falls.

The assessment report stated that throughout the river, ice scour was toppling large, older trees on the tops of banks that previously would have been rarely affected by ice (Lower

Churchill Development Corporation, 1980). Ice scour has probably also increased on the more stable, naturally armoured shores. Several islands with cobble shores were specifically identified as having been partially or entirely eroded since the Churchill Falls project was commissioned (Pien Penashue, pers.comm. 2005).

Figure 79. Ice-Scoured Bank on the North Shore of Gull Lake
(Photo: A.Luttermann, 2000).

While looking at recent pictures of uprooted mature trees on islands in the lower river, Pien Penashue commented:

> *It never used to be like that when we went there before. When we were traveling there when our kids were very small, it wasn't like that. There was no damage to the trees like that* (Pien Penashue, pers. comm., 2005).

Pien Penashue (pers. comm., 2005) also mentioned that Muskrat Falls was one place that did not freeze over completely in past years. However, the islands downstream of that falls had well-established, mature trees. A combination of factors, including warmer, higher, and more variable winter flows, is likely responsible for the creation of more open water and unstable ice in some downstream reaches during winter, plus an earlier spring break-up. Climate warming trends may also be contributing to an earlier average spring break-up. This would contribute to the build-up of frazil ice downstream of open water areas, thicker, rougher ice in many sections of the river, and likely increased ice damming. These processes are likely causing the lower reaches of the river, far downstream of the powerhouse, to be more susceptible to ice scouring and erosion of the shoreline. Such changes in winter ice dynamics have been observed in other northern regulated rivers, such as the Peace River in British Columbia and Alberta below the W.A.C. Bennett Dam (Northern River Basins Study Board, 1996).

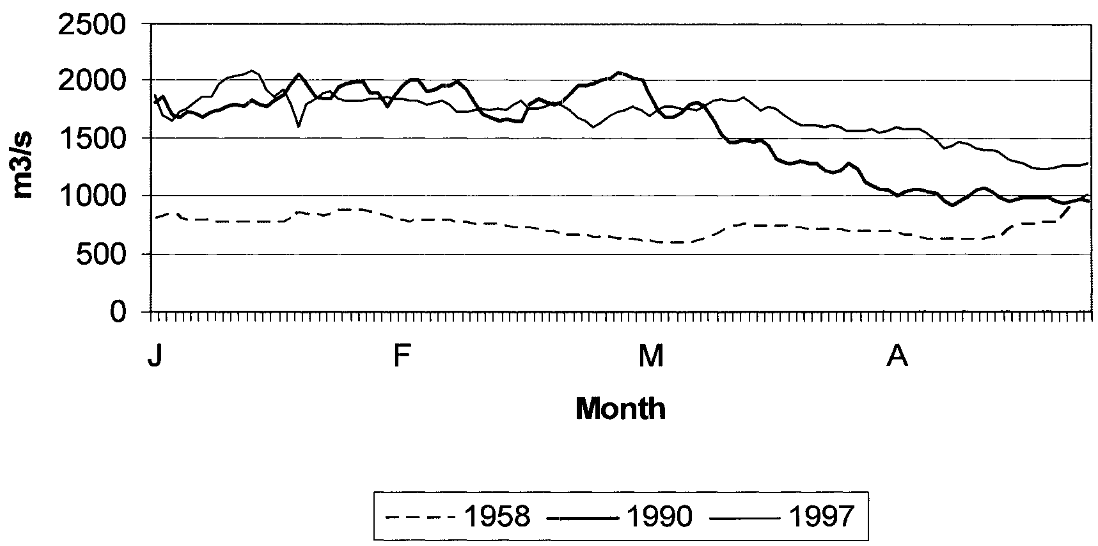


Figure 80. Daily Mean Winter Flows at Muskrat Falls in Selected Years Pre- and Post-Regulation (Data source: Water Survey of Canada).

Winter flow is now on the order of 1.55 x 10^3 m^3/s higher than under pre-regulation conditions; and it fluctuates on a daily basis. The hydrograph in Figure 80 compares years when winter flows were particularly high. The highest pre-regulation winter flow on record is much lower than what has been experienced in recent years, and pre-regulation river flows were much more stable during the winter months.

Extreme high flows in winter have a particularly strong influence on bank stability and rates of erosion. In winter, periodic extreme high flows along with continual daily fluctuations can cause the ice to remain unconsolidated, creating more frequent and larger ice jams that can dislodge vegetation and substrates much more effectively than late spring or summer floods (Prowse and Culp, 2003). The hydrograph in Figure 65 shows that since 1972, peak winter flows at Muskrat Falls have occurred during the months of January to March, on average 1050 to 1392 m^3/s higher than pre-regulation flows and as much as 2650 m^3/s higher in April and 1240 m^3/s in May than they did prior to regulation. The differences between minimum and maximum extreme flows during the winter months ranged from .59 x 10^3 to .90 x 10^3 m^3/s pre-regulation, and 1.3 x 10^3 to 3.1 x 10^3 m^3/s post-regulation. These conditions contribute to a large increase in ice scouring of the riverbanks.

Concern has been expressed by many people that future hydroelectric development will further disturb traditional travel routes and camping places along the river shorelines through flooding or erosion. For example, a section of an old portage that has been used for many generations of Innu and Metis to travel around Muskrat Falls across the saddle to the north has already been partially removed in the slump along the shore at its eastern end (Figure 81). In addition to increased downstream erosion, a new dam at this site would cause major disturbance to the area through the construction of infrastructure, possibly obliterating this path completely. The shore of the upstream side of the saddle would be inundated and the steep slope would need to be armoured to resist erosion and major slumping into the new reservoir. Those people who continue to use this route particularly lament the destruction of the cultural landscape and the loss of historical value to contemporary travelers. Other camps and portages along the lower river above the dams would also be completely erased.

Figure 81. Elizabeth Penashue on the Portage Route around Manitu Utshu and Muskrat Falls (Photo: A.Luttermann, 2000).

As far as I am aware, no studies have been conducted of sediment transport or channel and bed morphology of the downstream riverbed to assess changes in rates of erosion over time. Some work on sediment transport and geomorphology is expected to be completed for the pending environmental assessment for the proposed Gull Island dam. Some monitoring of ice patterns in the lower river has been carried in the post-regulation years, but those data were not available at the time of writing this report.

River regulation can also change the thermal regime of rivers, and it is known that this can affect aquatic organisms (Caissie, 2006). The temperature of water discharged from the Churchill Falls tailraces in winter may be warmer than in years prior to the development as water is drawn into the penstocks from the hypolimnion of the deeper reservoir (Petts and Amoros, 1996). No long-term water temperature data are available to investigate this hypothesis.

Increased disturbance from ice scour affecting the tops of banks and lower summer water levels exposing larger areas of shoreline to plant colonization could be increasing the diversity of riparian vegetation along parts of the lower river. However, it probably does not provide adequate habitat structure for many species, particularly aquatic mammals and nesting waterfowl.

5.5.9 Fred's or Oxalis Island

An example of the effects of increased post-regulation erosion is Fred's or Oxalis Island. This island is located near the south shore of Gull Lake or Tshiashkueish, an expansion of the Churchill River, located about 238 km downstream from the Churchill Falls generating facility (Figure 82). It is known as Fred's Island by local Metis trappers after Fred Blake, who had a trap line there. As there was no name on the maps, it was re-named Oxalis Island by researchers doing site assessments for the International Biological Program (IBP) in the early 1970's (Northland Associates, 1979).

The sites of interest to the IBP biologists included the island and the nearby shore. They were investigated for possible future conservation designation because the most northerly population of *Oxalis acetosella* subsp. *montana* (syn. *Oxalis montana*, common wood sorrel) was recorded there, and was the only known occurrence of the species in Labrador. This species is relatively common throughout central and southern Ontario, southern Quebec, and the Maritimes. It has been classified as rare in Newfoundland (Meades et al., 2000, Ringius and Sims, 1997).

Oxalis Island was predicted to be lost through erosion if further hydroelectric development occurred on the river. I have observed that this site has already been considerably eroded, probably due to increased ice scour from increased winter flows in the river resulting from the Churchill Falls project. Oxalis Island no longer supports a stand of mature white spruce.

Oxalis acetosella subsp. *montana* is a shade-tolerant, perennial herb that is considered to be an indicator of moist, subacidic, medium to nutrient-rich soil. It is commonly found on moist sites in boreal coniferous and mixed-wood forest and in the upper watersheds of hardwood forest near watercourses. The species is often present in *Picea glauca* stands, but is less often found in *Picea mariana* stands (Ringius and Sims, 1997). It is not a strictly riparian species as it requires a more stable, forested habitat. On the island of Newfoundland, it is found on the south coast in sheltered valleys in hardwood thickets and stands of balsam fir, while in Labrador, it is only known from a few locations in the Churchill River basin (Meades et al., 2000). Fred's Island may have periodically experienced overbank flooding during extreme high water events in late spring in the past, which would have contributed to higher moisture levels and nutrients at the site.

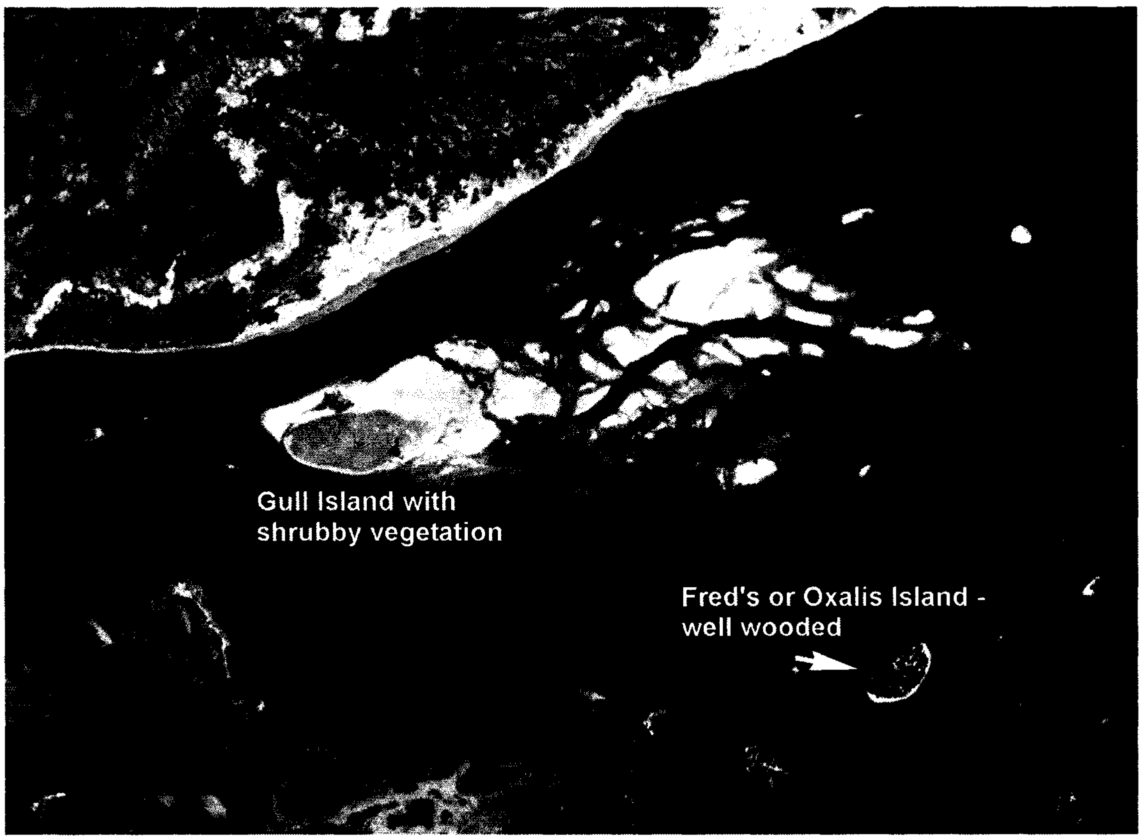


Figure 82. Gull Lake in 1957 Showing the Shrub-Covered Gull Island and the Well-Wooded Oxalis or Fred's Island (Photo: National Air Photo Library). (Text added).

This occurrence of a disjunct population of a regionally rare plant was of interest during our survey because it was recorded on sites on the shores of the Churchill River that have been identified as at risk if additional hydroelectric development was to occur on the river. A report completed for the Lower Churchill Development Corporation in 1979 stated that a dam planned at Muskrat Falls downstream of Gull Island would likely deteriorate one I.B.P. site and completely destroy the other (Northland Associates, 1979). It did not mention effects that may have already occurred from the Churchill Falls development upriver.

The 1979 survey located *O. acetosella* subsp. *montana* on the south side of the island, sheltered under deadfalls of white and black spruce and balsam fir (Northland Associates 1979). Northland Associates reported that the vegetation associated with *Oxalis montana* included "young balsam fir, blackberry, alder, currant, white birch, ferns (*Onoclea sensibilis* and *Dryopteris* spp.), fireweed (*Epilobium* [*Chamerion*] *angustifolium*), bunchberry (*Cornus canadensis*), and feather moss (*Ptilium crista-castrensis*)" (Northland Associates, 1979: 33). *Oxalis montana* was also found on the adjacent mainland shore in the riparian zones of small tributaries. Similar habitat along four other large rivers in the region was surveyed by them (Goose, Kenemu, Kenimish and Traverspine Rivers but no *O. montana* was found there.

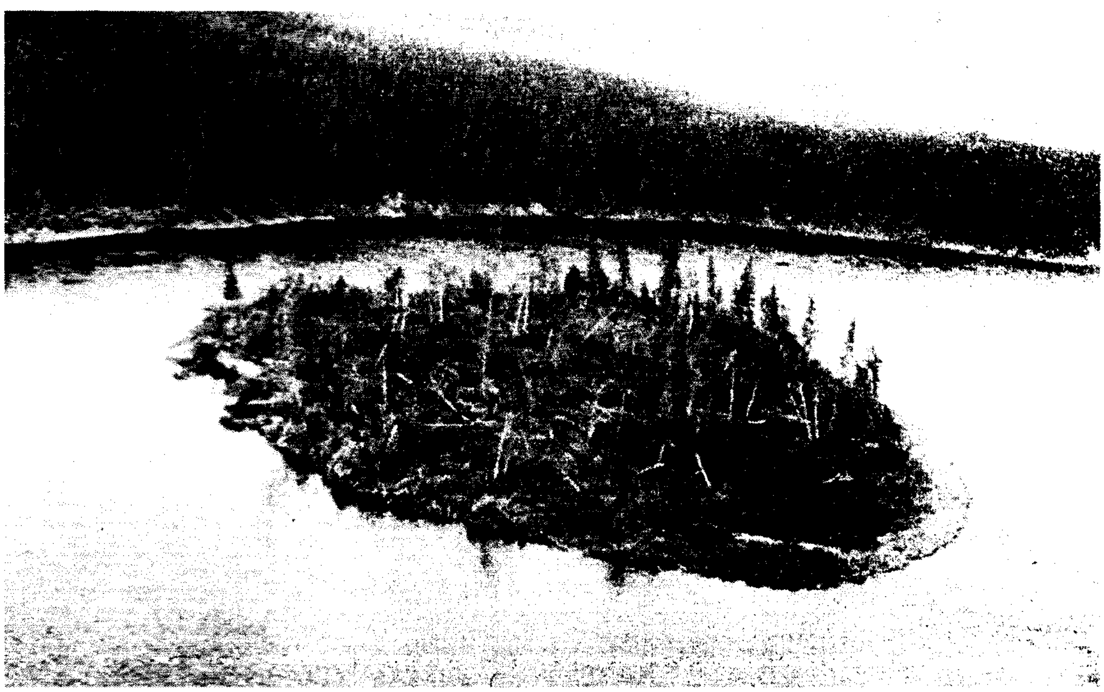


Figure 83. An Aerial View of Oxalis Island in 1979, Showing a Few Remaining Standing Mature Trees (Photo: Northland Associates, 1979: 28).

The report concluded that with the construction of a dam at Muskrat Falls creating a reservoir extending up to Gull Island, "It is probable that this most northerly community of *Oxalis acetosella* L. subsp. *montana* (Raf.) Hultén will be eliminated and with it the value of this I.B.P. site." (Northland Associates, 1979: 34). We found no *Oxalis* during our survey in 2001. This species does persist on main shore sites nearby as confirmed by surveys conducted by another research party in 2006 (Bill Freedman, pers. com.).

The Northland Associates report also stated that "the increased winter flows caused by Churchill Falls power discharges contribute directly to the changed ice regime of the river" (Northland Associates, 1979: 14). However, they did not predict that the higher winter flows might result in the elimination of the mature forest stands from Oxalis Island even without the new dams at Gull Island and Muskrat Falls. The island was already experiencing increased ice scour and erosion by this time, eight years following the initiation of flow regulation. Horace Goudie observed that, "*Gull Island Lake doesn't look like it once did at all. It's because of all this ice drifting out all the time. It changes everything.*" (pers. comm., 2005).

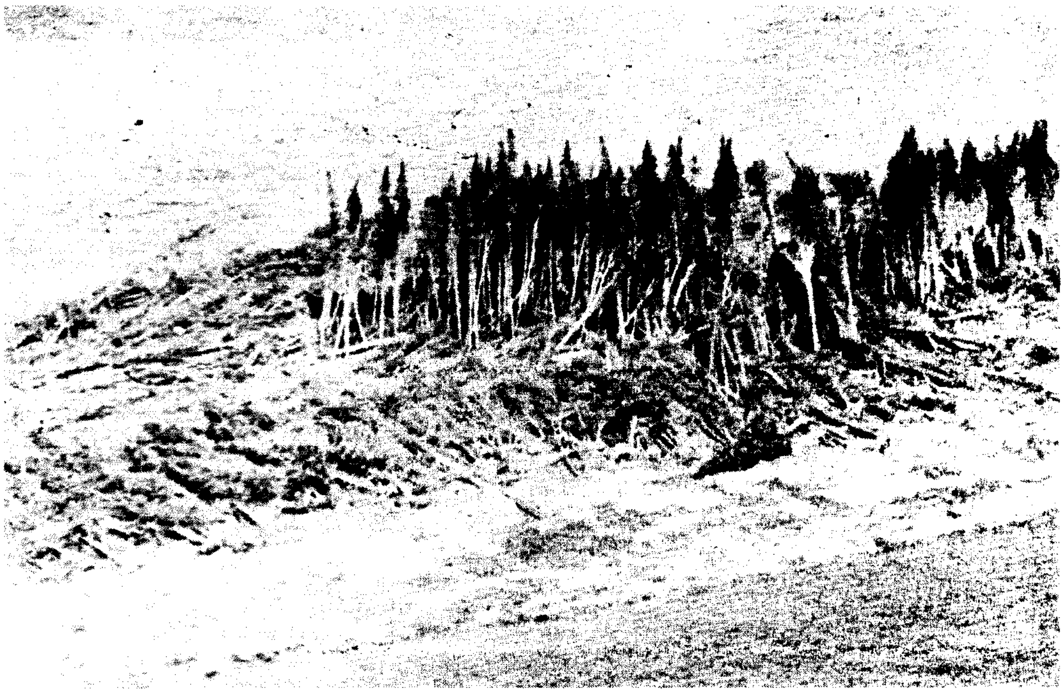


Figure 84. Trees Felled by the Forces of Moving Ice at Gull Island Lake (Photo: Northland Associates, 1979: 29).

There were still some standing mature trees on the island in 1979, as seen in photos taken at the time (Figure 83). However, the majority of the trees had already been killed and felled by ice push (Figure 84). An air photo from 1998 shows only shrub growth on the island (Figure 85).

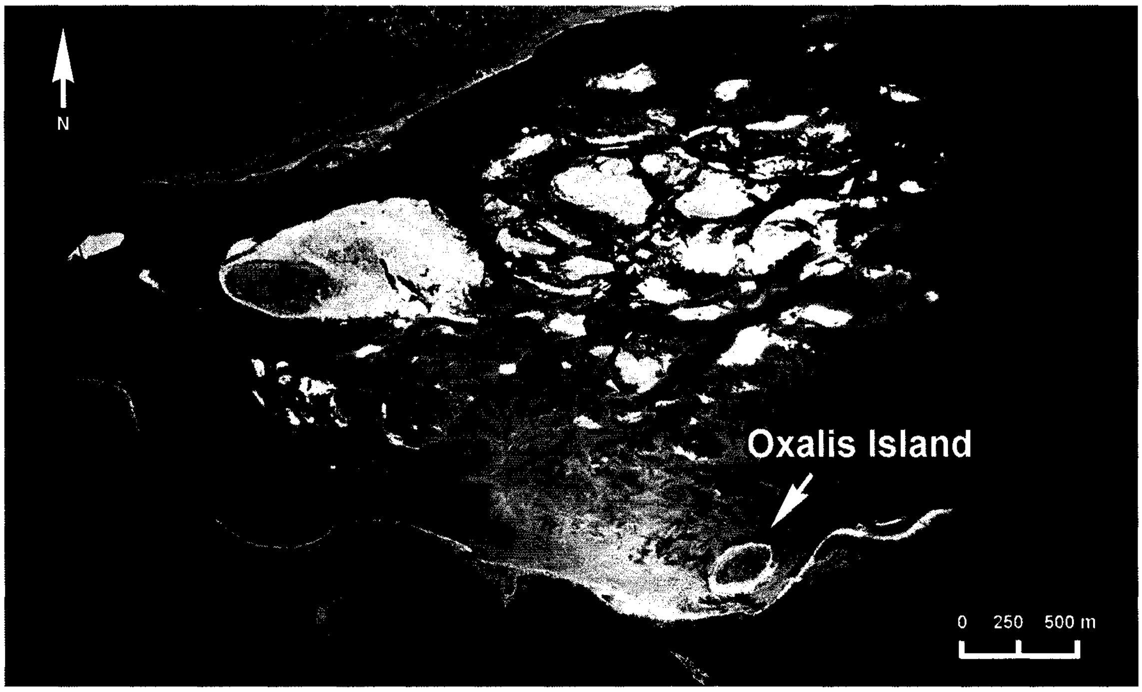


Figure 85. An Aerial View of Gull Island Lake in 1998. The photo shows Oxalis Island with no mature forest cover. It supported a community of herbs, grasses, sedges, and shrubs (Photo: Newfoundland and Labrador Hydro).

There were no standing trees remaining on Oxalis Island in 2001 (Figure 86). Many large deadfalls are laying uprooted (Figure 87). The island has clearly been affected by severe ice scouring and erosion, and is now essentially a high cobble bar with dense shrub and herb cover. It has been entirely converted to an active riparian zone. The Northland Associates report (1979: 29) also mentioned scarification of trees on Gull Island by ice and wind, and included photographs.

Figure 86. Oxalis Island in 2001. There are no standing trees remaining. The entire island has been scoured by floodwaters and ice (Photo: A.Luttermann).

Figure 87. Large White Spruce Uprooted on Oxalis Island. The mainland riparian zone and adjacent forest can be seen in the background (Photo: A.Luttermann, 2001).

In 2001, the island was dominated by *Thalictrum pubescens* var. *pubescens*, *Calamagrostis stricta* subsp. *stricta* var. *borealis, Alnus incana*, subsp. *rugosa*, *Salix lucida* subsp. *lucida*, *Calamagrostis canadensis*, with abundant *Rubus pubescens, Equisetum sylvaticum,* and *Iris versicolor. Onoclea sensibilis* (sensitive fern) was observed only at this site among those surveyed. *Lychnis alpina* var. *american* and *Lysimachia* c.f. *thyrsiflora* L., two species more specific to riparian zones in the area, were recorded here. In total, a relatively high richness of 44 vascular plant species was documented on this riparian island. Few bryophytes were observed on the island.

Judging by the size of the deadfalls and previous photographs, Oxalis Island must have been fairly stable for many decades to develop the former mature stand of large trees. As mentioned, severe ice scour, slumping, and bank erosion were also observed during my survey along the northern banks of Gull Island Lake. Many large trees had been recently uprooted at the top of banks.

Observations as the Oxalis Island site demonstrate that some of the effects predicted to result from a new dam at Gull Island have in fact already occurred as a result of the Churchill Falls development. The effects of the operation of the Churchill Falls hydroelectric project on river morphology and shoreline habitat extend for a considerable distance downstream of the facility.

5.5.10 Riparian Plant Communities

General observation of the shores along the lower Churchill River, along with detailed survey data from individual sites, suggest that that this river corridor presently supports a relatively broad range of riparian habitats with complex vegetation structure and high species richness. Tributary deltas, especially those of the lower gradient alluvial streams, are important areas for the development of riparian shrub and graminoid communities. Lower Brook (Ushakusk-shipiss in Innu-aimun), is a good example of an alluvial floodplain complex supporting diverse patches of riparian vegetation on point bars, meander cut-offs and in filled oxbows (Figure 88).

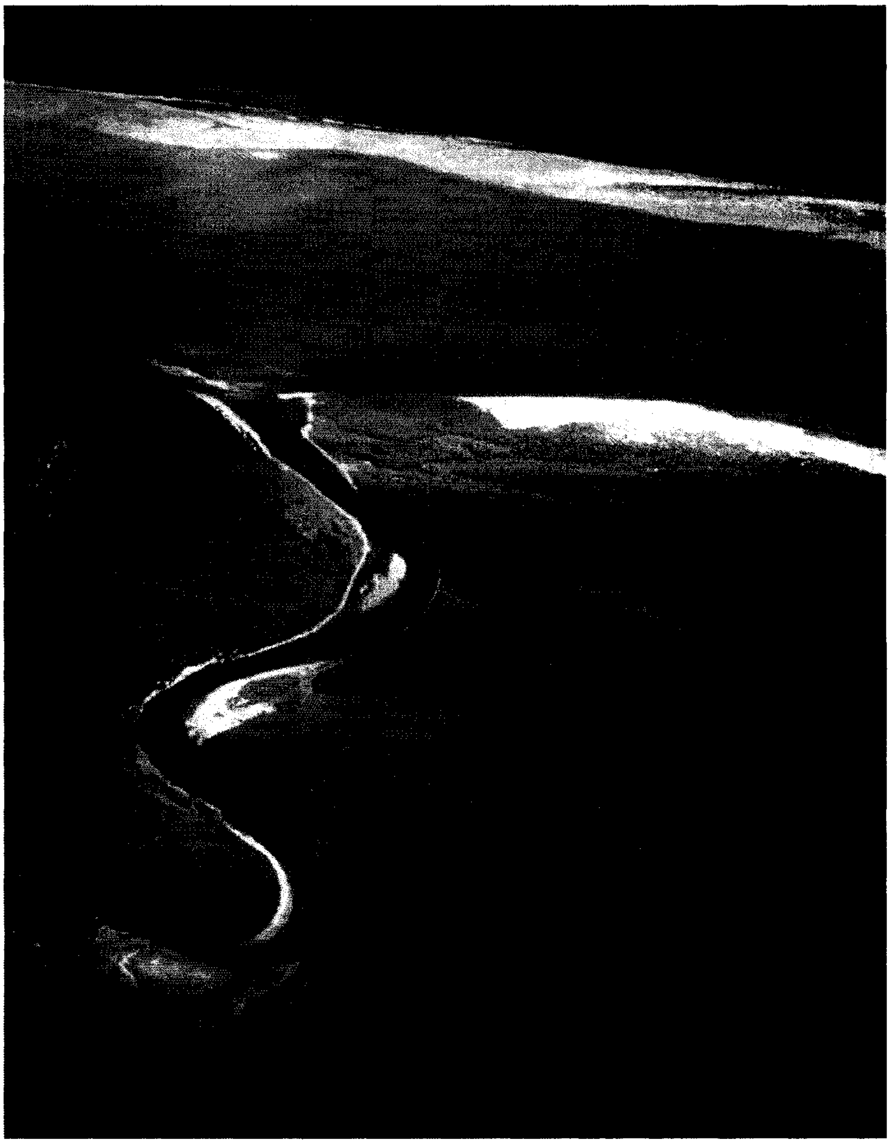


Figure 88. An Alluvial Floodplain Complex at the Delta of Lower Brook (Ushakusk-Shipiss). This area of extensive willow and alder flats on point bars, meander cut-offs and in filled oxbows offers excellent wildlife habitat, and potential for high plant species richness (Photo: A.Luttermann, 1999).

Research in European boreal regions suggest that the larger the size of a river, the higher the species richness of its riparian habitats (Nilsson et al., 1991, 1994). Main stem riparian sites of large rivers tend to have higher species richness of vascular plants per site than their tributaries (Nilsson et al., 1994). They also have higher species richness when compared to smaller rivers in the same region (Nilsson et al., 1991). These observations are attributed to the fact that larger rivers encompass more varied phytogeographical areas, and are thus more likely to accommodate more species. Given that the lower Churchill River also flows through a deep, sheltered valley with a longer growing season, compared to the surrounding region, the opportunities for some boreal species more typically found further south may increase.

I have noted that in late summer, the lower zones of many reaches along the river have sparse plant cover. This may be due to a combination of low late-summer water levels, more frequent fluctuations in water levels during the growing season, and variable interannual summer flows. Central Labrador experienced much lower than average precipitation in the year of my survey (2001), as well as during 2000. This could account for the relatively bare lower shorelines in many reaches. Innu who have traveled the river every year for the past ten years, commented on the exceptionally low water levels during the time of our survey work.

A section from Margaret Doutt's notes describes the river shore at the upstream end of a portage route around Muskrat Falls on July 13, 1939 as follows:

> *A few feet back from the shore of the river there is a wide and dense shrubby zone composed of Myrica gale nearest the river, and back of it Salix pyrifolia, S. lucida, S. agyrocarpa, Alnus crispa and Cornus stolonifera. In a moist, protected opening in the woods, there are tall clumps of Osmunda claytoniana. Between the edge of the river and the shrubby zone there is a narrow area on which there is a mixed growth of Thalictrum polygamum* [syn. *Thalictrum pubescens* var. *pubescens*], *Dryopteris phegopteris* [syn. *Phegopteris connectilis*], *Carex aquatilis, C. canescens, C. angustior* [syn. *Carex echinata* subsp. *echinata], Scirpus rubrotinctus* [syn. *Scirpus microcarpus*], *Juncus brevicaudatus, J. filiformis, Trisetum spicatum var. molle* [syn. *Trisetum spicatum*], *and Calamagrostis canadensis. Along the moist shore and in crevices among boulders Sanguisorba canadensis is frequent* (Abbe, 1955: 18).

The reach surveyed by Doutt is shown in Figure 89 at the time of my survey in 2001. Note that the lower zone above the high-water line was virtually bare of vegetation in 2001. Nevertheless, the entire riparian zone was still very species rich. I recorded 69 species of vascular plants along this reach.

Figure 89. The West-Facing Shore Just Upstream of Muskrat Falls (Site 22) (Photo: A.Luttermann, 2001).

The sparse vegetation in the lower zone consisted of scattered individuals of *Poa palustris*, *Equisetum sylvaticum*, *Juncus filiformis*, and two species of the genus *Potamogeton*. In the higher zones there was dense growth of shrubs, herbs, and graminoids with the dominant species being *Alnus viridis*, *Alnus incana* subsp. *rugosa*, *Cornus stolonifera*, *Symphyotrichum novi-belgii* var. *novi-belgii*, *Salix planifolia*, *Populus balsamifera*, *Salix discolor*, *Salix pyrifolia*, *Myrica gale* and several species of *Carex*.

Typical reaches had sparse vegetation in the lower zones, becoming denser and more diverse higher on the shore (Figure 90 and Figure 91). Along these reaches, patches of vegetation with higher cover values frequently occur adjacent to the shore in moist depressions (Figure 90).

Figure 90. A Typical North-Facing Riparian Shore on the Lower Churchill River with a Heterogeneous Substrate. Forty-eight species were observed here, including emergent sedges and aquatic macrophytes (Site 19) (Photo: A.Luttermann, 2001).

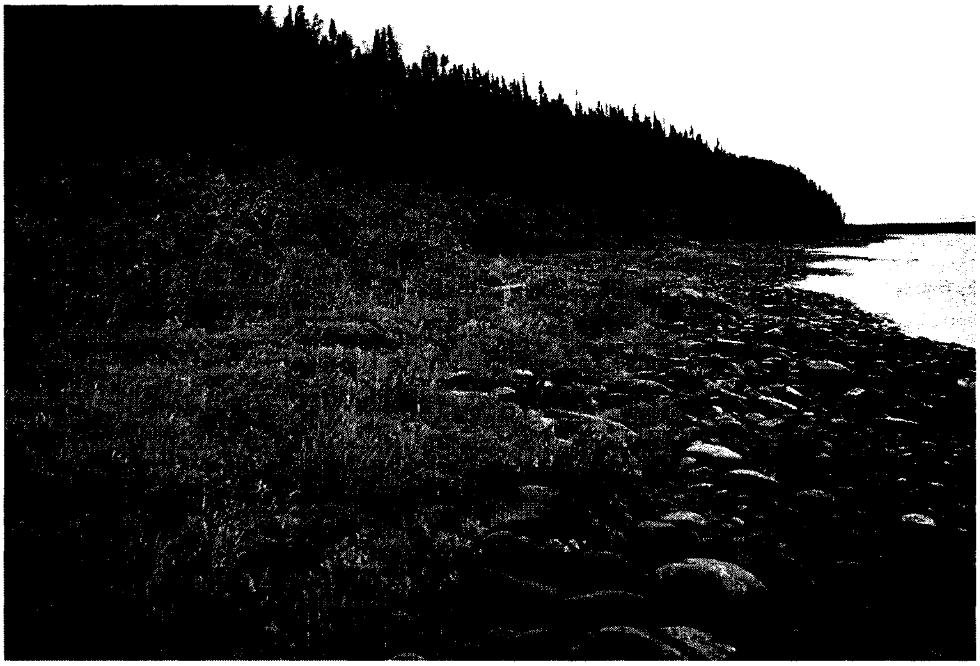


Figure 91. A North-Facing Shore with Coarse Substrate along a Straight Reach. Grasses and sedges were well grazed in the middle of the zone, likely by geese. At this site 54 species of vascular plants were observed, including 4 species of willows, 4 species of *Equisetum*, and aquatic macrophytes, including *Sparganium* sp. (Site 20) (Photo: A.Luttermann, 2001).

Figure 92. A Lush Riparian Zone at Survey Site 8. (Photo: A.Luttermann, 2001).

Some depositional reaches with fine substrate and slower river flow supported dense vegetation growth down to the waterline and just beyond. Aquatic species were evident at some of these sites. At the reach in Figure 92, I observed a muskrat burrowing in the densely vegetated low bank. This site is on the upstream end of Lake Winokapau adjacent to a tributary delta where sands and fine sediment accumulated. There was 100% vegetation cover down to the water, with a wide zone of dense graminoids, herbs, and low shrubs, and a wide, high shrub zone. This site supported the largest number species (n= 79) recorded in a single 200 m reach.

5.5.11 Floodplain Forests

Wilton (1965) described the typical species composition of forest types associated with alluvial soil in the immediate vicinity of the larger rivers in Labrador. His report on forest types and site classification for the Federal Department of Forestry did not refer specifically to shrubby, early successional riparian zones. He addressed the alluvial forest that develops on nutrient-rich fluvial deposits that build up through events of overbank flooding during high spring run-off. These forest stands develop on zero-to-moderate slopes just above the more actively disturbed riparian zone that I investigated. Wilton stated that these stands generally occur no more than 1.5 metres above the normal water level of the river. These stands are stable, not necessarily flooded annually, and are less likely to suffer ice scouring. He described them as one form of the "Fir-Spruce-Birch/Rich-Herb Type" that includes alluvial forest as well as stands further up on the lower slopes of the large river valleys. These forest types contribute to the "excellent" class that makes up less than 1% of the forest of Labrador.

Wilton reported that the soil of alluvial forest is composed of fine glaciofluvial sand in the upper profile, gradually becoming coarser with increasing depth. White spruce often grows to a large size in these stands, and although there are few individuals, they make up a large percentage of the stand volume. Mosses are more abundant in the understory than in other forest types in the region. The shrub layer is not well developed but is richer in species than in other forest types. The species most frequently observed were *Sorbus decora*, *Alnus viridis* subsp. *crispa* , *Alnus incana* subsp. *rugosa*, *Viburnum edule*, and *Acer spicatum*. These forests also host a particularly high variety of herbaceous vegetation, although the cover values are not high under the relatively dense overstory of large balsam fir, white spruce, and white birch. The most abundant herbs are *Cornus canadensis* and *Maianthemum canadense*, followed by *Clintonia borealis, Dryopteris campyloptera, Goodyera repens*, *Listera cordata,* and *Trientalis borealis*. Wilton also reported that *Oxalis acetosella* subsp. *montana* was present in small patches in some stands of this alluvial forest type (Wilton 1965).

As will be discussed in the concluding chapter, further study of the species composition of the flood plain forests in the lower river valley is highly recommended.

5.6 Comparisons among Sites

5.6.1 Vegetation Cover

Observations made of vegetation cover during the growing season at the survey sites are consistent with the impressions of typical shores in reaches affected by various hydrological regimes as observed on air photos. Most striking is the overall homogeneity of the reservoir shorelines (Figure 93). The exposed riparian zones in the storage reservoirs were typically 80 – 90% bare of plants in mid-summer to early fall. Most of the vegetation occurs in the upper part of the riparian zone and consists mainly of upland species. Most of these plants have likely become established in the years since full-pond was last reached in the reservoirs during the 1970s. The forebay control reservoirs also have low vegetation cover, but the active drawdown zones are quite narrow (Figure 94). Graminoids are somewhat more prevalent on the shores of the forebays. All reservoir shores had large quantities of woody debris from drowned trees, mostly stranded along the upper shoreline. In lower-energy areas of the storage reservoirs, considerable numbers of drowned trees remained submerged.

Air photos distinctly show:

- consistently wide, unvegetated shorelines of the storage reservoir
- narrower, similarly bare shorelines of the west forebay
- a narrow, essentially indistinguishable herb/shrub zone in the east forebay
- a wider shrub/herb zone along unimpounded lakes and streams in the surrounding area.

The lower river reaches also have many bare sand and cobble bars and shorelines with little vegetation cover that are easily distinguished on air photos or satellite images. However, the lower river shorelines are considerably more heterogeneous than the reservoirs. Field investigation of these areas suggests that many more species are able to establish on the newly deposited and/or scoured substrates than in the reservoirs.

Vegetation cover along reduced-flow reaches is also quite variable. Dewatered areas with finer substrates have developed dense shrub communities. Satellite images show that along the Naskaupi River where water levels have decreased, there are many sand bars that have become partially vegetated. There are oxbow lakes and side channels that previously may have been permanently or seasonally flooded before the diversion of the headwaters. Wide shrub/herb zones are apparent on adjacent unregulated rivers such as the Kenemu. All of these areas require more field investigation before the typical differences in vegetation cover and species composition can be thoroughly described.

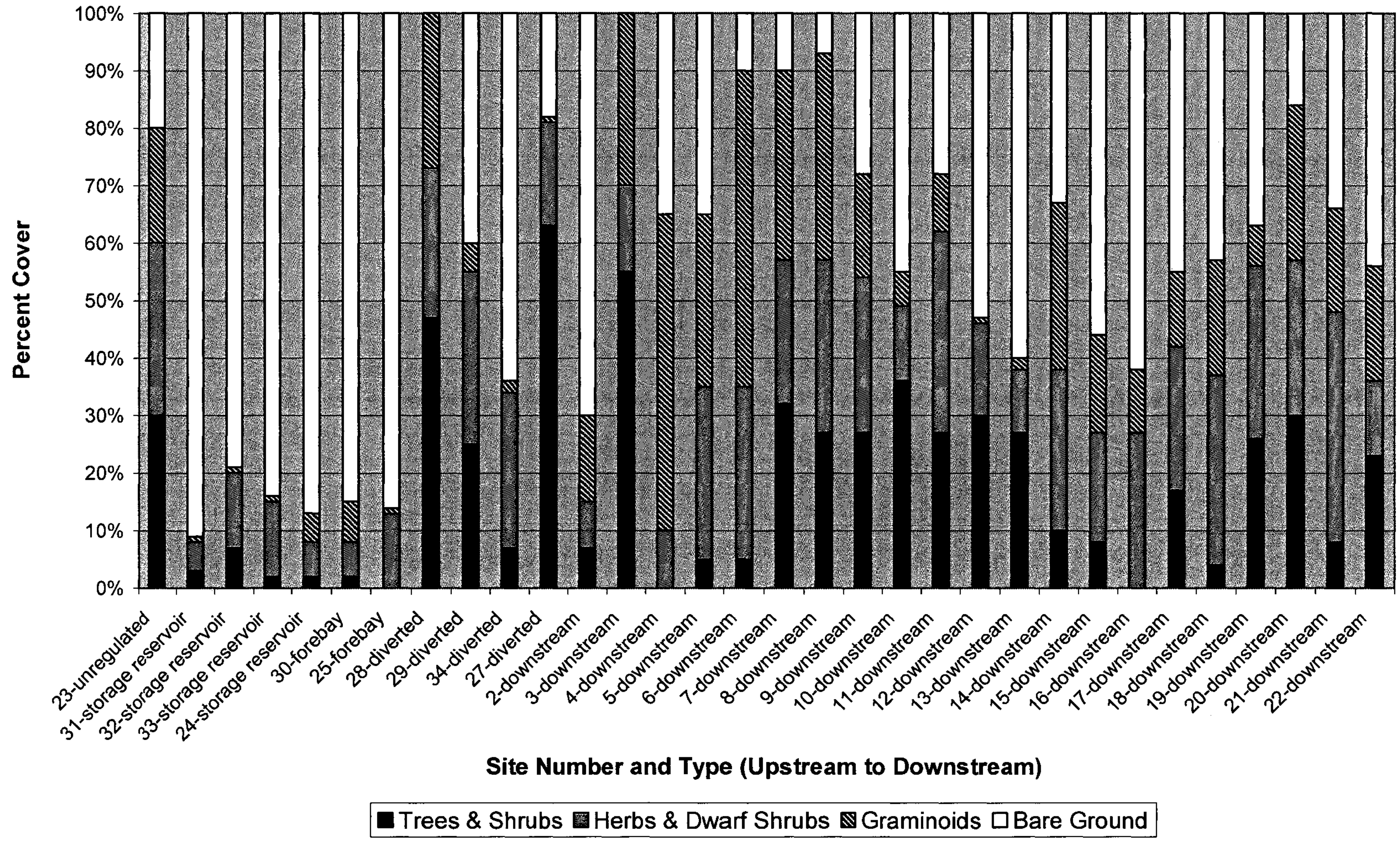


Figure 93. Percent Vegetation Cover Per Site (2001 Survey).

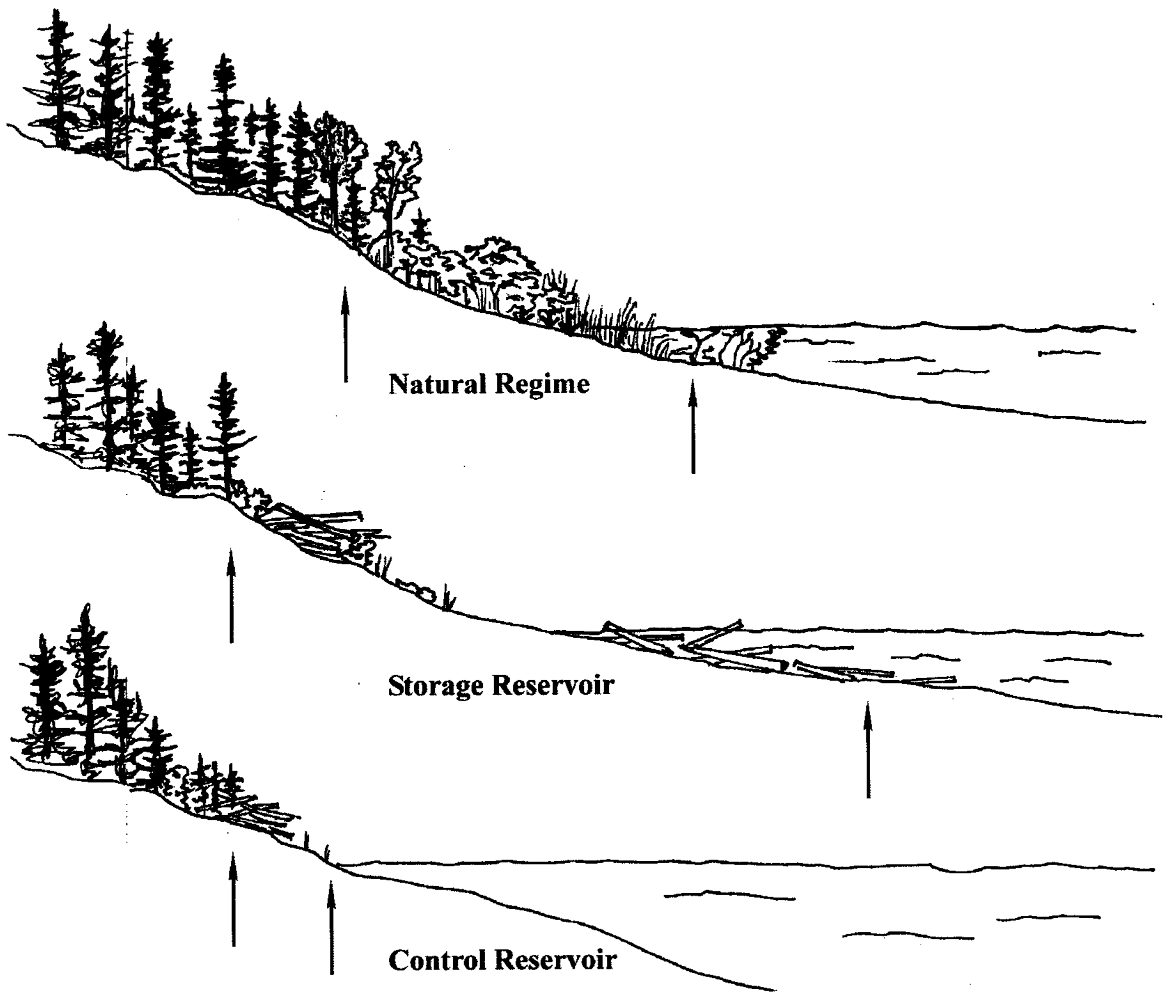


Figure 94. A Conceptual Diagram Comparing the Width of Active Riparian Zones and Vegetation Structure Typical of Slow Flow, Moderate Slope Shorelines under Various Hydrological Regimes. (Arrows indicate seasonal high and low water levels). The reservoirs typically have large quantities of woody debris stranded on the shores, and sparse vegetation cover in the riparian zone (Illustration: A.Luttermann).

5.6.2 Substrate Characteristics

Fine substrate texture and heterogeneity are positively correlated with species richness in other studies of riparian vegetation, and negatively with regulated regimes (Jansson et al., 2000). Raw data are presented here from my survey as an indication of the variety of site characteristics encountered. Statistical comparison among the various types of flow regimes would not be valid without additional data to better represent the reservoir sites.

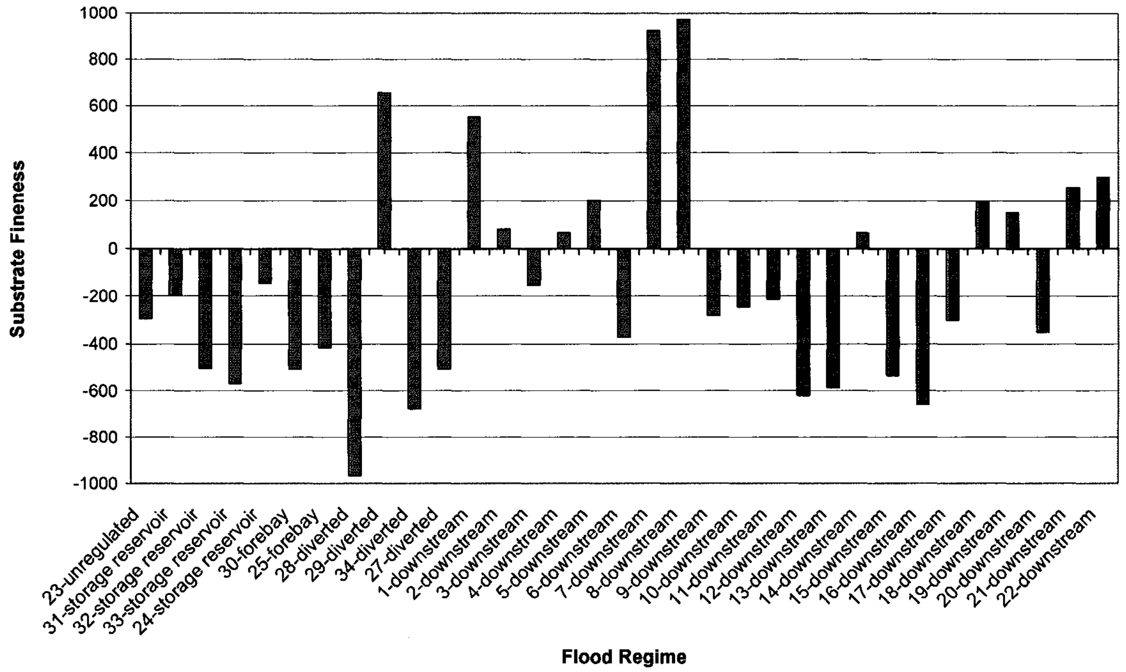


Figure 95. Relative Substrate Fineness. Higher values indicate finer substrates (2001 survey). Relative values of substrate fineness were calculated using the percentage composition of the riparian zone surface substrate as estimated by eye. Following Wright et al. (1984) and Nilsson et al. (1989), substrate types were weighted as organic/peat 12, clay 9.0 silt 6.5, sand 2.0, gravel -2.0, pebbles -4.5, cobbles -6.5, boulders -9.0, bedrock -12.

Substrates along reservoir shores tended to be coarser, which is what would be expected with frequent scouring and high rates of erosion of thin soil. Downstream sites along the main stem of the river exhibited more variation in substrate texture and heterogeneity (Figure 95). The values of substrate heterogeneity reflect the number of types of substrates observed on the surface at each site. These were identified from fine to coarse types as organic, clay, silt, sand, gravel, pebbles, cobbles, boulders, bedrock. This gives an indication of the complexity of the site and thus the habitat opportunities for species. The data suggest somewhat higher variability among sites in the diverted and downstream reaches. Again, statistical analyses cannot be made using these data as they are not sufficiently representative of the reservoirs and diverted reaches. Moreover, values obtained from observations of sites that are more densely vegetated are perhaps less accurate using this superficial method.

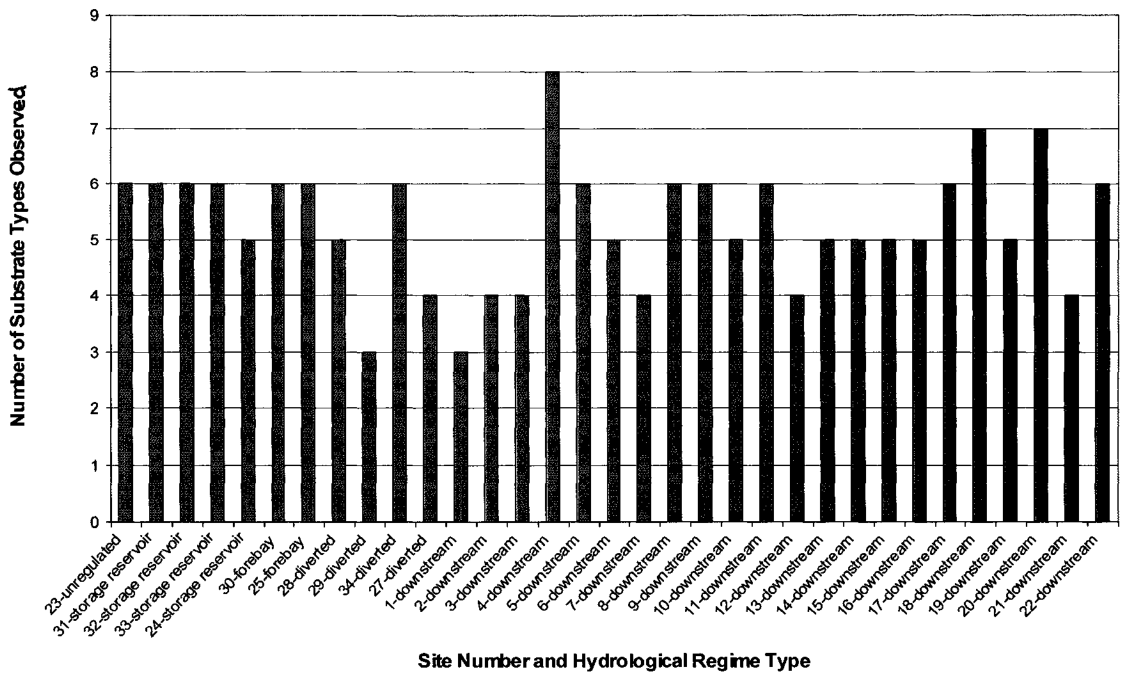


Figure 96. Substrate Heterogeneity of the 2001 Survey Sites.

5.6.3 Species Richness

A total of 133 species of vascular plants was identified in previous published studies in riparian zones of the Churchill River (Table 7). Because habitat descriptions or locations of collections were not always provided in detail, not all of these species were necessarily found within the active riparian zone as defined in this study. Other species that may have been collected from riparian zones in this region may not be included in our list because their specific habitat association may not have been included in the botanical records (e.g. Blake, 1953).

I observed a total of 189 species along the shorelines of the Churchill River. This represents 24% of the total recorded flora of Labrador based on the list of Meades et al. (2000). In comparison, Nilsson (1992a) reported that 13% of the total vascular flora known in Sweden was found along the unregulated Vindel River. This large, seventh order river had the richest single site for vascular plants in Sweden, with 131 species recorded along a 200 m reach (Nilsson, 1992a). The botany of Labrador is not as well studied as that of Sweden, therefore the portion of the total flora of the region found along the Churchill River may be smaller than this figure suggests. It would also be appropriate to include the flora of the north shore of Québec in any general assessment of the ecoregional flora.

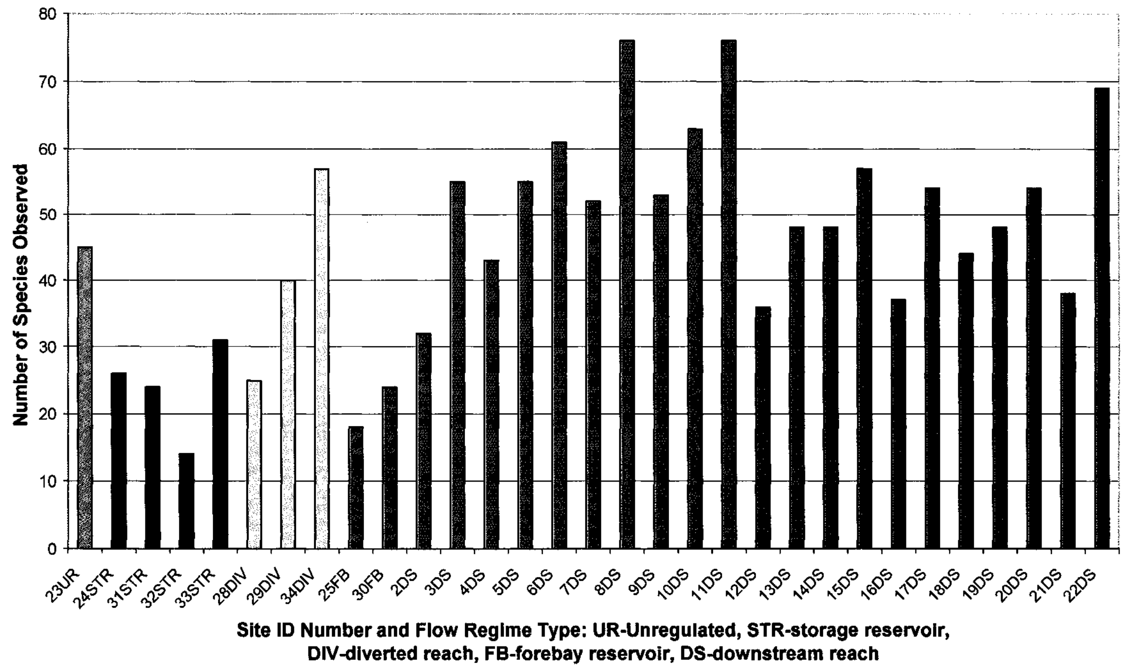


Figure 97. Species Richness Per Site by Hydrological Regime (2001 survey).

The number of species per site along the Churchill River was higher in 15 of the 21 downstream reaches surveyed compared to all other types of regulation (Figure 97). Two sites had 76 species (range 32-76, N=21). The highest number of species recorded in a diverted reach was 57 (range 25-57, N=3), in the forebays 24 (range 18-24, N=2), and in the storage reservoirs 31 (range 14-31, N=4). The data from the reservoirs and diverted reaches are not sufficient to conduct a statistical comparison of species richness among types of hydrological regimes. However, observations of typical shoreline vegetation structure among these regimes suggest that the data are indicative of existing variation.

Table 4. Average Species Richness by Hydrological Regime

	Mean Species Richness	Range	*N*
storage reservoirs	23.8	14-31	4
forebays	21.0	18-24	2
diverted reaches	41.7	25-57	3
downstream reaches	52.3	32-76	21

Table 4. shows the average species richness of sites in reaches with distinct hydrological regimes. The storage reservoirs and forebays had the lowest species richness. The average for the diverted reaches is relatively high, primarily due to the one site adjacent to the former falls.

Many of the species recorded in the riparian areas of the Churchill River are common in upland forest, barrens, bogs, and/or fens in central Labrador. Since the botany of central Labrador has not been extensively studied, it is not possible to ascertain which species may be relatively uncommon throughout the region and more restricted to the Churchill River riparian habitats.

Although comparative data were not collected for this study, some speculation about species presence and relative richness of the Churchill River riparian sites can be made by considering some other data sets that exist. For example, a botanical survey was done to evaluate the presence of rare vascular plants in areas of eastern central Labrador (Paradise River, Boreal Forest Region) that would be disturbed by the construction of a new section of the Trans-Labrador Highway (Anions, 2001). Of the 28 survey sites, there were 13 riparian areas, 6 wetland sites, 4 lacustrine sites (around small ponds), and 1 estuarine shoreline site. The distance surveyed at each site ranged from 100 meters to 2 kilometers and the waterways were walked on both sides. All species observed were recorded, including aquatic macrophytes, and particular attention was paid to minor variations in the landscape that may constitute microhabitats and host rare species. Species richness per site ranged from 6 to 53 with a mean of 20. Sites on the lower Churchill had a range of 20 -76 species with an average of 51. A total of 135 species of vascular plants were recorded, compared to the 189 recorded along the Churchill River sites. This is an indication that riparian zones along larger rivers may be more species rich per site and as a whole than the shores of smaller waterways in the region. Of course, more extensive work will need to be done to confirm this suggestion.

5.6.4 Species Composition

Sites in the lower reaches of the river hosted many species that are indicative of nutrient-rich, moist soil, with a well-decomposed forest floor and some accumulation of silt (Ringius and Sims, 1997). Some of these that were relatively abundant in the lower river sites include *Actaea rubra, Athyrium filix-femina, Cornus stolonifera, Galium labradoricum, G. trifidum, G. triflorum, Gymnocarpium dryopteris, Ribes glandulosum, Rubus pubescens,* and *Viburnum edule.* Other species, indicative of similar conditions but less abundant at these sites included *Circaea alpina, Cicuta bulbifera,* and *Ribes triste*. Moisture-loving species that thrive in more calcium-rich soils are more likely to be found in the riparian zone of large rivers than in the more acidic environments of bogs.

The most frequent species found along the entire river was the grass *Calamagrostis canadensis*, a good colonizer. It was found at all but one site. Abundance was much higher at the sites along the lower river reaches. Other grasses noted most often were *Agrostis mertensii* and *Deschampsia cespitosa.*

Carex brunnescens, C. lenticularis, and *C. trisperma* were the most common sedges. *C. aquatilis* was relatively common only in the lower river and in the former spray zone. The most common rush in all reaches was *Juncus filiformis*.

Shrubs or young trees recorded most frequently at various sites were *Abies balsamea*, *Alnus incana* subsp. *rugosa*, *Alnus viridus* subsp. *crispa*, *Betula papyrifera*, , *Myrica gale*, *Picea mariana*, *P. glauca*, *Rhododendron groenlandicum*, *Salix pellita*, *S. bebbiana*, *S. humilis*, and *S. planifolia. S. lucida* was common in downstream reaches only. *Viburnum edule* and *Cornus stolonifera* were common only in the downstream reaches, dewatered reaches, and at the spray zone.

The most common herbs at most sites were *Cornus canadensis* and *Chamerion angustifolium*. Other common herbs found mostly in the lower river or along dewatered reaches included: *Achillea millefolium* subsp. *lanulosa*, *Chamerion latifolium*, *Epilobium ciliatum* subsp. *glandulosum, E. palustre*, *Galium trifidum*, *G. triflorum*, *Iris versicolor*, *Linnaea borealis* subsp. *americana*, *Lycopus uniflorus*, *Potentilla norvegica, Ranunculus flammula* var. *reptens, Rubus idaeus* subsp. *strigosus*, *R. pubescens, Sanguisorba canadensis*, *Ribes glandulosum*, *Solidago macrophylla*, *Symphyotrichum novi-belgii* var. *novi-belgii*, S. *puniceum* var. *puniceum*, *Thalictrum pubescens*, *Trientalis borealis*, *Viola* *macloskeyi* subsp. *pallens* and, *V. renifolia*,

Possible new records for Labrador from the 2001 survey include:

- *Carex hostiana* (tawny sedge, host's sedge) was collected only at site 8 and identified by Dr. Paul Catling at the Department of Agriculture (DOA) Herbarium, where a single specimen is deposited. This species is classified as rare on the island of Newfoundland. The Flora of North America includes a Labrador report of *C. hostiana* (Flora of North America Editorial Committee, 1993+). It is listed as possibly rare in Québec under the Threatened or Vulnerable Species Act.[18]
- *Carex panicea* (millet sedge) was recorded at four sites in the lower river reaches and identified by Catling from two specimens deposited at the DOA Herbarium. This is a non-native Eurasian species, possibly recently introduced.
- *Epilobium* cf. *leptophyllum* (bog willow-herb) was collected at site 34, a diverted reach above the former Churchill Falls. One specimen was tentatively identified by Catling and deposited at the DOA Herbarium, but it requires confirmation with examination of more specimens.
- *Juncus articulatus* (jointed rush) was recorded at three sites in the lower river, and identified by Catling from a specimen deposited at the DOA Herbarium.
- *Listera borealis* (northern twayblade) was recorded at several sites in the lower river reaches. Although this species was previously recorded for Labrador, according to Meades et al. (2000) its presence required confirmation.

Other records represent range extensions within Labrador including: *Equisetum pratense* (meadow horsetail) which was previously reported only for southern Labrador at L'anse au Loup.

A few aquatic species were also recorded during my survey, although I did not

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[18] *Threatened or Vulnerable Species, An Act Respecting*, - R.Q. c. E-12.01, r.1

target aquatic species. All of those recorded were either in the downstream sections of the lower Churchill River, or on the unregulated Ashuanipi River. Those observed included:

- *Callitriche verna* (vernal water starwort) which was only at site 23 in the Ashuanipi River, outside the zone of influence of the hydroelectric developments;
- *Glyceria striata* var. *stricta* (fowl manna grass), at three sites in the lower river;
- *Hippuris vulgaris* (common mare's tail), only at site 20 in the lower river.
- *Ranunculus aquatilis* var. *diffusus* (white water crowfoot), at three sites in the lower river;
- *Potamogeton* cf. *alpinus* (alpine pondweed), at seven sites in the lower river;
- *Sparganium sp.* (burreed), at three sites in the lower river.

5.6.5 Exotic Species

Only five non-native species were observed along the riparian zones.[19] Most were recorded at riparian sites that are close to roads. Studies conducted on regulated rivers in northern Sweden also found few non-native species in the riparian zones of large rivers (Jansson et al., 2000). There is no evidence that any introduced species have yet spread appreciably along the banks of the Churchill River following regulation. The case has been different in some other areas such as in arid south-western regions of the U.S. with exotic species such as *Tamarix ramosissima* (saltcedar) invading regulated river corridors and replacing native cottonwood and willows (Naiman et al., 2005).

Carex panicea L., millet sedge from Europe, was observed at three sites downstream of Churchill Falls that are not near roads. CF(L)Co has seeded several areas around road cuts in the vicinity of the town. It is possible that this species was introduced in this way, or it may be dispersing from a disturbed area such as at site 17 adjacent to the Gull Island dam location. This site has experienced considerable disturbance from preliminary construction activities during the 1970's, including a gravel road down to the

[19] A total of 66 introduced species has been recorded on uncultivated sites throughout Labrador (Meades et al., 2000).

river.

In addition to *Carex panicea* noted above, other introduced species recorded at the riparian sites include:

- *Poa annua* (annual bluegrass) - recorded only at site 28, a diverted reach above the falls, which is close to a maintenance road by the Jacopie Spillway;
- *Poa compressa* (Canada bluegrass, wiregrass) - recorded only at site 16;
- *Trifolium aureum* Pollich (golden clover, hop clover) - only one record at site 22, Muskrat Falls portage. This is at the end of a well-used portage that crosses a road. It is easily accessible by foot from the road. The surrounding area has also experienced a great deal of disturbance over the years by activities associated with the engineering planning for a dam at Muskrat Falls.
- *Trifolium hybridum* L. (alsike clover) - only one record at site 4, just a few kilometers downstream from the tailraces and the town of Churchill Falls.

There are many diverse sources and modes of dispersal of exotic species aside from operations at the hydroelectric facility. The non-native species *Galeopsis bifida, Leontodon autumnalis, Leucanthemum vulgare, Phleum pratense, Taraxacum officinale, Trifolium pratense, T. repens,* and *T. agrarium* and were recorded as far back as the 1920s in the settlements of Mud Lake and Northwest River (Wetmore, 1923). *Phleum pratense* was also observed at the Muskrat Falls portage during that survey. None of these species were observed during our survey along the river.

Certainly much more work can be done on the phytogeography of this region to better understand the patterns of distribution of shrubs and herbaceous plants.

5.6.6 Habitat Affiliation of Species Observed

The species recorded during our surveys were classified according to the following wetland indicator system developed by the U.S. Fish and Wildlife Service (1996) for a National Wetlands Inventory:

Indicator Categories

- Obligate Wetland (**OBL**). Occurs almost always (probability >99%) under natural conditions in wetlands.

- Facultative Wetland (**FACW**). Usually occurs in wetlands (probability 67%-99%), but occasionally found in non-wetlands.
- Facultative (**FAC**). Equally likely to occur in wetlands or non-wetlands (probability 34%-66%).
- Facultative Upland (**FACU**). Usually occurs in non-wetlands (probability 67%-99%), but occasionally found in wetlands (probability 1%-33%).
- Obligate Upland (**UPL**). May occur in wetlands in another region, but occurs almost always (probability >99%) under natural conditions in non-wetlands in the region specified.

The categorization for the northeastern region of the U.S. system was applied to my list of species, except for a few northern species for which the classification for Alaska was used. Some species not included on the U.S. National Wetlands Inventory list were classified by the author based on habitat descriptions in other references (Aiken et al., 1999; Flora of North America Editorial Committee, 1993+; Gleason and Cronquist, 1991), (i.e. *Lychnis alpina* var. *american*, *Castilleja septentrionalis*, *Carex hostiana*, *Betula cordifolia*). The designations therefore do not necessarily correspond accurately to the habitat affiliations that would be specifically typical for Labrador. Because the system includes all wetland types, some obligate wetland species may, for example, be found primarily in bogs or fens and only occasionally in riverine environments.

Of the 189 species observed in riparian zones:

- 59 (31%) are obligate wetland plants
- 63 (33%) are facultative wetland plants
- 41 (21%) are equally likely to occur in wetlands or non-wetlands
- 23 (12%) are facultative upland plants
- none are obligate upland plants.

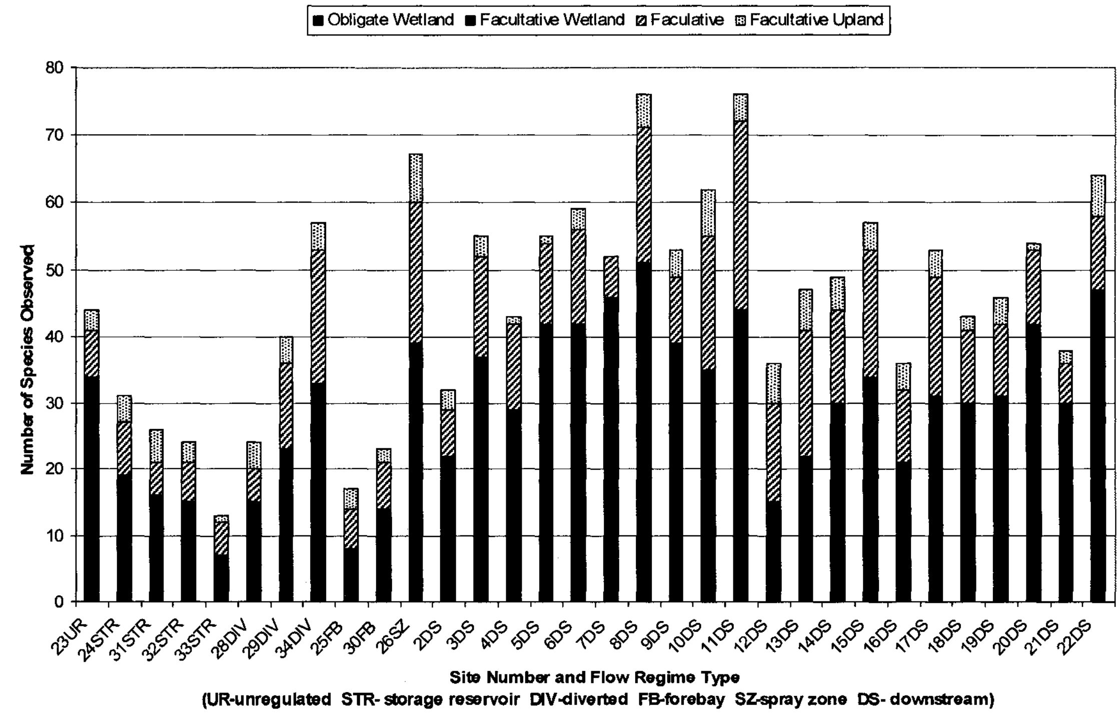

Figure 98. Habitat Affiliation of Species Per Site (2001 survey).

Figure 98 illustrates the proportions of total species at the sites according to their wetland affiliation. Figure 99 shows the percentage of species observed at each site according to their habitat affiliation. The site totals are less than 100% in some cases because species with uncertain taxonomy and exotic species were not included. Three of the reservoir sites (STR and FB), and diverted reaches (DIV), had slightly higher proportions of facultative upland plants than the lower river sites. Thirteen of the lower river sites had slightly larger proportions of obligate wetland and facultative wetland species than the reservoirs and diverted reaches. The unregulated site also had a relatively high proportion of wetland affiliates. This pattern is generally what might be expected. However, a good deal of variability exists among sites in the various reaches, with two of the lower river reaches having relatively low numbers of wetland affiliates.

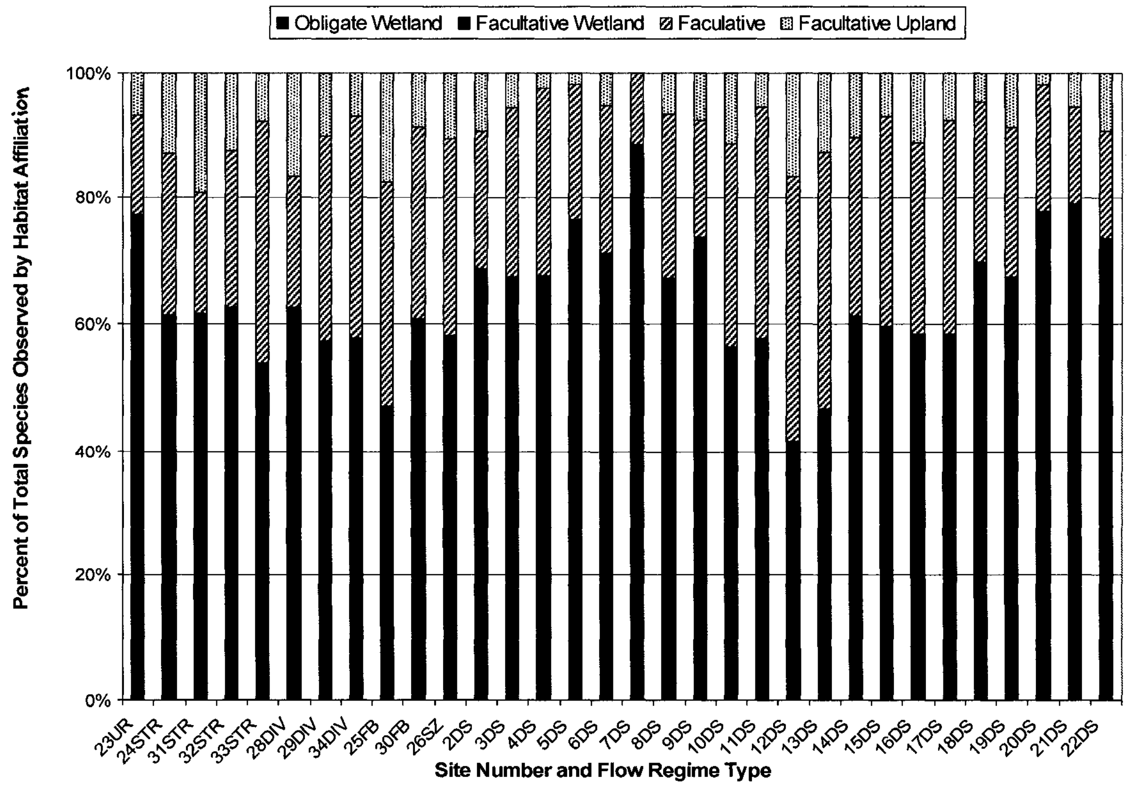

Figure 99. Relative Proportion of Species Per Site According to Habitat Affiliation (2001 survey).

5.6.7 Rare Species

Thirty-seven species recorded during my survey are ranked by the Atlantic Canada Conservation Data Centre (ACCDC) as potentially rare within Labrador (Table 5). Included here are those ranked between S1 and S3.[20] These classifications are considered

[20] S-rank is a term used by Conservation Data Centres (CDCs) and NatureServe to refer to the sub-national (provincial, state) conservation status rank of an element, as determined at the sub-national level by given CDCs.

S1 Extremely rare throughout its range in the province (typically 5 or fewer occurrences or very few remaining individuals). May be especially vulnerable to extirpation.

S2 Rare throughout its range in the province (6 to 20 occurrences or few remaining individuals). May be vulnerable to extirpation due to rarity or other factors.

S3 Uncommon throughout its range in the province, or found only in a restricted range, even if abundant in at some locations. (21 to 100 occurrences).

S4 Usually widespread, fairly common throughout its range in the province, and apparently secure with preliminary, because the ACCDC has relatively limited botanical data from the region. Many species recorded in the region have not yet been classified according to their rarity due to a lack of data.

All of the eight species listed as possibly extremely rare (S1) were observed only in the lower river sites or at the unregulated Ashuanipi site (*Ranunculus* cf. *pennsylvanicus* or *R. macounii*). One species which is possibly rare in the region but has undetermined status (*Listera borealis*) was observed in several lower river sites, in the former spray zone, and at one diverted site. This species is also listed in Québec as potentially threatened or vulnerable.[21] The taxonomy and conservation status of the specimens identified as *Salix cordata* are uncertain.

Most of the additional species listed as possibly S2 (N=16) were found only in the lower reaches with the following five exceptions:

- *Carex stipata* var. *stipata* (S2S3) was found in the diverted reach above Churchill Falls;
- *Agrostis scabra* (S2S3) was located at two reservoir sites, the diverted reach above the falls and three lower river sites;
- *Schizachne purpurascens* subsp. *purpurascens* (S2S3) was found only in the former spray zone;
- *Scutellaria galericulata* (S2S3) was found in one reservoir site and two lower river sites;
- *Mitella nuda* (S2?) was located at three lower river sites, in the former spray zone, in one reservoir site and one diverted site.

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many occurrences, but the Element is of long-term concern (e.g. watch list). (100+ occurrences).
SU Unrankable: Possibly in peril throughout its range in the province, but status uncertain; need more information.

[21] *Threatened or Vulnerable Species, An Act Respecting*, - R.Q. c. E-12.01, r.1

Table 5. Rare Species Recorded Along the Churchill River in 2001

Species (taxonomy according to Meades, et al., 2000)	**Wetland Indicator Category**	**S-Rank**
Equisetum fluviatile L.	**OBL**	**S1S3**
Equisetum palustre L.	**FACW**	**S1**
Equisetum pratense Ehrh.	**FACW**	**S1**
Lycopodium dendroideum Michx.	**FACU**	**S3S5**
Lycopodium lagopus (Laest. *ex* C. Hartm.) G. Zinserl. *ex* Kuzen.	**FAC**	**S3S5**
Athyrium filix-femina (L.) Roth *ex* Mertens var. *angustum* (Willd.) G. Lawson	**FAC**	**S3S5**
Onoclea sensibilis L.	**FACW**	**S2S3?**
Botrychium multifidum (S.G. Gmel.) Rupr.	**FAC**	**S1**
Carex leptonervia (Fernald) Fernald	**FACW**	**S2S3**
Carex projecta Mackenzie	**FACW**	**S1S2**
Carex stipata Muhl. ex Willd. var. *stipata*	**OBL**	**S2S3**
Scirpus microcarpus J. & C. Presl (syn. *S. rubrotinctus*)	**OBL**	**S2S3**
Iris versicolor L.	**OBL**	**S2S3**
Juncus arcticus Willd. var. *balticus* (Willd.) Trautv.	**OBL**	**S3S4**
Juncus brevicaudatus (Engelm.) Buch.	**OBL**	**S3**
Luzula parviflora (Ehrh.) Desv.	**FACU**	**S3S4**
Clintonia borealis (Aiton) Raf.	**FAC**	**S3S4**
Corallorhiza trifida Châtelain	**FACW**	**S3S5**
Listera borealis Morong	**FACW**	**SU**
Agrostis scabra Willd.	**FACU**	**S2S3**
Schizachne purpurascens (Torr.) Swallen subsp. *purpurascens*	**FACU**	**S2S3**
Potamogeton alpinus Balbis	**OBL**	**S3S4**
Scheuchzeria palustris L. subsp. *amer*	**OBL**	**S3**
Astragalus cf. *robinsii* (Oakes) A. Gray	**FAC**	**S1**
Ribes lacustre Pers. (Poir)	**FACW**	**S2S3**
Mentha arvensis L. subsp. *borealis* (Michx.) Roy L. Taylor & MacBryde	**FACW**	**S2S3**
Scutellaria galericulata L	**OBL**	**S2S3**
Circaea alpina L. subsp. *alpina*	**FACW**	**S3S4?**
Actaea rubra (Aiton) Willd. subsp. *rubra*	**FAC**	**S3S4**
Ranunculus abortivus L.	**FACW**	**S2**
Ranunculus cf. *pennsylvanicus* L.f [P.C.] or *R. macounii* Britton	**OBL**	**S1**
Prunus pensylvanica L.f. var. *pensylvanica*	**FAC**	**S2S3**
Galium triflorum Michx.	**FACU**	**S2S3**
Populus balsamifera L. subsp. *balsamifera*	**FACW**	**S2S3**
Populus tremuloides Michx.	**FACU**	**S2S3**
Salix cordata Michx. (or *S. eriocephala*? Not sure which species ranked S1 is referred to on the TransLabrador Highway list)	**FACW**	**S1**
Mitella nuda L.	**FACW**	**S2?**

Of the eleven additional species listed as possibly S3 or more common, all were found in the lower river only with the following exceptions:

- *Athyrium filix-femina* var. *angustum* (S3S5) was found at six lower river sites, the former spray zone, and at one diverted site;
- *Luzula parviflora* (S3S4) was found in the lower river and the former spray zone;
- *Clintonia borealis* (S3S4) was found in the spray zone and one diverted reach;
- *Actaea rubra* subsp. *rubra* (S3S4) was observed in the lower reaches and the spray zone;
- *Carex hostiana* was found at one site on the lower river, and is a possible new record or confirmation for Labrador. It is listed by Québec as a possibly threatened or vulnerable species.[22]

Mountain maple (*Acer spicatum*) is listed by the Atlantic Canada Conservation Data Centre (ACCDC) as a rare species in Labrador. The rarity ranking assigned to this species is S1, meaning it is considered extremely rare throughout its range in the region, and may be vulnerable to extirpation. M.J. Doutt reported mountain maple growing near Gull Island rapids in a forested site during her survey in 1939 (Abbe, 1955). She suggested then that this observation represented a marked northward extension of this species. This species has since been observed downstream of the Minipi Rapids on a small island in the main stem of the Churchill River called Minipi Island by local people (Joe Goudie pers. comm., 2005; Grand River Keeper, 2006). Mountain maple was not observed during the riparian surveys conducted for my study. Minipi Island was not surveyed. Another Labrador location at the mouth of the Cape Caribou River at Grand Lake has been recorded recently for this species (Swiatoniowski, 2001).

Some plants were identified by Innu elders as growing only in a few areas close to shores along the lower Churchill River valley. For example, Pien and Nishet Penashue

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[22] *Threatened or Vulnerable Species, An Act Respecting*, - R.Q. c. E-12.01, r.1

identified a shrub they know as "ashiwashuk"[23], used for medicinal purposes, that they know to be growing on an island on the south side of the river near the Gull Island rapids. There are two well-established wooded islands in that location. We discussed the known locations of this shrub …

> *Yes, there is a brook and another brook that come together near that island. They are dry in the summer time. It is called Shipashtuk [stream that is joined together]. I have always wanted to go back there to get that medicine. The name of that tree is ashiwashuk. It looks like Inasht* [Balsam fir] *but it is not the same. That is the only place it is found* (Nishet Penashue pers. comm., 2001).

The species they described resembled *Taxus canadensis* (Canada yew). They had mentioned this plant during previous conversations, so the author brought a specimen of *Taxus canadensis* from Nova Scotia to show them. We also discussed the size and habit of the shrub. Nishet and Pien were certain that it was the same species.

> *It is a small, short tree that bends down. It does not grow very tall. One of our daughters almost died on that river. We cooked that tree up and put it over her head and on her stomach. She was vomiting. They used this plant for heart problems too* (Pien Penashue pers. comm., 2001).

Canada yew is considered an indicator of rich, moist mineral and organic soils, particularly in seepage zones and rocky banks of waterways (Ringius and Sims, 1997). Ringius and Sims reported that it has not been confirmed in the botanical literature from anywhere in Labrador (1997). However, it appears on Meades et al. (2000+) annotated list for Labrador. Nishet and Pien Penashue knew this plant only from that one location on the Churchill River near the shore. It was not previously documented in any of the botanical surveys along the river. In 2006, *Taxus canadensis* was identified from the area along the river mentioned by the Penashues by a field team conducting a survey for the Gull Island project environmental assessment. It was most likely growing in the floodplain forest.

5.6.8 Species Previously Recorded

Species that were recorded previously by other biologists in the riparian zones along the river, and were not observed during any of our surveys (see Table 7), include

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[23] This spelling was suggested by an Innu interpreter who was unfamiliar with this plant. There is no standard orthography in Innu-aimun. *Ashtshiuashishk*[u] is given as the name for Canada yew (*Taxus canadensis*) in Clément, 1990. It is most certainly the same plant.

the following (Wetland habitat affiliation classifications are added):

- *Alopecurus aequalis* Sobol. var. *natans* (Wahlenb.) Fern. (OBL)
- *Anaphalis margaritacea* L. (FACU)
- *Arabis alpina* L. subsp. *alpina* (FAC)
- *Aralia hispida* Vent. (FAC)
- *Bromus hordeaceus* L. syn. *B. mollis* L. (UPL)
- *Capnoides sempervirens* (L.) Borkh. [syn.*Corydalis sempervirens* (L.) Pers.] (FACU)
- *Carex canescens* L. (OBL) [could be confused with *C. brunnescens*]
- *Carex bigelowii* Torr. (FACW)
- *Carex echinata* Murray subsp. *echinata* syn. *Carex angustior* Mackenz. (OBL)
- *Carex stylosa* C.A. Meyer var. *nigritella* (Drej.) Fern. (FACW)
- *Isoetes echinospora* Dur. (OBL)
- *Maianthemum trifolium* (L.) Sloboda (OBL)
- *Osmunda claytoniana* L. (FAC)
- *Oxalis acetosella* L. subsp. *montana* (Raf.) Hultén (FAC)
- *Persicaria vivipara* (L.) Ronse-Decr. syn. *Polygonum viviparum* L. (FAC)
- *Parnassia kotzebuei* Cham. & Schlecht. (FACW)
- *Parnassia parviflora* DC. (OBL)
- *Parnassia palustris* L. var. *neogaca* Fern. (OBL)
- *Pinguicula vulgaris* L. (OBL)
- *Platanthera dilatata* (Pursh) Lindl. ex L.C. Beck var. *dilatata* syn. *Habenaria dilatata* (Pursh) Hook. (FACW)
- *Poa alpina* L. (FACU)
- *Prunella vulgaris* L. var. *lanceolata* (Bart.) Fern. f. iodocalyx Fern. (FAC)
- *Potentilla tridentata* Ait. (syn. *Sibbaldiopsis tridentata* (Solander) Rydb.) (FAC)
- *Rubus arcticus* L. subsp. *acaulis* (Michx.) Focke (FAC)
- *Salix argyrocarpa* Andersson (FACU)
- *Salix glauca* L. var. callicarpaea (Trautv.) Argus syn. *Salix cordifolia* Pursh var. *callicarpaea* (FAC)
- *Saxifraga aizoides* L. (FACW)
- *Selaginella selaginoides* (L.) Link (FACW)
- *Utricularia vulgaris* L. (OBL)

Of those species listed above, *Oxalis acetosella* subsp. *montana* is designated as (S1S3); *Osmunda claytoniana* as (S2S4), and *Parnassia kotzebuei* is listed as (S3S4) on the regional conservation status list for Labrador.

Some populations of species in this list may have been affected by flow regulation, especially those with wetland associations other than bog habitats. However, more investigation is required to establish whether they continue to be present along the river, and to assess their abundance within other habitats in the region. *Anaphalis margaritacea* (pearly everlasting) is a common ruderal plant that was observed previously along the river and was not recorded during our study. However, this species was documented by Swiatoniowski (2001) at the mouth of the Beaver River tributary. As discussed in section 5.5, *Oxalis acetosella* subsp. *montana* has been observed by others more recently in the valley of the lower river.

Because there is little information on their previous abundance or distribution within the watershed of the river, trends in the abundance of particular species since regulation are impossible to establish. Many members of the families Cyperaceae, Poaceae, and Salicaceae are difficult to identify to species. It is possible that some of them have been incorrectly recorded in the past.

Chapter 6. The River's Future

We can tell you that the land and the animals are being destroyed but they don't listen to us. They [the project proponents] *just want to build more dams* (Pien Penashue, pers.comm. 2005).

6.1 Proposals for Additional Hydroelectric Development

Plans to build two additional hydroelectric dams on the lower reaches of the main stem of the Churchill River were already being made during the 1960s when the Churchill Falls project was under construction (Smith, 1975). Due to various economic and political constraints, these initiatives have been pursued and then halted several times over the past four decades (Churchill, 2003). However, in November 2006, Newfoundland and Labrador Hydro registered a project proposal under the province's Environmental Assessment Act[24] to build two large dams and power plants on the lower Churchill River (Newfoundland and Labrador Hydro, 2006). The project description also initiates the environmental assessment process under the Canadian Environmental Assessment Act (CEAA).

There are two main sites of interest for construction of the dams and generating facilities (Government of Newfoundland and Labrador, 2005) (Figure 100). One is located at the head of Grizzle Rapids about 1.2 km upstream of Gull Lake, 225 km downriver of the existing Churchill Falls facility. The other is at Muskrat Falls, located 60 km further downriver. The exact configuration of the project, including the number of turbines, remains subject to further engineering design and market studies, however the installed capacity is expected to be about 2000 MW at Gull Island and 800 MW at Muskrat Falls. At Gull Island, the earth embankment dam would be 99 m high and 1,315 m long spanning the valley. At Muskrat Falls, a concrete dam is planned in two sections – one 32 m high and 180 m long, the other 29 m high and 270 m long. At maximum operating levels, the reservoirs behind the dams would flood about 85 km^2 and 36 km^2 of terrestrial habitat, respectively. The Gull Island reservoir would be 225 km long with a total surface area of 200 km^2, and at a maximum operating level of 125 m, would extend

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[24] Newfoundland and Labrador *Environmental Protection Act*, SNL 2002 c.E-14.2

from the dam to the base of the tailraces of the existing Churchill Falls power plant. (The actual centerline distance between the dam site and the tailraces is 231.7 km.) The reservoir at Muskrat Falls would extend 60 km from the dam to the tailraces of the Gull Island facility, with a surface area of about 100 km^2 (Government of Newfoundland and Labrador, 2006).

Both facilities have been described as "run of the river" operations in hydroelectric engineering terms. This means that the reservoirs would not have the capacity to store water for more than a few days. Thus, the quantity of water available for power generation at the new facilities would depend to a large extent on discharge rates from the Churchill Falls generating facility plus additional run-off directly from the lower watershed. Operations would have to be largely coordinated (~75%) with those of the Churchill Falls power plant. However, water levels would be strictly controlled in the reservoirs. The Gull Island reservoir would have a larger active storage capacity, which would allow water levels to be controlled within a range of 3 metres. The smaller Muskrat Falls reservoir would have little active storage capacity. Water levels there would need to be kept within a range of .5 metres. There would be daily fluctuations in water levels as power demand varied from morning to night. Such a regime would eliminate the remaining influence of the tributaries on the seasonal flow patterns of the main stem of the lower river. There would be no large spring floods to rejuvenate riparian zones with nutrients, scour the banks, and prevent succession from shrub/herb communities to forest or to create seedbeds for pioneering riparian species.

In the late 1970s, an environmental assessment process was undertaken to evaluate the predicted effects of a 100-metre dam, powerhouse, and spillway at Gull Island, and a similar but smaller facility at Muskrat Falls (Lower Churchill Development Corporation Ltd., 1980). Data on the magnitude of the reservoirs and area of land that would be flooded are offered in assessment reports and more recent project descriptions as an indication of how the projects would inflict relatively less environmental impact per unit of power produced than the Churchill Falls facility, because the reservoirs would not be nearly as large as the Smallwood and Ossokmanuan reservoirs (Government of Newfoundland and Labrador, 2005). However, the data must be understood in the context of the quality of habitats that would be affected, and the cumulative degradation of

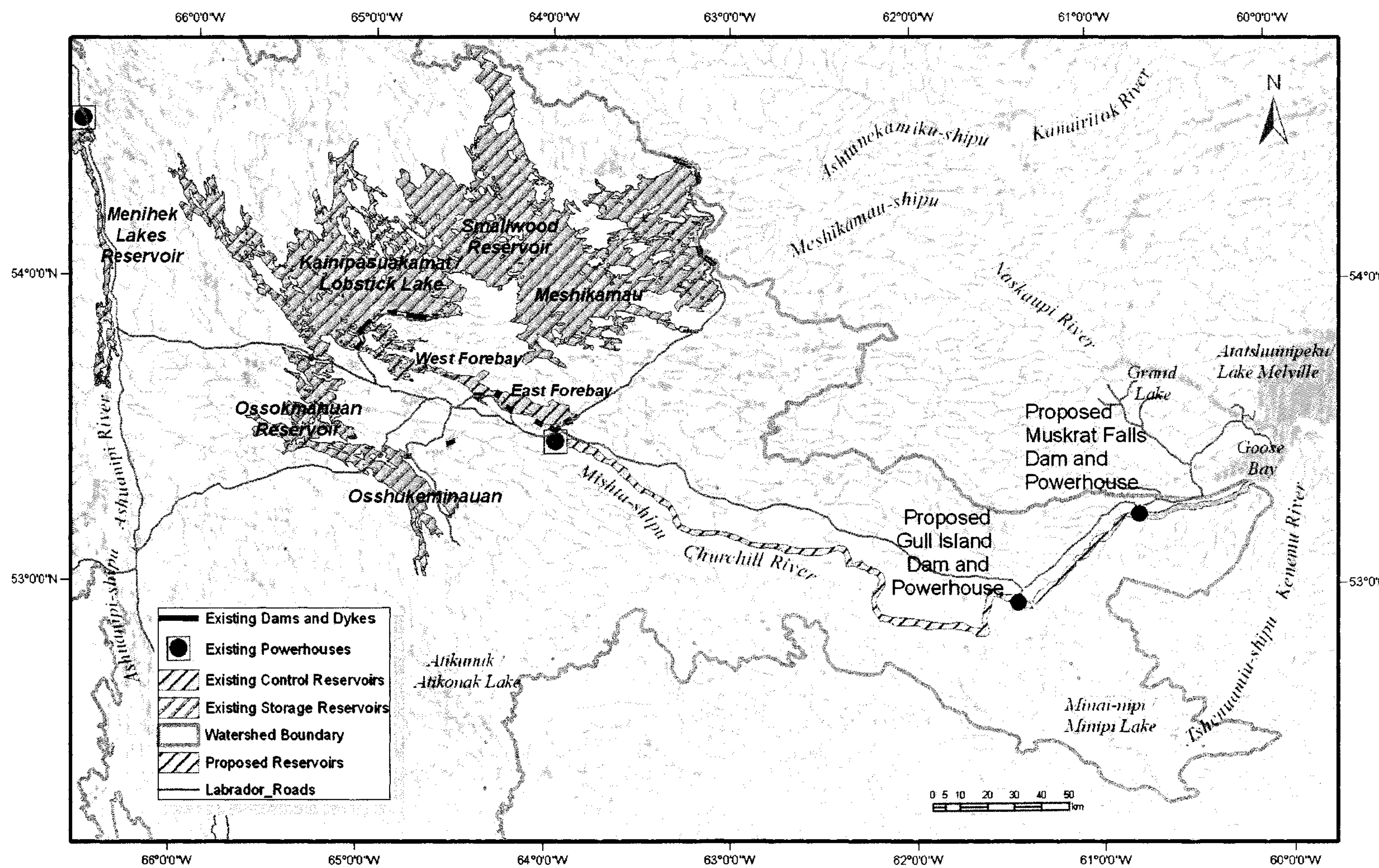

Figure 100. Location of Proposed Dams and Powerhouses at Gull Island and Muskrat Falls (Map produced on ARC GIS by A.Luttermann. Data obtained from: Environmental Systems Research Institute (ESRI); Geogratis; Innu Nation; National Topographic Data Base (NTDB), 1:250,000 map sheets).

riverine habitat throughout the watershed. Essentially the entire lower main stem of the river would be converted into control reservoirs, except for a 43 km reach downstream of Muskrat Falls to the mouth of the river.

Future floodwaters from the proposed new dams would inundate most of the existing riparian habitat in the lower main stem of the river. All existing shorelines, islands, tributary deltas, and shallow, fast-water habitat would be flooded along the main stem of the river from Gull Island to the base of the tailraces at Churchill Falls, and from Muskrat Falls to the base of the Gull Island dam. The flooding would convert the existing swift-flowing riverine environment into a deeper, slower-moving reservoir. Seasonal fluctuations in water level would be eliminated, thereby removing the processes that create the species rich, early successional river shoreline habitat. Alder and willow shrub, herb, and graminoid communities along river shorelines, bars and flats that provide important browse and cover for many species, and nesting and staging areas for waterfowl would be lost. This type of habitat would not likely re-establish along the new reservoir banks, due to the steeper slopes where the new shorelines would be located, and changes in the hydrological regime (Nilsson, 1996). Added to the habitat conversion that has already occurred in the upper watershed, these changes would constitute the near elimination of natural riparian habitats along most of the river.

With the creation of reservoirs in the reaches above dams at Gull Island and Muskrat Falls, the scouring effects of ice damming and ice jams would no longer occur along most of the main stem of the river (see Rosenberg et al., 2005). A stable ice cover would develop on the reservoirs in winter, providing it is sufficiently cold. The new reservoirs above Gull Island and Muskrat Falls may be operated to fluctuate daily within a range of about one meter over the course of an entire year. Maximum drawdown for the Gull Island reservoir has been predicted to be about 3 metres. This would provide an ability to control the flow for some degree of weekly or monthly regulation. However, the seasonal fluctuations in flow throughout most of the lower reaches of the river would be almost entirely smoothed out. There would be little to no shoreline zones that are flooded in spring and exposed throughout the growing season to provide opportunities for riparian plant growth. It is therefore likely that these reservoirs would develop riparian zones with vegetation structure and cover more similar to the forebay reservoirs above the Churchill

Falls powerhouse. Vascular plant species richness would probably be considerably reduced throughout the river corridor.

Increased slumping of steep slopes of marine and glaciofluvial sediments would likely occur. It is not known how long this would continue before the new shorelines become stabilized. Such events would create habitats that would be colonized by early successional plant communities. If an eroded slope then stabilized, it would eventually develop a forest cover. Alder/willow thickets or graminoid communities would not be expected to persist over the longer term on stabilized slumps. The species composition of slumped habitats that presently exist could be studied to better understand the similarities with seasonally flooded riparian zones, particularly the lowland willow flats.

The 43 km reach of the river below Muskrat Falls to the mouth of the river would experience large changes in flow patterns as the bulk of the upstream drainage would be regulated through the dams. The hydrograph here would also be smoothed out, except for extreme flood events, because the new reservoirs would not have the capacity to hold these back. This downstream reach would likely be subject to increased rates of erosion due to the capture of sediment behind the dams. As sediment settles out behind the dams, the water released through turbines would pick up a new sediment load from the downstream riverbed and banks. Some predictions suggest that erosion below Muskrat Falls may decrease due to the stabilization of ice cover in winter, which might prevent the formation of frazil ice and the massive ice jams in the bowl below the falls (Lower Churchill Development Corporation Ltd., 1980). Additional study of sediment transport is required to make more specific predictions of changes that may occur downstream from the additional reservoirs. Added to this, a sediment-mining operation has recently been proposed for the entire reach of the lower river, and increased commercial forestry activity could also affect shoreline vegetation and riverine aquatic communities.

6.2 Assessing Additional Loss of Riparian Habitats in the Churchill River Watershed

As discussed in Chapter Two, riparian habitats along large rivers may typically host a higher level of plant species richness than smaller rivers (Kalliola and Puhakka, 1988; FORAMEC, 1992a; Nilsson, 1991c, 1992a; Nilsson et al., 1994). This may be due to a combination of the quantity and variety of habitats along larger rivers, and other factors such as dispersal corridors and the occurrence of microclimates. It is clear that the construction of various large-scale water regulation schemes in the Québec/Labrador peninsula in recent decades has extensively reduced the quantity of natural riparian habitat on large rivers.

When assessing the cumulative effects of a development project or environmental change, it is useful to estimate the amount of habitat or habitat potential that is lost or gained. While data representing changes in the areal extent of riparian zones may suggest the direction that cumulative effects may be taking, it is necessary to understand whether the effects are simply additive or whether synergies are occurring, in which the consequences are larger than the sum of their individual parts. For example, as this thesis demonstrates, changes in hydrology will directly affect the local structure and species richness of riparian vegetation, and may also affect the dispersal patterns and persistence of plant populations over time. Changes in these habitats may compromise the life cycles of dependent populations of animal wildlife in the broader region.

The environmental assessment conducted in the early 1980's for the proposed dams on the lower Churchill River recognized that riparian habitats would be lost and degraded. A report for the EIS stated that:

> *The best Riparian Habitat Types in wildlife terms are within the flood zone and will be destroyed with flooding. However, new Habitats will develop upslope following flooding. The rate at which those Habitats will be replaced might be enhanced by clearing the new shoreline prior to flooding, but will be dependant on the degree of slope at which the shoreline will develop, as fairly extensive wet (but not flooded) flats are required* (Hunter and Associates, 1981:33).

This early assessment of new riparian habitat development along reservoir shorelines was quite optimistic, and seemed to ignore the important influence of natural hydrological regimes. There was an assumption that new shoreline vegetation communities would develop that may be similar to those flooded and could to some extent replace those lost in the main river valley. However, even in reaches where the slope is not very steep, it is unlikely that the vegetation communities that will develop will be similar to those that currently exist. The new riparian zones will almost certainly be very narrow, subject to constantly fluctuating water levels, and lacking the influence of a large spring flood in the main river followed by a summer growing period on exposed substrates. It is possible that areas where major tributaries intersect with the new reservoirs new deltas could develop some complex riparian vegetation structure and species richness (Johnson, 2002). However, this is unlikely to be very extensive compared to the current conditions. The tributaries flow mainly along steep gradients into the main river valley. There may be cases where the intersection occurs at a terrace with low slope and these areas should be investigated for the purposes of long-term monitoring if the project goes ahead. Nevertheless, any calculations conducted for a cumulative effects assessment must consider that most of the remaining riparian habitats in the main stem of the river and lower reaches of the tributaries will be entirely lost. The riverine landscape as known to local people will also be gone.

6.2.1 Quantifying Riparian Habitat Loss

The quantification of riparian habitats has been cited as an important research objective (e.g., Nilsson et al., 2003). Because these habitats are being increasingly altered through hydrological manipulation, a better understanding of the extent of such changes within a broader regional context may be considered critical to decision-making for environmental management and economic development.

Remote sensing is increasingly being used as a tool to map and quantify habitat change (Mertes, 2002; Nilsson et al., 2003). However, riparian habitats can be difficult to map with remote imagery due to technical limitations. (See: Colorado Division of Wildlife, 1998). In particular, the resolution of many of the images, especially those that are older, is not fine enough to map the small-scale heterogeneity of riparian zones and their ecological attributes. In general, riparian zones must be at least 100 m wide to be mapped and quantified using remote sensing with accuracy (Nilsson et al., 2003). However, remote sensing technology is improving rapidly, particularly with regards to resolution.

A spatial analysis using a geographical information system (GIS) could provide an estimate of the area of riparian habitat lost or altered in various ways. A reasonably accurate representation of the aerial extent of current riparian shrub habitat could be made by classifying the riparian zones on digitized air photos and measuring the area thus obtained. Unfortunately, a complete set of the most recent air photos taken in 1998 and owned by Newfoundland and Labrador Hydro was not available to the author.

To accomplish this analysis, a preliminary sample classification would be completed of the air photos and Landsat TM imagery, or Ikonos for finer resolution, for representative sections of the river. These areas could then be ground-truthed and further classification and interpretation carried out. A classification methodology could be developed to identify different types of riparian habitat along the reaches of the river. Sub-categories could be developed according to slope and substrate characteristics and, if possible, prior flood regimes. The older air photos could be digitized to roughly define these latter areas. In the areas that were entirely flooded, an estimate of the direct loss of riparian habitat of different types could be then be calculated if the necessary resolution is achieved. In the reduced-flow sections and partially regulated reaches, a combination of pre-development digitized air photos, geo-referenced and overlaid with recent Landsat TM imagery could provide an image for spatial analysis of changes in area of riparian habitat.

Remotely sensed images with a resolution of less than 3 $m^{2,}$ such as Ikonos, could also be used for such an analysis. However, coverage for the entire area would be very expensive. All of these approaches may underestimate the riparian zone affected by the natural hydrological cycle. The species richness of forested areas above the strip of early successional vegetation or the limit of more recent high water levels may also be influenced over time by episodic extreme floods (Lewis, 1996).

In terms of floral diversity, the riparian zone of influence should perhaps be considered to include the spatial extent of the 100-year flood, as suggested by Lewis (1996). These infrequent but extreme flooding events may be prevented by hydrological regulation. Mapping of visible riparian zones in aerial photography may represent a time frame restricted to several decades at most. Mapping longer-term flood zones can be done using the existing hydrological data and digital elevation models in a GIS. Additional vegetation surveys within the 100-year flood zone along the main stem of the Churchill, as well as several reference sites compared to sites further upland, would aid in determining if vegetation in this region is different in zones that are infrequently flooded. Long-term analysis of remotely sensed imagery may provide a more accurate estimate of changes of the extent of riparian shrub habitat over time.

Because the shores of a major river are continually changing due to erosional and depositional processes, the area available for plant growth varies over time. Important factors are the effects of temperature and precipitation on the magnitude and timing of floods, ice formation and breakup, and rates of sediment transport. Thus, the formation of riverine landforms can be highly variable, as are water levels during the growing season. Without long-term spatial data, it is not known to what extent the area or quantity of the riparian habitat may vary over time under natural or regulated conditions in this river system. Available historical air photos and the observations of local elders provide some relatively short-term data.

In the lower zones of the main stem reaches, the present summer water level fluctuations due to releases from the Churchill Falls generating facility may affect the growth of certain riparian plant species. Some species are adapted to inundation for a period in spring, followed by a steady decrease in water levels during the summer. Plants that colonize the lower zones may be prevented from flowering if they are subsequently flooded during the growing season. Plants in the higher zones may suffer from a decreased water table due to the normally lower water levels following regulation. Previously, water levels tended to fall more gradually throughout the summer. Past conditions may have supported the growth of more emergent vegetation in shallow waters. For all of these reasons, an estimate of the area of riparian habitat loss can be used only in a general sense to consider the area of potential riparian habitat.

The results from a quantitative analysis of riparian habitat change could be reviewed with local community members and environmental managers associated with the proposed hydroelectric development to explore the implications of the information and interpretations for cumulative effects assessment. This may be a worthwhile endeavour. However, there are many problems to consider with regards to the potential results. As will be discussed, it remains questionable whether such data would improve decision-making to any substantial degree.

For the purposes of discussion, a rough estimate was calculated of the area of current riparian habitat that might be lost in the lower Churchill River due to regulation by dams proposed at Gull Island and Muskrat Falls. This is based on the method used for a similar calculation for an environmental assessment of a project proposed for the Great

Whale River basin in Québec (Hydro-Québec, 1989, 1993a, 1993b). My estimate assumes that the dams at Gull Island and Muskrat Falls would flood the upstream reaches of the main stem of the river up to the tailraces of the next facility. As stated previously, all existing shorelines, islands, bars and tributary mouths would be inundated. The new shorelines would be situated in what is now terrestrial habitat, except in small areas where the reservoir shores intersect with tributary valleys. Virtually all of the new shorelines would develop under the direct influence of the particular operating regime of the reservoirs.

The calculation considers only a rough estimate of the length of the main stem of the river and does not measure the finer fractal complexity of the shoreline or include the ecologically significant islands, bars, and deltas of tributaries. Portions of the lower reaches of tributaries would also be flooded and controlled, however the widths of riparian zones any distance up the tributaries were not measured in my surveys.

The average widths of the existing riparian zones are based on measurements made for my survey sites in the lower river. As defined by my survey methodology, this area includes the entire riparian zone that is periodically flooded and then exposed and made available for colonization by plants. The entire width of the exposed shores during the growing season could be considered to be potential habitat for riparian plants. However, not all of this area is currently colonized by riparian vegetation. The lower portions of the zones often have large areas of bare ground. The structure and composition of potential riparian vegetation is quite variable, depending on factors such as slope, substrate, stability, velocity of river flow, whether it is a depositional or erosional site, and degree of exposure to ice scour. As discussed, the increased scouring of higher winter flows combined with lower average summer flows below the Churchill Falls facility likely create larger areas of bare shoreline in these downstream reaches than occurred prior to regulation. Under present conditions, the area of shoreline potentially available to colonization by riparian species may be greater than prior to the Churchill Falls project, but some portion of this area may not sustain plants from one season to the next.

To obtain an estimate of the area of the existing riparian zone the following calculations were made:

<u>Churchill Falls tailraces to Gull Island</u>

- 25.5 m is the average width of 12 riparian sites between Gull Island and the Churchill Falls tailraces
- 232 km is the distance along the centerline of the river from the proposed Gull Island dam to the Churchill Falls tailraces
- Therefore the estimated present riparian habitat is 232 km x 0.0255 km x 2 shores = 11.83 km^2

<u>Gull Island to Muskrat Falls</u>

- 32.8 m is the average width of 5 sites surveyed below the Gull Island dam site
- 59 km is the distance along the centerline of the river from Muskrat Falls to the proposed Gull Island dam site
- Therefore the estimated present riparian habitat is 59 km x 0.03280 km x 2 shores = 3.87 km^2

The total estimated area of riparian habitat along main stem of the lower Churchill River is 3.87 + 11.83 = 15.7 km^2

Note that the estimate of 15.7 km^2 is conservative, as it excludes islands and bars, and the lower reaches of the tributaries that would also be flooded. The widths of the riparian zones of those tributaries have not been measured so their riparian area was not estimated. Using topographic maps depicting the proposed reservoirs, I estimated that flooding and reservoir conditions would extend roughly the following distances up these major tributaries:

- Between Muskrat Falls and Gull Island: 4.5 km up each of two branches of Lower Brook; Upper Brook 4 km; Edwards Brook 1 km; Pinus River 1.5 km.
- Between Gull Island and the Churchill Falls Tailraces: Beaver Brook 1.75 km; Minipi River 7 km; Cache River 4 km; Shoal River .5 km; Fig River .75 km; Elizabeth River 2 km; Metchin River 1 km. Numerous smaller tributaries would also be affected, those closest to the dams with the lowest topography would be the most extensively flooded.

This exercise is easier to apply in the main stem of the lower river flowing through a deeply incised valley than it would be in the upper reaches of the river on the plateau that are already flooded. There, the course of the main channel of the river meandered extensively around numerous islands, and the reservoir covers a huge area of the upper watershed including lakes, small tributary streams, and wetlands. In short, the margin of error in doing a rough calculation of the length of the former shorelines would likely be much greater.

I have also estimated the lengths of the new reservoir shorelines in terms of the potential riparian habitat. As has been seen in the storage and forebay reservoirs on the plateau, and observations of reservoirs in other similar regions, these habitats would be simplified structurally and in terms of species richness compared to the former shorelines. It is estimated that the perimeter of the Gull Island reservoir would be about 560 km, and that of Muskrat Falls reservoir would be 172 km (Procter and Redfern 1980). These areas may develop some minimal riparian vegetation in a narrow zone similar to the Forebay reservoirs, but perhaps with somewhat higher species richness. This can be added to the perimeters of existing reservoirs in the upper plateau area of the watershed as measured with ARC GIS:

- Menihek Lakes: 434.5 km
- Ossokmanuan Reservoir: 751.9 km
- Smallwood Reservoir: 3395 km
- West Forebay: 416.7 km
- East Forebay: 93.6 km

These data suggest a total of 5752 km of severely degraded shorelines with limited potential to develop structurally complex and species-rich riparian vegetation. The new reservoirs in the lower reaches of the river valley would represent only an additional 14% in terms of linear kilometers of degraded riparian habitat, but the quality of this habitat is likely much richer than what has already been lost on the upper plateau.

Mitigation measures that have been proposed to offset the net loss of riparian habitat focus on creating new areas of early successional deciduous shrub communities by cutting some areas of forest in appropriate areas (i.e. Procter and Redfern, 1980). This could provide additional forage for species such as moose and snowshoe hare. However, such measures could only be applied practically in very small areas relative to the scale of the habitat losses due to reservoir development. Further study would need to be done to determine to what extent such areas could mimic the habitat complexity, species richness, and utility to wildlife of natural riparian areas.

6.2.2 Interpreting Quantitative Measures of Riparian Habitat Loss

When conducting an environmental assessment of new projects and when considering the cumulative loss of riparian habitat or other habitats, it may be considered necessary to estimate the area of habitat potentially affected. However, one could ask, to what degree does the quantification of the loss of these habitats and others in the region actually affect the ultimate assessment of the affects and acceptability of this river regulation scheme?

In discussion with local people, the mention of specific figures was not immediately meaningful. In fact, most people were offended and frustrated when asked what their views were about the loss of a particular quantity of riparian habitat. The area of habitat lost, as an absolute number or relative to the rest of the region, was not considered to be an important question. For many people, scientific efforts to quantify the loss of habitat types or populations of species are viewed as being suspect at best. This quantitative approach is considered to disregard the uniqueness of the specific places that are lost or dramatically changed, and that of the creatures that inhabit them.

Similarly, the concept of creating certain habitat types to offset or "replace" those that are lost is not accepted as a legitimate form of mitigation by many local people. In their view, the individual places cannot be replaced. The loss of a particular river landscape as a whole, and the unique places within the valley that are known and important to humans and other animals, is what is considered important.

6.2.3 Corridor Function of the Major Rivers

From an ecological perspective, the areal extent of riparian habitat is only one factor that may influence the biodiversity of the riparian zones and the region. The linear extent of the riparian zones throughout the landscape, their overall structure and heterogeneity, their proximity to the river, and their distribution and connectedness to other parts of the landscape may all be important to long-term local and regional biodiversity.

In addition to the direct loss of riparian habitat through permanent inundation, and the lack of seasonal flooding patterns to re-establish new shorelines with early successional vegetation, the available pool of riparian species may be affected. Dams and reservoirs may act as barriers to plant dispersal along rivers. South of the Churchill River watershed, the rivers all flow southward into the Gulf of St. Lawrence. The Churchill River, flowing roughly west to east, provides a potential water route for the dispersal of plant propagules from the Central Laurentians ecoregion towards the east, down into the Churchill River valley and into the Lake Melville area.

The extent to which the Churchill River and other east-flowing rivers such as the Naskaupi have functioned historically as corridors for the dispersal of boreal species into central Labrador following the Wisconsin glaciation is not well understood. However, it is possible that this may have been an important route for plant dispersal, contributing to the establishment of the relatively species-rich boreal forest in the lower Churchill and eastern Lake Melville and Grand Lake areas, especially for those species dispersed primarily by water (hydrochory).

Abbe (1955) looked at the patterns of arctic, sub-arctic, boreal, and temperate-affiliated vascular plant species in central Labrador, based on data collected at the time. One question he addressed was whether there was evidence to support the idea that the disjunct closed canopy forest that occupied areas around eastern Lake Melville, Grand Lake, and the lower Hamilton River (Churchill River) was a relic boreal forest from a time of a thermal maximum that was thought to have occurred since the last glaciation. This forest is quite different in structure from the entire surrounding region (see Figure 9). Abbe questioned whether the flora of this region was similar to that of the boreal forest further south. He examined the affiliations of species with different vegetation zones. He concluded that the current flora is most similar in species composition to the surrounding region, and it differs significantly from the main boreal forest further south.

However, several boreal species have since been located in rare or disjunct populations in the lower river valley. The closed-canopy forest that is established in the warmer microclimate of the lower river valley and Lake Melville region also has richer alluvial soil deposited from the large rivers, particularly the Churchill and the Naskaupi.

It may be that since the last ice sheet retreated, certain boreal plant species were able to disperse along these river corridors, but they did not thrive until they reached the lower Churchill and Lake Melville region.

It is probable that the range extension of boreal species of relatively southern affinity has been an ongoing process and will continue in the future, especially with climate warming. However, it is possible that the Churchill Falls project has contributed to stalling or preventing an ongoing range extension for some boreal species into Labrador by presenting barriers along the riparian corridors and creating a large area of poor-quality riparian habitat between Québec and western Labrador in the upper watershed. The dikes and control structures of the Churchill Falls project may be already curtailing the dispersal of some species downstream. With the initial flooding, some shoreline species may have been locally extirpated. In the subsequent years of reservoir operation, the persistent extreme shoreline disturbance from unseasonable drawdown prevents the re-establishment of most riparian species in the reservoirs. Those species that are common or already well established in downstream tributaries may persist and provide a source of propagules for the surrounding area. Others that are initially rare may not persist or go on to establish strong populations.

Additional barriers and reservoirs along the lower river valley could further impede future plant dispersal and the persistence of some populations.

6.2.4 Provision of Closer to Natural Flow Regimes

The provision of more natural flow regimes (sometimes referred to as ecological flow regimes) to re-establish and/or preserve certain downstream processes such as those that maintain riparian or aquatic habitat is being investigated for regulated rivers in many regions (e.g. Bayley, 1991; Richter and Richter, 2000; Hughes and Rood, 2003; Suen and Eheart, 2006). It is an attempt to maintain some semblance of a natural hydrological regime, and/or a vestige of aquatic habitat by spilling necessary water past a generating facility during periods when the water might otherwise be stored for future use under conventional operating regimes. The idea is that there must be a better balance between exclusively human needs for hydrological processes, and the needs of down-river ecosystems.

Examples of prescribed flow regimes for reaches downstream of dams may include "flushing flows" and "floodplain maintenance flows". These are deliberate water releases to mimic periodic natural flooding. The idea is to deliver sediment, nutrients and propagules to the floodplain, and induce channel movement, erosion and deposition, to open up areas for pioneer vegetation (Hughes and Rood, 2003; Naiman et al. 2005). The timing and magnitude of the releases is important in order to provide the conditions necessary to life cycles of many riparian plant species.

Hydroelectric facilities are usually designed to utilize the maximum waterpower available; indeed to alter the landscape in ways economically feasible to produce the largest quantity of energy from any one site. For example, where it is physically and economically feasible, diversions are frequently created to increase the storage capacity of a reservoir. A power project may thereby affect the flow regimes of more than one river system. From conventional engineering and economic perspectives, water that is "spilled" past a hydroelectric facility without generating power is essentially considered to be "wasted". An economic feasibility analysis of a hydroelectric development is generally based upon a combination of the maximum power output that can be expected, given the predictions of available water and the height (or head) from which it can be made to fall onto the turbines. Since large quantities of electricity cannot be stored, it must be produced and delivered to market at the time it is in highest demand. These factors are responsible for creating the hydrological regimes associated with hydroelectric facilities. Any large deviance from the design engineered to optimize power output would decrease the capacity of a plant and affect its economic bottom line, unless there was more water available than predicted to generate at full capacity, and/or inadequate storage capacity. In these latter cases, if markets existed, the inclination would be to increase the generating and/or storage capacity of the facility.

In terms of mitigating the effects of flow regulation on riparian habitats in the Churchill River watershed, the provision of ecological flows in some reaches would be one of the only measures that would have any meaningful positive effect. Researchers doing work on waterfowl habitat in the 1970s recommended that the operating regime of the Churchill Falls project be altered to provide regular flow to reduced flow areas (Keast, 1973). However, this was not implemented by the company.

In the years since, with water levels in the storage reservoirs of the Churchill Falls facility routinely lower than expected, this is not something the owners and operators will be remotely considering. The economic feasibility of new projects now in the planning stages is already highly uncertain. Altering the design to construct power stations that would use the seasonal flow of the river, while maintaining a more natural hydrological regime, or building smaller dams, or flooding a smaller area, would all result in less generating capacity. It is unlikely that any proposals in that direction would be entertained seriously if conventional economic criteria are the primary basis of the decision-making process.

6.2.5 Some Potential Implications of Climate Change

The cumulative effects of climate change, river regulation and other industrial activities have the potential to exert considerable influence on freshwater ecosystems of the boreal regions (Schindler and Smol, 2006). Changes in the quantity of water and timing of river flows, coupled with numerous stresses from contaminants affecting water quality, could all act together to affect the health of northern aquatic and riparian ecosystems in ways we have yet to comprehend.

According to NASA scientists, the five warmest years in the past century have occurred during the past eight years. The year 2005 was the warmest year globally in over a century, and the years 1998, 2002, 2003, and 2004 follow as the next warmest during that period (Gutro, 2006). The largest annual and seasonal increases in temperature have occurred in high latitudes of the northern hemisphere. It is likely that climate-change trends will significantly affect patterns of precipitation and runoff in the Churchill River basin, as is also forecast in other regions across the continent (Henry, 2002; Environment Canada, 2004; Manabe et al., 2004). However, the direction of change in precipitation levels in various regions is not at all certain.

Schindler (1997) predicted that in boreal regions, if climate change leads to more precipitation in the form of rainfall rather than snow throughout the year, this will in turn lead to an extended ice-free season, increased evapotranspiration and an overall increased incidence of forest fires (Schindler, 1997). Under this scenario groundwater levels, river and stream flows, and lake levels would all be expected to decrease (Schindler, 1997).

Some long-term modeling exercises have suggested that in the generally moist regions of the northern latitudes, increases in atmospheric Co_2 and other greenhouse gases will lead to increased annual river discharge over a period of several decades as glaciers and permafrost melt, followed by a decrease in run-off (Manabe et al., 2004). With only discontinuous permafrost in the Churchill River watershed, this would not likely be the case. There may be a larger spring run-off, but overall lower summer flows in the Churchill River basin in the immediate future in response to climate change (Environment Canada, 2004).

As mentioned in Chapter 3, the total annual precipitation recorded for several years at Wabush Lake in the western region of the upper Churchill River watershed (Figure 10 and Table 1 on page 60), and at Churchill Falls since 1969 (Figure 11), has shown a downward trend. During the period 1984 to 2005, Wabush Lake received on average 10.6% less precipitation than it did between 1962 and 1983. Since the 1970s, when most of the large hydroelectric facilities were constructed on the Labrador/Ungava peninsula, average precipitation and run-off has been lower than initially predicted. If total annual precipitation continues to decrease as it has in recent years, the storage reservoirs will be further drawn down, and the generating capacity at the existing power plants will be lower. This has already been observed over the past two decades in the Smallwood Reservoir. Incentives to further modify the landscape by diverting other adjacent rivers to capture more run-off and better utilize the installed generating capacity of existing turbines may then increase.

In the James Bay region of Québec, additional diversion schemes are under construction, and more are proposed to increase the generating capacity of the La Grande power plants. The industry does not make it clear whether these are intended primarily to create a net increase in power production or to make up for an anticipated deficit from lower than predicted reservoir levels due to several droughty seasons. If precipitation in fact increases over time, as some regional climate models predict, there may be an even greater motivation by government and industry proponents to construct more hydroelectric capacity. Regardless of the reasons, increased capacity usually results in further changes to hydrology and riparian communities.

6.3 Perspectives on the Ecological Integrity and Cultural Significance of the River

> *When the Land is flooded, plants will be destroyed. The hills on the sides of the river will be flooded. Innu medicines which come from the trees and the bushes will be gone. The river is a breeding ground for all kinds of wild animals. Birds and waterfowl raise their young on the river and streams. Rabbits, ducks and geese use swampy areas. Grasses will be gone when the river is flooded.* Kathleen Nuna (Innu Nation Hydro Community Consultation Team, 2000: 52).

Despite the extensive ecological changes known to occur due to large-scale hydroelectric development, it is commonly marketed to society as "green" or "environmentally friendly" energy (e.g. Burleton and Kalevar, 2005), and even as being environmentally "desirable" (Churchill, 2003). Recently, with the vital focus on reducing emissions of greenhouse gases through such initiatives as the Kyoto Protocol, large-scale hydroelectric facilities are promoted by some interests as being a sustainable alternative to burning fossil fuels. Hydroelectric development of the lower Churchill River, it has been suggested, could help Canada meet 15% of its [former] Kyoto commitment to reduce greenhouse gas emissions (Churchill, 2003). Hydroelectric power is not emission-free. Significant quantities of fossil fuels are burned during all phases of the planning, construction and operation of these large, particularly remote hydroelectric projects. Methane and Co_2 are emitted from reservoirs at higher rates than background. Nevertheless, if the hydroelectric facilities succeeded in replacing existing fossil fuel generators, emissions reductions could be realized. If they mostly serve to increase the available power on the grid, this goal would not be met. Moreover, the full range of environmental effects resulting from large hydroelectric developments must be taken into account in assessing their overall environmental "desirability".

A question that many elders raised was, "Should we not be asking ourselves whether the hydrological resources of the Churchill River and adjacent watersheds have already been exploited as much as they should be?" People regularly emphasized that large areas of the river are already used intensively for hydroelectric power production. One man from Sheshatshiu commented:

> *The magnitude of the upper Churchill is a legacy, a burden that we will carry for a long time. We are saying that this legacy should not be passed on to our children. We need to maximize the benefits, but we need to look at developing hydro projects*

not of the same magnitude as what is proposed for the lower Churchill.
Anonymous (Innu Nation Hydro Community Consultation Team, 2001:20).

Studies have been done to examine the potential for harnessing some of the larger tributaries of the lower Churchill to produce hydroelectricity (e.g. the Fig, Cache, and Minipi Rivers).[25] There is merit in looking at these smaller options for the production of electricity for local or regional consumption. However, these projects would entail a very different development framework since it is primarily the government interest in large-scale commodity production for export revenue that drives the mega-projects. The standard approach to hydroelectricity development is to maximize production at any given site by using all of the available kinetic energy. Water that drains off without passing through turbines is commonly considered to be "wasted". It is akin in some ways to mining operations. Economies of scale and maximization of profit are clearly a focus of developers, but the grand scale of "large hydro" also results in extensive environmental degradation. Even though the water continues to flow and return to the system at some point (except for diverted rivers), the ecological functions performed by a natural hydrological regime are severely curtailed.

Many elders I spoke with argued that fewer animals are now found in the areas of the flooded shorelines. For example, Aniet Nuna stated:

> *"We traveled on the Mishta Shipu in the spring and in the summer. We would hunt beaver, otter, black bear, and anything edible. We would travel by canoe. We mostly hunted near the shore. There used to be a lot of animals there but all that is gone now. There were lots of furbearing animals. The areas that are flooded are all destroyed. It is not safe for them there now."* (Aniet Nuna, pers. comm., 2005).

For local people who have traveled the country widely, major changes across the landscape that restrict their use are not considered acceptable under any circumstances, even if it is argued that there are other places where they can still travel.

> *We don't like it. People travel to hunt, we don't stay in one place. We want to go to different places. Sometimes I would stay in one place for two years, and then after that go to another place to hunt. It's not just the fish that are affected by this. The other wildlife are affected too. It is hard to accept that we can no longer hunt and fish there freely* (Pien Penashue, pers. comm., 2001).

People who are intimately familiar with a particular landscape may give greater

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[25] Twenty-two sites in Labrador, and five sites on rivers flowing into the Gulf of St.Lawrence with headwaters in Labrador, have been assessed for hydroelectric power development (Churchill, 2003).

standing to individual tragedies than other people such as scientists who tend to assess changes from a more detached perspective. Therefore, the loss of breeding habitat for a particular pair of loons, or of spawning grounds for a local population of fish, may be considered to be more important. Empathy is expressed for the loss of the animals' homes. For example, Pien Penashue commented:

> *A couple of summers ago we went out in a helicopter to see the place with Pien Nuna and Jack Selma. We had a map. I explained to them about the names of the places. They were all written in English before. We saw a lot of trees under the water. It looks almost like it was burnt, all the dead trees. It was very sad. I didn't like it. I thought about the animals that had lived there* (Pien Penashue, pers. comm., 2001).

I wondered whether some people would feel that the river is already damaged and therefore not worth protecting any further. This was not the attitude of any of the elders I spoke with. Rather, the cumulative effects of additional dams were the focus of many comments. For example, Horace Goudie stated:

> *The more times you're going there, the more work you do, the more damage you're going to make. The fish there ... however many years it is since the Churchill Falls project was built... the fish are finally starting to find new spawning grounds and starting to breed a little better again. If you put 300 feet of water on top of that, where the hell are they going to go after that? They'll have to start all over again. All the new spawning grounds that they are just starting to make will be gone again. Every time they* [the developers] *do something, they destroy something. And every time they destroy a certain amount of fish, a certain species, they're interfering with animals, all kinds. Minks, martens, etc. they eat certain kinds of fish, but not all kinds of fish. If I can help to salvage what's left of Labrador, I'd go anywhere.* (Horace Goudie, pers. comm., 2005).

The vast changes to the aesthetic quality of the landscape are not something that is well captured in scientific studies. As we looked at photos of the Smallwood reservoir shore, Aniet Nuna declared:

> *"It is not right to dam the river. It is not very natural and not very healthy to look at. There is not much growing in the flooded areas. The animals wouldn't touch those shorelines. It used to be nice country there around Lake Michikamau ... lots of animals and very beautiful"* (Aniet Nuna, pers. comm., 2005).

Elizabeth Penashue has spoken at length about the how the hydroelectric development has affected her enjoyment of the Mishta Shipu. Below she comments on some photos of the diverted reaches above Churchill Falls

> *This river is so beautiful. Every time when I look at pictures, I am very sad to see*

the dams. There is a lot of change. Everything is not the same anymore. Everything was so beautiful when we went canoeing when I was young. There was a river here before and now it is all dry (Elizabeth Penashue, pers. comm., 2005).

There is a sense among local elders that many of the people making decisions about these large developments, including some of their own elected leaders, do not fully understand what they are doing. Pien Penashue stated:

Before I was blind, I went with leaders in the community out to meetings in Ottawa and other places, and I often disagreed with people. I tell people that they don't know what they are doing. They don't know that land. They haven't walked that land. (Pien Penashue, pers. comm., 2001).

There is a sense that the majority of people involved in planning and executing these projects have a weak understanding of the richness and unique values of the places affected. This feeling is strengthened when effects are expressed in numbers, for example, in terms of percentages of habitat types lost, square kilometers of land flooded, or pairs of breeding ducks likely lost. Many of the elders think that we actually understand less when we focus on describing these sorts of changes primarily with numbers. It is not that the numbers themselves are not relevant or understood, but we need meaningful reference points in order to understand them better.

Indeed, how well do we know how to measure the significance of major changes to the landscape, especially cumulative effects? In any research for the purposes of environmental assessment, there are many questions that can be investigated: e.g. What were the populations of various species in the past? Those numbers naturally fluctuate, so long-term, rigorously collected data are needed. Such data are rarely available. Often developments are permitted to go ahead and populations of species may be monitored. Effects on future habitat potential are perhaps more meaningful. What then is known of the longer-term potential of certain habitats within an evolving landscape? Mapping can be done of the changing geomorphology of a river using air photos and satellite imagery, for example. These can help us to better understand changes over time. However, many people feel that all this additional effort is redundant if it is intended to help us understand whether further development of the Churchill River is environmentally acceptable. The results of the Churchill Falls project are plain to see in many people's eyes. As Jerome Pone commented with frustration;

Why is no one listening to us? No one is listening to us! The dams have already *caused too much damage on this river. There shouldn't be any more* (Jerome Pone, pers. comm., 2005).

For Joe Goudie, on a personal and cultural level the significance of flooding the lower river valley cannot really be measured. As he observed,

> *There's evidence of the Innu culture, there's evidence of the Labradorian culture, for generations and generations, all along the river... Just to illustrate the point, up at Slackwaters, which is where my grandfather Blake trapped, there's what we call a family shrine there. He made a food cache back in 1908 or 1914 ... I can't quite recall. It's still there, his initials, the date, inscribed in the clay, and hundreds of initials and little carvings and stuff since then. It's almost a hundred years old and it's still there. I don't know why the snow or rain doesn't damage it.*
>
> *I do know that if you build a dam, or at least I can speculate, at Gull Island rapids, and it's probably going to be about 300 feet high, if they are going to develop the river the way they had originally proposed, they are going to eliminate the river and create a lake.* (Joe Goudie, pers. comm., 2005).

People who have lived along the river for extended periods of time, during different seasons, know that these major changes have considerable effects on the current and future potential of the habitat. They know for certain that unique places they have known and value highly are entirely gone. Moreover, they wonder, what do you measure that against? Gone is gone. It has been destroyed to service an ever-increasing demand for electricity; for escalators, air conditioners, aluminum drink cans ... billions of aluminum cans.

The need for more serious consideration for energy conservation, as one alternative to new large-scale hydroelectric development, was raised as an issue by many people during our discussions. This was with reference to all people, including themselves. Pien Penashue commented:

> *There is a lot of waste of electricity. Even ourselves, we leave the T.V. on. Even when it is a nice day outside, we put the clothes in the dryer. It's because we don't understand very much about electricity.*
>
> *In the old days in the tent, we didn't have electricity. We couldn't have a television. We lit candles and burned wood. But there are a lot of changes in the community. Many people don't know how to live without electricity. But we were not brought up like that. Maybe the young people today think that it is their land that the electricity comes from and so they think they can waste it. We need to educate people about that* (Pien Penashue pers. comm., 2005).

Horace Goudie reflected on the ultimate goal pursued through the damming of the river, the production of electricity, and questioned its cost. He said, "I've lived more than half of my life by candle light, and what a good life it has been" (Horace Goudie, pers. comm., 2005).

Chapter 7. Discussion

> *Innu people were able to travel the land without destroying it. But the flooding like this* [viewing photos of the Smallwood reservoir] – *it's a disaster* (Mathew Penashue, pers. comm., 2001).

7.1 Interpreting Environmental Observations

Many of the Innu and Metis elders who discussed the issue of evaluating the effects of additional hydroelectrical development on the Churchill River wondered to what extent more research would influence decision-making surrounding the proposals to build more dams. They argued that enough should be understood by viewing the river in general to know that the impacts from such developments are extensive and severe. They questioned what kinds of effects it would take to cause people to rethink these large schemes.

Years of research in other regions, including in boreal environments, have shown that large-scale hydroelectric development impoverishes the biodiversity of affected rivers. In a review of the downstream geomorphological affects of dams, Ligon et al. (1995) state:

> *Preserving the physical habitat of a stream is likely to be a major step toward conserving its biota. However, knowing that something geomorphologically undesirable is likely to happen as a result of a dam does not mean that it will be possible to propose anything, short of not building the dam, to prevent it from happening. Further research into how dam design, siting and operation can ameliorate ecologically deleterious geomorphic changes will eventually reveal how often we will be able both to identify and to avoid significant alterations of river ecosystems* (Ligon et al., 1995: 191).

In many regions of North America where human populations are larger, and more people witness first-hand the effects of large dams on the landscape, such development is no longer considered to be wise. Indeed, there is a strong movement to dismantle some dams and attempt to rehabilitate degraded riverine ecosystems (Bednarek, 2001; Hart et al., 2002; Shafroth et al., 2002). However, in more remote areas, the maximization of resource extraction approach is still very much *de rigour*.

It is a perennial challenge to interpret scientific data and then apply it to complex decisions involving economic, social, and political objectives. The Churchill River already has one of the largest hydroelectric facilities in the world, and it supplies power to regions remote from the site of production. The ecological "costs" of this power are extensive, but have received little attention in the process of planning for further regulation of the main stem of the river, despite the well-known effects of river regulation (i.e. Kalff, 2002). The economic benefits of the Churchill Falls project have not been well distributed, and the social imperative for additional large dams is questionable. This is especially so given the grossly inadequate level of effort applied to energy conservation initiatives across North America.

A review of the potential environmental, social, and economic effects of any future dam construction will be conducted under processes guided by the Innu land rights negotiations, Canadian Environmental Assessment Act (CEAA), and the Newfoundland and Labrador Environmental Protection Act. There are requirements under the CEAA to assess the cumulative effects of proposed developments. Some of the shortcomings of the CEAA with regards to cumulative effects assessment will likely be addressed with input from the First Nations within the context of guidelines for the EIS. Innu and Metis have repeatedly emphasized the importance of thoroughly considering the environmental degradation that has already occurred as a result of the Churchill Falls project prior to and in concert with evaluating the effects of hydroelectric facilities in the region. They want to see that cumulative effects assessment is conducted using a broad spatial and temporal scope that at the very least includes other developments within the watershed. The proponents of the new projects are still working within a narrow conceptual framework that considers cumulative effects to mean only those project effects that directly overlap spatially. They would prefer to concentrate on the direct consequences of the current development proposals, using the contemporary environment as the baseline, while the Innu are asking, 'But what will be *left* of the river that we once knew?'

Analysis of hydrological regimes and riparian vegetation structure and species richness is an exercise in relating pattern to process on a landscape scale (Wiens, 2002). It is the most relevant scale of observation for analyzing risks to ecosystem integrity (Leuven and Poudevigne, 2002). Taking a holistic approach is especially necessary when data are limited for the region. The use of changes in hydrological regimes as an indicator of ecosystem health is logical. In this case, the extent of the watershed should be the minimum boundary for the study area of cumulative effects. Arguably, the scope could be substantially larger considering that the Churchill Falls project had direct hydrological effects on several adjacent rivers. Indeed, the fact that there are numerous large-scale hydroelectric developments throughout the Labrador/Ungava region in boreal and subarctic environments raises the question of what are the cumulative ecological effects of selectively degrading the riparian habitats of so many large rivers?

The observations and perspectives of those people most familiar with the watershed over time make an important contribution to our collective ability to describe and better understand the local and regional ecological effects of the Churchill Falls project, particularly in the absence of adequate scientific research over the past decades. Will these views be afforded sufficient weight in the ultimate decision-making process about whether or not to proceed with further hydroelectric development of the river? The elders are the most knowledgeable people this author has encountered with regards to changes in the land since the hydroelectric development. Unfortunately, there are now few elders left who have longer-term empirical observations of this area and a strong sense of meaningful ecological reference points.

The loss of specific places that have historical and cultural meaning is highly important to the local people who have used these areas, or whose ancestors did so. Traditional camping and stopping spots located in the riparian zone along the river have been used for generations. It is a cultural landscape. When it is radically changed, there is a loss of history, a loss of ecological knowledge, and a loss of potential to build upon this in the future.

It is essential that we cultivate a broader understanding of how the ecology of the landscape has responded to the existing and potential changes wrought by existing developments. Furthermore, we need to build this understanding within a temporal and spatial framework that is relevant to the lives of people and the adaptive capacities of other organisms.

7.2 Limited Ecological Literacy

In addition to obtaining adequate information about baseline conditions, we face other fundamental challenges in assessing cumulative environmental impacts and making decisions about additional developments. Some of these challenges relate to notions about the past and current ecological integrity of a study area. For example, a weak understanding of ecological processes and disturbances, and of the evolution and adaptations of organisms, can influence the ways in which anthropogenic changes are interpreted. Consider the following quotation from a document prepared for the inauguration of the Churchill Falls development in 1972. It claims that the project did not cause any noteworthy environmental degradation, and moreover, that it improved upon previously poor environmental conditions:

> *Man all too often comes into the wilderness as an intruder, disregarding the basic laws of nature's survival. The changes that he has brought to Labrador so far, studies show, remain within the relatively narrow limits that nature can tolerate. This is in part because these changes are of a type that can and do occur naturally and because they introduce no elements foreign to the land. Indeed, some effects of construction in the particular Labrador context are beneficial in tempering the ravages of spring floods and in raising, at least temporarily, the levels of nutrients in the reservoirs that have been created* (Coté, 1972).

It appears that this writer did not recognize the importance of spring floods to the maintenance of riparian habitats. Nor was he aware of other ecological consequences of dams and reservoirs. Increased nutrient levels for a few years do not have an appreciable effect on the health of the ecosystem over the long-term. While all ecosystems experience continual changes that "occur naturally," these are frequently not comparable to those that are created under modern anthropogenic forces such as the industrial management of rivers. The types of hydrological changes caused by water regulation schemes, which systematically affect riparian habitats over extensive regions and over a relatively long period of time, are a cause for concern.

Ideas such as those embedded in the above quotation could be dismissed as merely representing the propaganda of industrial and development interests. However, they also represent the level of much of the current public discourse surrounding large developments in remote regions, including the existing Churchill Falls project and additional schemes proposed within its watershed. For example, an article was recently printed in the Toronto Star about additional infrastructure needed to meet energy needs in Ontario. In relation to promoting new large-scale hydroelectric developments, the author stated that:

> *One way to help justify such an investment is to learn from Québec, which has*

> *built transmission lines to areas where wind and hydroelectric projects can complement each other. Waterpower is emission-free, but unlike wind, it's flexible and easy to control. When the wind isn't blowing, a hydroelectric facility can increase its water flow. It can also turn down its water flow and build up its storage reserves when the wind is at its strongest. Ontario has 190 potential waterpower sites that, collectively, could produce about 7,500 megawatts of power on their own. Most sites are located in northern Ontario where, like wind, transmission will be needed to tap it.*
>
> *Another hitch is that many are in provincial parks or are on Aboriginal lands, meaning a potential minefield of regulatory, environmental and land-claim issues. The challenge for the power authority is to find the least controversial locations where wind and hydroelectric projects are clustered, ultimately improving the economic case for a speedy buildup of transmission* (Hamilton, 2006).

Siting wind and hydropower projects where they are least injurious to human communities and where they can complement one another in a technical sense is certainly a laudable goal. However, the above author appears to give little consideration to the inevitable ecological effects of large-scale hydroelectric facilities. In an effort to focus scientific and public attention on the serious issue of climate change, we may be in danger of ignoring the broader range of important environmental effects of energy production, aside from the direct emission of greenhouse gases.

7.3 Diminished Conservation Value?

Another common idea is that a system already affected by hydrological regulation is no longer "pristine" or "natural," and therefore has diminished conservation value. If this idea is accepted, then some people may more readily support additional development on that river system, compared to one that is still free running. For example, the environmental assessment report for two additional dams proposed for the lower Churchill River in the 1970s stated that, *"In considering the* [combined] *impact of the project, the basis of comparison is the existing environment, which in this case is different from the natural environment as a result of the Churchill Falls Development"* (Lower Churchill Development Corporation Ltd., 1980: 361). The document further suggests that additional dams would stabilize water levels in the lower river, which now fluctuate in a rapid and unnatural way because of the existing generating facility. They state that this would *"...have a positive impact on most biological components"* (Lower

Churchill Development Corporation Ltd., 1980: 362) and that:

> *The operating regime will encourage establishment of a new shoreline, one exposed to less fluctuation than now occurs. The long-term effect will be to produce a situation that appears more "natural"* [sic] *than the existing condition* (Lower Churchill Development Corporation Ltd., 1980: 382).

These authors were suggesting that additional dams on the lower reaches of the Churchill River would help to mitigate some of the negative effects of the existing infrastructure, or at least appear to mitigate them. This may be partially true, in that some sections of the channel may be subject to decreased erosion over time (although other reaches will experience considerable slumping of the banks over a period of time), and the water levels would not been so low during the summer months. However, they fail to point out that the modified waterway would no longer be a riverine environment at all for most of its length, but rather would become a series of reservoirs that lack the physical and biological dynamics of a large river. The resulting hydrological regime would be radically different from the original, natural disturbance regime. It would be, in fact, much further from its "pristine" state.

This view of sequential mitigation does little to help us understand the cumulative implications of building additional dams on this river. It suggests that further manipulation can be reasonably pursued with perhaps less consideration for the ecological and cultural values of the original river that are already lost, as well as those that have survived or have subsequently developed. The future reservoir shores may well appear quite "natural" from a distance to many people, even though they do not resemble the original riparian habitats and are substantially impoverished biologically and ecologically.

Local people who traveled the river prior to the construction of the Churchill Falls project have their own perspectives on the importance of the changes that have already occurred, and those that might be expected from additional dams. These people have personal connections to the region and have knowledge based on empirical observations that are spatially and temporally extensive. As such, their knowledge and interpretations of environmental change are often broader and more personal than those of many scientists, who may have more limited experience in the region and are generally familiar with only short-term data. The perspectives of these local people, who value the landscape for its inherent as well as its useful qualities, are essential to sensible deliberations over the future of the river.

7.4 Relative Ecological Values

It is often observed in environmental assessment reports that subarctic and boreal regions are less ecologically diverse and productive compared to ecosystems further south. This is certainly true in terms of the relative numbers of species and ecological productivity. However, these statements seem to imply that it is therefore less significant if the biodiversity or levels of productivity of these areas are altered. This is a flawed construct if applied to what should be questions of regional biodiversity and even the conservation of cultural diversity. The quality of the habitats in the partially regulated lower reaches of the river must be evaluated for the existing and potential ecological and cultural values they hold in and of themselves and within the context of the region, rather than in comparison to distant ecosystems within other climatic zones.

Unfortunately, certain aspects of our culture of "development" – change, urbanization, and economic growth, continue to foster a high level of ecological illiteracy. In the effort to expedite development projects, the public discourse on the complexity and extent of the ecological effects of major infrastructure such as hydroelectric facilities is frequently hampered by simplistic promotional claims by proponents, e.g., "Hydro is Green Power". Not only is more long-term research required on the effects that do occur, but a much more open and honest learning environment is needed to help us to better comprehend the knowledge that already exists, and the consequences of the choices we collectively make – whether consciously or by default.

7.5 Recommendations for Further Research and Learning Opportunities

7.5.1 Riparian and Upland Surveys

In part, my study is intended to contribute to our knowledge of the vascular flora of the present Churchill River riparian habitat and how it has been affected by changes in flow regimes caused by existing hydroelectric development. However, my surveys of riparian vegetation are preliminary, as is the overall analysis. A more extensive survey effort should be made throughout the watershed on all sections of the river in order to gather a more representative sample from all areas affected by the various types of hydrological changes (i.e. at sites throughout the storage reservoirs, especially to the north, both forebay reservoirs, reduced-flow reaches, and downstream reaches). The comprehensive sample should also strive to include more of the heterogeneity of the riparian zones in the various sections of the main stem of the river.

In the lower river, all major tributary deltas, all of the more extensive willow/alder thickets, and all of the areas where the river channel widens, slows, and deposits sediment, such as several areas at the west end of Lake Winokapau, should be sampled thoroughly. Special features within the historically active riparian zone, representing various fluvial land forms as described in Beak Consultants and Hunter and Associates) (1978) should be investigated.

Survey sites should be enlarged to include areas above the most recent high-water marks. Lewis (1996) argues that, particularly in large rivers, the extent of the 100-year flood should be used to define riparian zones rather than the high and low water marks evident from the recent and frequent flood events. These areas may also host a greater diversity of vegetation, because they have been influenced by infrequent flooding, bringing in more water dispersed propagules and nutrients, and have historically experienced a higher water table in the growing season than areas further upland. Sites should focus on areas of lower topography, especially surrounding tributary deltas. Due to the constant down-cutting of the channel through glacio-fluvial and marine sediments since the wane of the most recent glaciation, the banks of many reaches of the lower river valley are steep and high, surrounded by glacio-fluvial and marine terraces. Many of these will have never flooded in recent millennia, even during the most extreme flood events.

Transects up the slopes above the riparian zone should be sampled in order to compare species richness and composition of the upland and riparian communities. Other comparisons could include sample sites along transmission-line corridors, cutovers, wildfires, blow downs, and other disturbed sites to assess overall species richness and habitat structure, and the occurrence of species that thrive in the riparian zone of large rivers.

Future surveys of the riparian zone of the rivers should also include the bryophyte and lichen flora, and better sampling of aquatic vegetation in the river and along the tributaries. Surveys should be conducted to compare the present bryophytes and vascular plants with the observations made by Brassard in the early 1970s in the four spray zones. Additional research is necessary to compile a more comprehensive list of floral species diversity in this zone and a better understanding of the habitat structure and relationship to species presence. Additional survey plots of the same size should be examined in all reaches of the river, particularly in the reservoirs. These sites should include the mouths of several smaller and all large tributaries, and a diversity of physical characteristics along the entire length of the river. Bryophytes and lichens should be included.

In order to better understand how the species richness and diversity of the Churchill River riparian zones compare to the regional flora, these data should be compared with information from upland sites to determine the degree to which the riparian species are common in other habitats. Surveys should also be conducted on reference rivers and streams to compare the Churchill River riparian plant communities to unaltered watercourses.

For predictive purposes and for future ecological monitoring if the dams were to be built, surveys should be conducted along 200-m stretches above the current riparian survey sites at the level of the proposed reservoirs, especially in those areas where major tributaries would flow into the reservoirs. This would develop a better picture of the present species richness and physical habitat characteristics in areas above the present shoreline that would influence the development of the new shoreline in the event that the valley is flooded. Propagules of species that currently thrive in the riparian zones may re-establish on the new shorelines if conditions are suitable. Transects should be surveyed from the current riparian zone up to and beyond the proposed reservoir shoreline elevations.

Useful reference data to compare with present reservoir conditions could be collected in the unregulated waters of Atikonak Lake upstream of the Ossokmanuan Reservoir and along the unflooded portions of the main stem of the Churchill to the west. These surveys would assist in building a more comprehensive data set that describes present riparian habitat structure and community composition under natural conditions in the upper watershed.

Ideally, analogous surveys would be completed on a reference river adjacent to the Churchill to control for natural variation in precipitation, climate, or other variables over the past thirty years that may have affected riparian habitat (Dynesius et al., 2004). However, several factors limit the validity of establishing specific reference sites along adjacent rivers. As Nilsson et al. (1991c) observed, species richness tends to be substantially higher per site along larger rivers as opposed to smaller watercourses. A comparison of the unregulated Vindel River in northern Sweden showed that the main stem of the river had greater species richness per site than any of its tributaries (Nilsson et al., 1994). There are no rivers in the study region of central Labrador that are generally comparable to the Churchill River in terms of catchment area, channel length, or annual discharge (these criteria were used by Jansson et al. (2000) to choose comparable rivers). The Churchill is by far the largest river in Labrador that drains eastward into the Labrador Sea.

The Naskaupi is the second largest river in Labrador. It flows eastward into the Atlantic, but its drainage basin is less than one-sixth that of the Churchill. The Naskaupi and Kanairiktok Rivers both lost a large portion of their headwaters when they were diverted into the Smallwood Reservoir. The Naskaupi River watershed was reduced by almost 50% (Anderson, 1985). The dikes do not allow for water release from the Smallwood Reservoir, so the lower reaches of the Naskaupi, although experiencing reduced flows, still maintain an essentially natural hydrological cycle with the seasonal runoff from unregulated tributaries. Additional research is needed to address changes in these adjacent watersheds. However, due to the large disparities in size and reductions in flow, the Naskaupi and Kanairiktok Rivers cannot be used as reference sites to compare the diversity of riparian vegetation in regulated and un-regulated rivers as was done by researchers in Sweden (Nilsson et al., 1991a; Jansson et al., 2000).

The Kenamu is the third-largest, completely free-flowing watercourse adjacent to the Churchill. Again, since it is orders of magnitude smaller than the Churchill and does not flow through nearly as diverse a landscape from its headwaters to its mouth, it does not offer a valid comparison with the Churchill to directly assess regulated and unregulated conditions. However, surveys to document the structure and community composition of vegetation in riparian habitats along the Kenemu would be useful for general comparison of regional riparian floral biodiversity. Other smaller rivers flowing into Goose Bay, such as the Goose River, should also be surveyed.

Additional research can help us to gain a better understanding of how the riparian plant species richness and community structure compares with other floristic communities in this region, and what the relationships are with faunal communities. Not enough is known at this time to assess the importance of the natural riparian communities to regional biodiversity from a strictly scientific perspective.

7.5.2 Research on Other Anthropogenic Influences within the Watershed

Several types of human activities within the watershed may have an influence on hydrology and sedimentation processes in the river and in turn affect the riparian zones. Of these, road systems and commercial forestry may be two of the most important factors in the future (i.e. Laursen, 1996). The Trans-Labrador Highway travels through the upper watershed over the Ossokmanuan Reservoir and south of the Smallwood Reservoir. It then travels north of the lower reaches of the Churchill River to its mouth at Happy Valley-Goose Bay. The gravel roadway, along with numerous quarries for road construction and maintenance, could create a considerable increase in sediment load in tributaries flowing into the main stem of the river. One of the most important effects may be on spawning beds of fish, but the rate of sediment transport in the river and the formation of shorelines may also change.

Despite a regulatory requirement for riparian buffers, proposals for increased commercial logging in the area may also accelerate the rates of sedimentation of the main river. Again, further study should be conducted to investigate this potential influence.

7.5.3 Public Education and Review

A broad educational process and serious public consideration should be initiated of the regional effects of multiple hydroelectric developments. This should incorporate existing scientific research and the perspectives of elders who have a sense of historical reference points. Such a process has already been initiated for the Labrador Innu communities as a result of government obligations associated with respecting Aboriginal rights. Of course, the full range of ecological and social impacts of large hydroelectric projects needs to be better appreciated by anyone influencing decision-making on new developments. For the public at large, it is most likely that such an exercise will be mandated only within the context of a comprehensive environmental impact assessment conducted under the Canadian Environmental Assessment Act, for example, for a specific project proposal to regulate the lower Churchill. It is unfortunate that such a process would be subject to considerable time pressure and the influence of proponents who will have already invested substantial resources in proceeding with new developments. Indeed, such pressure already exists in any future review context as Newfoundland and Labrador Hydro must find ways to deal with enormous debt incurred partially through the Churchill Falls project and planning for new facilities in the lower river over the last four decades. This may result in misleading portrayals of the potential changes in the river due to regulation.

Figure 101. A Conceptual Image of the Proposed Dam at Gull Island Rapids Used to Promote the Project (Newfoundland and Labrador Hydro, 1998).

Figure 101 presents a rendering of the proposed Gull Island dam. Newfoundland and Labrador Hydro has used this image repeatedly over the past several years for promotional purposes. Unfortunately, this is the extent of the imagery that most people are exposed to in the media. The drawing is used to attempt to portray the dam as "green". Not only is this an odd colour for a dam, but the messaging is amiss in what it leaves out.

The reservoir upstream of a dam at Gull Island would likely have an extremely narrow riparian zone with little shrub growth. This is portrayed reasonably accurately in the image if the reservoir is full, minus any drawdown zone. Of course, this is not what a natural river shoreline looks like – it is missing a riparian zone. When such a facility is described using the engineering term "run-of-the-river", the average person may understand this to mean that the river is flowing in a natural seasonal cycle through the turbines. The term does not make it clear that the natural disturbance regime that allows rich and complex riparian habitats to develop is absent. The image also suggests that the surrounding forested landscape would remain intact, when in fact the quarries, roads, work sites, and transmission line corridors. This infrastructure would all leave long-lasting scars on the landscape. The image also gives no indication of the extent of changes in the riverscape that have already occurred with the Churchill Falls project. There is no sense of the issue of cumulative effects of the proposed project. In fact, extensive ultimate cumulative effects will occur when access to the area is increased for commercial forestry operations that will likely alter the structure of the forest and patterns of runoff in this part of the watershed.

Any process of public education must include accurate representations of the full extent of probable changes that would be created across the landscape by the proposed projects, and not exclude information about existing hydroelectric developments in the watershed (i.e. Churchill Falls).

7.6 Challenges of Cumulative Environmental Effects Assessment and the Need for a Precautionary Approach

Harmonized environmental assessment processes that can integrate and enhance the requirements of federal and provincial EA legislation and guidelines with the specific concerns of aboriginal parties who hold recognized land rights interests have been developed and implemented for several large assessments in recent years. For example, in

Labrador, a Memorandum of Understanding (MOU) on environmental assessment of the proposed Voisey's Bay mining development was signed between The Government of Newfoundland and Labrador, The Government of Canada, The Labrador Inuit Association, and The Innu Nation (Canadian Environmental Assessment Agency, 1997a). This agreement asked the proponent specifically to address the application of the precautionary principle to the undertaking and to assess cumulative effects. However, there was no detailed language with respect to how to accomplish these requirements.

7.6.1 Towards Regional Strategic Environmental Assessment

Although cumulative effects assessment (CEA) has been a topic of considerable interest and discussion by those involved in the regulation and implementation of environmental impact assessment, it has been argued that to date, practice in Canada has largely failed to live up to promise (Duinker and Greig, 2006). Many ecological processes respond in a cumulative way to local, regional, and global economic conditions, and require longer-term approaches to research and monitoring (Décamps and Fortuné, 1991; Risser et al., 1991, Tabacchi et al, 1998). Due to the complexity of understanding ecological changes related to multiple, large-scale human activities, the task of cumulative effects assessment presents a difficult challenge (see Beanlands and Duinker, 1983; Bedford and Preston, 1988; Cada and Hunsaker, 1990; Bunch and Reeves, 1992; Burris and Canter, 1997; CEAA, 2003; Duinker and Greig, 2006). It is especially problematic when there has been little documentation or monitoring of changes that have occurred from previous developments in the same ecological region or watershed. Moreover, adequate institutional and financial support does not always exist to pursue the wide range of questions that should be posed to address direct and indirect effects (see e.g. Nikiforuk, 1997).

There are many institutional factors that tend to hamper the success of CEA. Attempts to conduct CEA within the context of specific projects tend to be inadequate, in part because of a relatively narrow spatial and temporal scope of assessment. For the proponents of a project, the EIA process is often primarily seen as a regulatory hurdle, rather than an effort to determine the overall merits of a proposal in relation to environmental sustainability. EIA can also be quite expensive and adds to the overall cost of a project, potentially reducing its economic viability. CEA tends to be viewed as an exercise that is discrete from the evaluation of project specific effects. Efforts to conduct meaningful CEA are therefore relatively weak and may address only a few elements of interest, especially where historical data are lacking. Moreover, determining the significance of cumulative effects is challenging when there is only a vague consideration of regional environmental objectives and a poor understanding of ecological thresholds (Duinker and Greig, 2006).

For these reasons, a broader land-use planning approach which integrates cumulative effects assessment efforts may be more constructive. This is sometimes called strategic environmental assessment (SEA) (Nelson, 2005), or regional environmental assessment (REA) (Duinker and Greig, 2006). Recently, revisions that have been made to the Canadian Environmental Assessment Act suggest that the assessment of specific projects can be informed by existing regional environmental assessments.[26] This is meant to aid in building an understanding of cumulative effects. However, the focus of the wording is on possible future projects, and does not mention existing developments that may have been poorly studied. Moreover, there is nothing in the legislation to compel governments or proponents to invest in regional environmental assessment efforts.

Under an EU directive[27], SEA of plans and programmes is in the early stages of implementation in some jurisdictions such as the U.K. (Nelson, 2005). It is meant to complement and not replace environmental assessment of individual projects. A regional energy policy such as that currently being developed by the Government of Newfoundland and Labrador is precisely the type of plan that should be subjected to SEA if such a process were required in Canada. If sufficient time was afforded, and a greater degree of objectivity sought, it could conceivably provide a framework for broader consideration of the widespread and longer-term environmental and economic implications of various energy production and consumption choices.

An important element of the U.K. process is a requirement for consultation with relevant authorities and members of the public. Extensive consultation can improve the

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[26] section 16.1 in An Act to amend the Canadian Environmental Assessment Act Bill C-9 passed October 30, 2003.

[27] The Environmental Assessment of Plans and Programmes Regulations 2004, SI 1633/2004.

quality and amount of information available to decision-makers, possibly leading to substantial changes in a policy or programme. The strategic environmental assessment directive in the EU also provides for interjurisdictional consultation if the plan or programme is expected to have significant transboundary environmental effects in another state of the European Union (Nelson, 2005). However, there is presently no regulatory requirement for jurisdictions in Canada to conduct such a process for plans and programmes. The Newfoundland and Labrador Government is committed to developing the lower Churchill as a central part of their energy plan, leaving little room for longer-term, more impartial evaluations of the cumulative effects of these plans relative to alternatives.

More extensive consideration of alternatives to a proposed project has been promoted as an important part of environmental assessment in order to examine the potential to reduce environmental effects (O'Brien, 2000; Vanderzwaag et al., 2002). What is intended is a much broader view of alternatives than is generally considered at the level of a project-specific review. Alternatives may include the design of the specific project, for example changes in size, location and/or operating regime, or they may be entirely different technologies such as wind generation options, or energy conservation programmes. Consideration of radically different alternatives in pursuit of local economic development may include deliberate river conservation in support of tourism and guiding opportunities.

Newfoundland and Labrador is in the process of developing a policy and planning strategy for the development of energy resources in the province. Respecting the environment is cited as one of the objectives of the plan. This would be a good time and opportunity to take a broad view of the potential cumulative effects of various options. However, work on the energy plan to date appears to be focused on maximizing the economic benefits of energy development options to people of the province and maintaining centralized government control over energy production.

For example, it appears that the province has given little consideration to a recently proposed 1,000-megawatt wind farm in the upper Churchill region stating that the provincial Energy Plan is still in the early stages and they need to keep their options open. However, they are proceeding full steam with plans for the lower Churchill hydroelectric development. The wind energy project, proposed by a partnership between the Labrador Metis Economic Development Corporation and Toronto-based Ventus, was to be located on lands adjacent to the Smallwood reservoir to link into the existing grid. This project proposal was firmly rejected at the outset by the Newfoundland and Labrador government (Government of Newfoundland and Labrador, 2006)

The outstanding Innu comprehensive land claim is a priority consideration when any industrial projects are proposed in Nitassinan. However, part of the problem in pursuing a broader regional energy and economic development planning exercise that would more objectively consider alternatives to the lower Churchill Project, is that there is already so much invested in this particular scheme. Changing the location or the scale of the proposed hydro project would considerably alter its economic potential. The economic viability of this project is reportedly highly uncertain to begin with. Although there has been some local interest in looking at the possibility of smaller projects in the region, the design and location that produces the maximum amount of power is the expected focus of an energy development where the primary objective is to produce a lucrative export commodity.

It is clear that each additional hydroelectric development that alters the hydrology of a river system creates additive and probably synergistic effects altering the ecology (including the human ecology) of the watershed. It is necessary to make serious attempts to assess the cumulative effects of such projects using all existing knowledge in order to gain a meaningful understanding of the overall environmental impacts. Despite the challenges, we must attempt to consider cumulative effects within the context of much broader temporal and spatial scales than has been typical of past assessment processes (Rosenberg et al., 1997, Reid, 1998). The Innu Nation, in the process of negotiating its comprehensive land claim, has proposed many provisions to implement regional planning and ecosystem-based management processes that would work within a much longer-term conceptual framework focused on ecological integrity and cultural sustainability.

7.6.2 Taking a More Precautionary Approach to River Development

Environmental assessment processes such as that legislated under the Canadian Environmental Assessment Act (CEAA) are often understood basically as tools to assist proponents and governments in taking a more cautious approach to planning, project design and decision-making by reducing uncertainty and making sure that the risks of a specific undertaking are better understood. Cumulative effects assessment is crucial as it is meant to bring environmental assessment processes beyond the narrow focus on a single development (Duinker and Greig, 2006). Certainly, rather than being a separate exercise, assessment of the potential cumulative nature of all environmental effects should be considered as an integral aspect of environmental assessment in general.

The Rio Declaration on Environment and Development suggests that a reasonable threat of serious and irreversible environmental harm from a human activity should invoke the use of a precautionary approach in decision-making, in which cost-effective measures to *prevent* environmental degradation are widely applied by states.[28] Interpretation and application of the precautionary principle as recommended at Rio has taken diverse forms (Applegate, 2002). In what ways can the precautionary approach be applied to the topic of large-scale hydroelectric development on the Labrador/Ungava peninsula? Taking a precautionary approach in this case may mean for one thing, doing more than is strictly required by existing laws.

The Voisey's Bay Mine and Mill Review Panel developed its own interpretation of cumulative effects and the precautionary principle and produced guidelines for the preparation of the environmental impact statement requesting that the proponent assess the project in the context of its effects on a "reasonable geographic scale", suggesting watershed boundaries as an example of one meaningful category (Canadian Environmental Assessment Agency, 1997b). As the first requirement under their interpretation of the precautionary principle, the Review Panel asked the proponents to show that they had designed the project to 'avoid adverse environmental effects wherever possible'. Where it is not possible to avoid adverse effects, as is true, for example, when the hydrology of a river is radically changed, how then can we apply the precautionary principle? Where there are unavoidable residual effects from the use of conventional technologies in wide use, it is perhaps the case that these are more likely to be accepted by many people who do not experience the direct effects. Application of the

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[28] Rio Declaration on Environment and Development, Annex 1, princ.15, U.N. Doc. A/CONF.151/5/Rev. (1992).

precautionary principle certainly must start with a thorough scientific and public review encompassing a broad temporal and spatial scope, in order that at least a reasonable qualitative understanding of the range of effects is developed.

A central tenet of many interpretations of the precautionary principle is that the proponents of projects should be required to carry the burden of proof that their activity *will not* create unacceptable environmental consequences (Vanderzwaag et al., 2002). Under the Canadian Environmental Assessment Act (CEAA), the burden of proof ostensibly does fall to the proponent to demonstrate how the development *will* degrade the environment and what they can do to mitigate any predicted negative effects. This includes consideration of existing and likely future developments that would interact with the proposed project in affecting the same elements of the environment. However, there has been an inadequate implementation of the duty to conduct cumulative effects assessment in many past EIA processes for large hydroelectric projects in Canada (Duinker and Greig, 2006). From a broader regulatory perspective, it would be helpful if the Churchill Falls (Labrador) Corporation were required to develop more documentation on the environmental effects of their existing facilities and operations.

The precautionary approach or principle is most often used in reference to legal and management decisions in which there is scientific *uncertainty* in relation to the use of new technologies, or increasing intensity of the use of existing technologies (e.g. Peel, 2004; Applegate, 2003). As discussed in this thesis, available information suggests that river regulation causes inevitable and serious local ecological consequences for riparian habitats that cannot be mitigated to any meaningful degree if fundamental processes created by natural hydrological regimes are compromised. It is therefore questionable whether there are any cost-effective measures possible within the context of a large river regulation scheme that could prevent the direct environmental degradation likely to occur with the proposed dams. However, the *extent* of the long-term cumulative effects on regional ecological integrity of more dams on the Churchill River specifically, or within the Labrador/Ungava peninsula region broadly, is not well understood.

Where there are data lacking with regards to the effects of existing developments, such as the Churchill Falls project, it is a greater challenge to understand the risks of additional development. However, in the case of the cumulative effects of successive regulation of a single river, I would argue that even lacking extensive scientifically gathered historical data, there are cost-effective measures to more adequately assess cumulative effects in a meaningful way. As demonstrated in this thesis, an adequate focus on cumulative effects can provide at least a better qualitative understanding of an array of risks.

In terms of specific actions to implement the precautionary principle, it may be argued, as Hydro Québec suggests, that there is enough known about the effects of flow regulation on riparian habitats, and therefore we should not waste resources on additional research. If so, the action taken should still entail an adequate review of that research so that it can be taken into consideration by decision-makers and the public. A synthesis of all relevant existing information and application to the understanding of cumulative effects is clearly indicated as appropriate and necessary action.

There are varying interpretations of the seriousness of the harm that results from the loss of riparian habitat, or any other environmental effect of hydroelectric power production, and that should invoke specific precautionary action. Perspectives may depend in part of the degree of knowledge of the river system, or they may relate to the level of vested interest in the economic benefits of the proposed project held by a group or individual. Mitigation measures to try to reduce negative effects, or compensate them financially, may be seen by some as the most reasonable and cost-effective action. However, this is true only after a firm decision has been made to build the dams. In the case of the lower Churchill, that decision has already been made by the provincial government and its electricity utility, but it has not been made by many other members of society.

The only real political interest at the government level to invoke the precautionary principle is to apply mitigation measures to the existing design. These would have minimal success in offsetting the most serious environmental effects. River rehabilitation involving returning natural flow patterns to regulated reaches would not be deemed to be "cost-effective" by anyone involved in the hydroelectric power production industry. This is the only mitigation measure that would have any significant effect on the ecological integrity of riverine habitats.

There is reasonable scientific certainty with regards to at least two general effects of additional large-scale hydroelectric development in Labrador's Churchill River valley, i.e. degradation of riparian habitats as a direct result of flow regulation, and the loss of a riverine cultural landscape. There are few if any useful, let alone cost-effective, mitigation measures available in the context of the proposed lower Churchill project to reduce these effects. In terms of the regional effects on species and populations of the loss of riparian habitats, the consequences of each additional project are much less certain. If a precautionary approach to environmental assessment is intended, then a more thorough attempt at the consideration of cumulative effects must be made, using all relevant sources of knowledge and interpretation.

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Threatened or Vulnerable Species, An Act Respecting, - R.Q. c. E-12.01, r.1 Ministerial Order concerning the establishment of a list of threatened or vulnerable vascular plant species which are likely to be so designated and a list of threatened or vulnerable vertebrate wildlife species which are likely to be so designated.

Personal Communications

Numerous people participated in workshops, group discussions and personal interviews with the author and Innu researchers in the context of the community consultations in Sheshatshiu and Utshimassits. These are listed in the following reports:

Innu Nation Hydro Community Consultation Team. 2000. *Power Struggle: An Innu look at Hydro development in Nitassinan.* The Innu Nation Community Consultation on the new Mishta-shipu hydro project. Sheshatshiu: Innu Nation. 124 p.

Innu Nation Hydro Community Consultation Team. 2001. *Innu Nation community consultation on hydroelectric development in Nitassinan, Phase II.* Sheshatshiu: Innu Nation. 47 p.

Between 2001 and 2005, the following people from the communities of Sheshatshiu, Happy Valley-Goose Bay, and Natuashish participated in additional individual discussions about their observations of riparian habitat along the Churchill River before and after hydroelectric development:

Goudie, Horace
Goudie, Joe
Gregoire, George
Nuna, Aniet
Nuna, George
Nuna, Katnen
Nuna, Madeline
Pastitshi, Sebastian
Penashue, Elizabeth
Penashue, Francis
Penashue, Lizette
Penashue, Mathew
Penashue, Pien
Pone, Jerome
Pone, Mathias

Previous Interviews:
Joe Nuna - as recorded in 1993 by Pien Gregoire Jr. and Peter Armitage, Innu Nation, (Innu Nation, unpublished transcript)

Information or comments from the following people are cited in the text:

Hilyard, Barry, Iron Ore Company of Canada, Labrador City, June 9, 2006
Glen Windsor, Newfoundland and Labrador Hydro, St. John's, July 19, 2006
Blake-Rudkowski, Clarice, Grand RiverKeepers, May 20, 2006

Appendix A. Information for Participants – English Version

<u>Mishta Shipu (Grand River, Churchill River) Shoreline Ecological Study</u>

My name is Annette Luttermann and I am a Ph.D. student at Dalhousie University in Halifax, Nova Scotia. I have been studying the effects of hydroelectric development in the Labrador region.

There was very little research done on environmental effects when the Churchill Falls hydro project was built in the 1960's and 70's. More hydroelectric development has been proposed for the Mishta Shipu (Grand River, Churchill River). I would like to learn more about what changes have already happened on the river shores, especially in the areas directly affected by flooding, reduction in water flows, or changes in patterns of water flows during different seasons. By sharing the different kinds of knowledge we have, we hope to better understand the history of the river, its present state, and what more hydroelectric projects may mean for the future of the river and the people who know and value it.

For this study, I am particularly interested in talking about the shorelines of all parts of the Mishta Shipu (Grand River, Churchill River), including the areas above the height of land around Michikamau and Michikamats. I would like to talk with you about any areas you are familiar with.

The main questions we will talk about are:

- What did the shorelines in different parts of the river look like in the past (before the Churchill Falls development)?
- What kinds of plants and animals were found there in the past?
- What do the shorelines look like now and what changes, if any, you have noticed in the plants and animals live there now?
- How do you feel about the changes that have happened in the past and those that might happen in the future if more dams are built?

I am interested in talking with people such as you who have spent time in these areas before the Churchill Falls hydro development and/or in the years since. We will look at maps and pictures together and perhaps visit some places along the river to see what it looks like now if you are interested and able to go. We will talk about your experiences and what you may remember about the shoreline environments in the past and at present.

It is entirely up to you if you would like to participate in this study. If you do agree to participate, I will make notes about what you say and also audio tape our conversations if you agree to this. We may have an Innu co-researcher with us to help to explain and/or translate. The discussions will take two or three hours of your time. I will review the notes with you following our discussions to make sure that I write down what you say accurately.

It is your choice whether you would like your name to be used in the final report. If you do not, your comments will be summarized and your name will not be associated with them in the report or any other writing. However, it is important to be aware that it may be impossible to remain completely anonymous as other community members who know you may recognize comments as yours even if your name is not on them. You are of course free to decide at any time not to continue to participate in the study.

The final report will be available to the communities in Labrador, people associated with the universities, and the general public. Copies of all original written notes collected through this research will be stored at Dalhousie University for safekeeping. Individual names and personal information will be stored separately. Only Annette Luttermann and Bill Freedman will have direct access to these records at the University. Transcripts of interviews with Innu participants without personal identification, if that is what you choose, will be accessible to Innu Nation for use in environmental assessment processes and land rights negotiations.

Agreement with Participant:

I have considered the explanation of this study as written above. I have been given the opportunity to discuss it and my questions have been answered to my satisfaction. I agree to take part in this study. However, I realize that my participation is voluntary and that I am free to withdraw from the study at any time.

Participant Name:_________________________

Signature: __________________________

Conditions:

_____ I wish to remain anonymous and not have my name mentioned in relation to my comments in this study.

_____ I do not want my name to be associated with my comments in the report, but agree that I be listed as a participant in the study.

_____ I agree to have my name associated with my comments in the report.

_____ I agree to have our discussion audio-taped.

_____ I do not wish to have our discussion audiotaped.

Any other conditions specified by the participant:

____

Date: _______________________

Researcher : ______________________

Participant # _________

If you have any questions or comments about this study or your involvement in it please feel free to contact me anytime:

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In the event that you have any difficulties with, or wish to voice concern about any aspect of your participation in this study, you may contact Human Research Ethics / Integrity Coordinator at Dalhousie University's Office of Human Research Ethics and Integrity for assistance:
phone: 902-494-1462.

Appendix B. Information for Participants – Innu-aimun Version

Tshitapueten tshetshi minuen shtaimun – Mishta-Shipu naneu nantutshissentakanu

Annette Luttermann nitishinikashun kie nitshishkutamashun Ph.D. nete Kamishte tshishkutamashunanut Dalhousie University, nete Halifax, Nova Scotia. Nishtupun shash nitashpish atushkuaut Innu Nation ne Tshatatakant Kaui tshipeikant shipuu ute Labrador kie nantutshissentakanu tan etentakau nenu kassinu auentsent.

Tshitshue mishte apishish nantutshissentakanishapant tshekuan nene mishta-paushtuk Katshipeikant nete pet 1960's mak 70's. Eku ume anutshish minuat ui tutakanu tshetshi tshipeikant ne shipu tshetshi tutakantshi uashtenimakana uet pempantakantshi. Niui tshissentenan tan eishi matentakuak nene katshi nissipitakant ne assi kie ne shipu eshpish eiat ishikutakant. Eku ume tshi ntutshissentakanu kaishpish matentakuak nene ueshkat kanissipitakant ne shipu kie etitu tshetshi nishtutamak tan tsheishi matentamak nte assit minuat tshipeikantshi ne shipu. Eukun ume tsheuauitshikuiak tshetshi ut minu nishtutamak eishi pikunikant ne shtassinu kie tshika nishtutatishunan tan tsheitishutamak nenua kutaka atusseunna ua tshitshepantakantshi nete nikan aiashkat.

Eku ume tsheishi nantutshissentakant tshika tshitapatenan nete kanissipitakant ne assi kaasinu nete naneu Mishta-shipu kie nete Mishakamau kie nete Mishakamassit.

Umenu tsheishi kuketshimakanit innut:
Tan ishinakunipan nte naneu eshk eka nissipetakant?
Tan ishinakunipan uapukun kie tshekaueshishet tapant nete?
Tan eshinakuaki uapukuna anutshish kie tshekaueshishet nete etatau anutshish?

Nish (2) innut tshika utinakanut tshetshi uitshiatussemaht nenua akaneshaua kanantutshissentamintshi tshekuannu. Niui kukuetshimanant ntshent innut uiapatakau nenu assinu eshk eka nessipitakannit nenu assinu Tan ishinakunipan nte naneu shipit kie nte naneu shakaikant. Tshika tshitapatenanu assiu-mishinaikana kie akunikannit kie mak tshika itauntinan nete mishta shipit tshetshi uapatamek anutshish eshinakuak, shapentameku tshetshi shatshuapatamek nete shashish kauapatamek. Tsheuauitamuiat ne eishi tshissitamek tan ishinakunipan ueshkat nete naneu shipit.

Muk tshin etentamen ui minuenni shtaimun ume neantutshissentakant tshekuan. Eku tapuetamini tshetshi utinikant shtaimun tshika pitepantakanu ne essishuein nta kapetakushinanut kie mak nta kaishetshimakanit tshika nukueikun. Epeikushin tshika eimikun kie mak emitshetinanut mamu tshika eiminanu. Tshika uapatinikun ne etishtakant tshitaimun kaishpish issishuein. Eku tapuetamini tshetshi uinikuin nta mishinaikant neme kaishpish issishuein tshekuan. Kie mak eka tapuetamini tshetshi uitakant ne shtishinikashun muk neme kaissishuein tshika mishin ateikanu nta mishinaikant. Tshin neme tshika tshissenten tsheishpish punin eminuen shtipatshimun.

Eku tshimiatshi nete pushiatshi nutshimit nika tshishikashunan mitshim mak apishish tshika tshishikakun. Kie tshika uauitshitinan tshemitaieku tshipitshuiantshuap.

Eku tshishtakantshi ne mishinaikan tshika itisheikanu nte kassinu utenaua nte Labrador, kie tshika itisheimuakanut ntshent akaneshaut nte Universities, kie kassinu auen tshetshi uapatak. Pisse ntshent kaishetshimakanit tshika apatshiakanut neta tutuakantaui kaishetshimakanit nete katshipeikant shipu.

Eukuan ume tsheishi tapuetamin tshetshi pitshitinimen shtaimun:

Shash kassinu nitshishimamitunenten ume mishinaikan etishtet. Kie shash nitshi minikun tshetshui kukuetshitshemuian tshekuan kie shash nasht niminu nishtuten kassinu tshekuan. Nitapueten tshetshi minuian nitaimun ume niantutshissentakant tshekuan. Niminu nishtuten kie nin u nitapuetatishun tshetshi tapuetaman ume eishi nantutshissentakant tshekuan kie ninishtuten muk eshpish ui punian nikatshi puntan eminueian nitaimun.

Umenu eishinikashut auen: ____________________
Unishta shtishinikashun_____________________

Eshitapuetamen:

_______Apu ui mishinateiman nitishinikashun neta kaminuian nitaimun
_______Apu tapuetaman tshetshi unishtakant ne nitishinikashun ntea mishinaikant, muk nitapueten tshetshi uinikuian mamu ntshent kutakat auentshe kaminueht utaimunuaua.
_______Nitapueten tshetshi uitakant nitishinikashun neta nashuk neme kaissishuian tshekuan.

Uta tshemishinateikant ne kutak tshekuan tiapuetaman:
Pishum eshpish tshishtauakant:________________________
Kanantutshissentesht:______________________________
Tshin shtishinikashun:______________________________

Etakunikue kutak tshekuan ua kukuetshitshemune kie mak etakunikue tshekuan ua issishuein tshepet eimian uenishk.

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Tikuaki tshekuan ua issishueiek kie mak tekunikue tshekuan eka menipunikuiek tshepet eimiek ute, Human Research Ethics/ Integrity Coordinator ute Dalhousie University's Office of Human Research Ethics and Integrity: Kaiminanut etishtet: 902-494-1462.

Appendix C. Interview and Focus Group Discussion Guide

The following questions were used to guide open-ended discussions:

- What areas of the land around the Grand River (Mishta Shipu) did you travel during the 1950's and 1960's?

    (Some previous map biography work has been done by other researchers with some of the potential participants. These maps will be referred to during the discussions where appropriate).

- What areas have you visited since the Churchill Falls hydro project was built?
- What times of year did you go there? (before and after the Churchill Falls project)
- What were weather conditions like at different times?
- What did you see there on the shores of the rivers and lakes?
- Have you noticed any physical changes in the shorelines since the Churchill Falls hydro project? What kinds of changes have you noticed?
- What kinds of plants did you see on the shorelines? Where were you most likely to find them? What times of year did you see them?
- What kinds of plants did you use? What did you use them for?

    (Photographs of riparian habitats and plant specimens will be used for discussion and identification)

- Do you think that the shorelines of lakes and big rivers are important for some plants and animals? In what ways are they important?
- What kinds of wildlife did you see? When and where were you most likely to see them?
- Which animals did you hunt on the shorelines?

Structure
Guide the discussion to focus on the shorelines PAST – PRESENT – FUTURE

PAST
Start by looking at the old maps to show the land before the Churchill Falls project. With older people, talk generally about the places they had been and what kinds of things they did there – (travel through, hunt, fish, pick berries, camp, etc.)
Talk about any spots where they remember camping on the shorelines.

PRESENT

Then look at new maps and describe the hydrological changes in the various parts of the watershed. Explain how the water levels are controlled seasonally. Look at some pictures of the dams as well if people would like some clear explanation of how the water flows have been changed. What areas have they seen since the project was built? Talk about what the shorelines look like in those areas that they have seen.

Look at some pictures of the shorelines in various areas and discuss what they think of these and what the possible significance of the changes may be for human use, for other animals, for plants. etc. Are there any particular spots that were important to people that have now changed?

Look at some plant specimens from the river shores together and talk about whether they are generally common plants in places other than river shorelines, their importance for wildlife, etc.

FUTURE

Look at a map of proposed projects and show the sites where dams have been proposed and how much of the river valley would be affected. Explain the reservoir shoreline effects with pictures of different areas that would mimic the new reservoirs.

Discuss what the significance of these changes might be for human use, for plants and for wildlife. No rapids, possible less growth of shrubs and herbs, etc.

Discuss how the existence of the Churchill Falls hydroelectric complex influences their opinions of future projects on the same river.

Appendix D. Definitions of Categories and Methods for Riparian Habitat Survey

Distance from Mouth of the River: determined from measurements on Newfoundland and Labrador Hydro 1:50,000 map series "Churchill River Power Project, Churchill River Centre Line"

Elevation: Values given are approximate in meters above mean sea level at the low-water mark of the sites surveyed. Elevation was estimated from contours on 1:50,000 contour maps. The map sheets currently available use 50-foot contour intervals.
The value reported represents the elevation at the midpoint between the lowest contour adjacent to the shoreline site and the next lowest contour. This would give a value that would be at least within 25 feet (7.62 m) of the site. Thus, the value given for a site lying between the shoreline and the 400-foot contour would be 375 feet (114.30 m).

The exact elevations at water level are not known. The current topographic maps contain many inaccuracies. Moreover, the water levels fluctuate, and the sites themselves encompass variable elevation gradients depending on the slope and degree of flooding. Approximations of elevation are therefore considered adequate since it is primarily important be able to make broad comparisons among sites to test for the relative influence of elevation in future analyses.

Flood regime:
1- downstream reaches
2- reduced flow reaches
3- forebay reservoir
4- storage reservoir
5- natural river reach

Width of active riparian zone: Distance between the summer low-water level and spring high-water level.

Site area: Calculated as the mean of five measurements the width of the active riparian zone multiplied by the length of the site (200 m).

Height of the bank: measured as the vertical distance between the summer low water and spring high-water marks using a rod and level.

Width of the river channel: measured on 1:50,000 topographic maps. Some sites are on open reservoir bodies; therefore, channel width was not measured since this parameter is only relevant to the river reaches.

River Flow:
1- reservoir
2- river lake
3- very slow
4- slow to moderate

5- eddy
6- swift flowing
7- rapids
8- dewatered

Height of Bank in Riparian Zone: Measured with a rod and level.

Slope:
1- low
2- low to moderate
3- moderate
4- moderate to steep
5- steep

Substrate % Cover: Estimated by visual observation of the entire site

Substrate Heterogeneity: This is simply the number of different substrate types observed on each site.

Substrate Fineness: Values of substrate fineness were calculated using the percentage composition of the riparian zone surface substrate as estimated by eye. Following Wright et al. (1984) and Nilsson et al. (1989), substrate types were weighted as organic/peat 12, clay 9.0 silt 6.5, sand 2.0, gravel -2.0, pebbles -4.5, cobbles -6.5, boulders -9.0, bedrock -12.

Vegetation Structure: Estimated by visual observation of the upper, middle and lower zones of each site.
T&S - trees and shrubs (individuals of woody species >0.25 m)
H&DS - herbs and dwarf shrubs (individuals of woody species <0.25 m)
GR - graminoids
BG - bare ground

Species Richness: The total number of species observed in each site.

Codes based on the Braun-Blanquet method to estimate species abundance

Species Abundance:	Code
Sparsely or very sparsely present <1%	+
Plentiful but covering 1- 5%	1
Covering 5 - 25%	2
Covering 25 - 50%	3
Covering 50 - 75%	4
Covering 76 - 100%	5

Table 6. Sample Vegetation Survey Field Data Recording Sheet

Site #15 **Date:** 17-Jul-01 **Photos:** **Film #** 7A

Observers: 3 **Frames** 8-May

Description: 200 m reach of narrow cobble shore just west of Beaver Brook adjacent to a large eddy

Km from mouth: 146.7 **Location (UTM):** 0577555 5861110

Width of riparian zone (m): 3, 4.1, 6.4, 5.3, 3.8 **Width of River Channel (m):** 350

Average Width (m): 4.5

Height (m): 1.9 **Slope:** moderate to steep

% Cover Substrate: (x is present but <1%)

clay		**gravel**	10	**boulders**	5
silt		**pebbles**	20	**bedrock**	
sand	5	**cobbles**	60	**organic**	

River Flow: large eddy near mouth of brook, main stem of river has moderate flow

% Vegetation cover in Zones:

	Upper	**Middle**	**Lower**
Trees and shrubs	25		
Herbs and Dwarf Shrubs	15	40	10
Graminoids	25	20	10
Bare Ground	35	40	80

	Species	**ZONE** Upper	Middle	Lower
1	Abies balsamea (L.)1 Mill.	1		
2	Achillea millefolium L. subsp. lanulosa (Nutt.)Piper	x	x	x
3	Actaea rubra (Aiton) Willd. subsp. rubra	x		
4	Agrostis mertensii Trin.		x	
5	Alnus viridis (Chaix) DC. in Lam. & DC. subsp. crispa (Dryand. ex Aiton) Turrill ex Aiton	1		
6	Alnus incana (L.) Moench subsp. rugosa (DuRoi) R.T. Clausen	9		
7	Symphyotrichum puniceum (L.) Á & D. Löve var. puniceum	x	x	

Table 7. Comparative List of Vascular Plant Species Recorded in the Riparian and Spray Zones of the Churchill River

Sources of previous botanical observations:

MTD - Abbe, E.C. 1955. Vascular plants of the Hamilton River area. *Contributions to the Gray Herbarium* v.176. pp.1-44. (Collected by Margaret T. Doutt)

GRB - Brassard, G.R., S. Frost, L. Marshall, O.A. Olsen and D.H. Steele. 1971. Studies of the spray zone of Churchill Falls, Labrador. *Biological Conservation* 4:13-18.

DB - Bajzak, D. 1971. *Vegetation classification and mapping of the "Smallwood Reservoir" area, Labrador.* St. John's: Memorial University of Newfoundland. 46 p.

BH - Beak Consultants and Hunter and Associates. 1978. *Lower Churchill biophysical study.* Prepared for Newfoundland and Labrador Hydro, St. John's.

Pien and Lisette Penashue - personal communications 2001 and 2005

The order of families and taxonomy follows: Meades, Susan J., Stuart G. Hay and Luc Brouillet. 2000. *Annotated checklist of the vascular plants of Newfoundland and Labrador.* The Provincial Museum of Newfoundland and Labrador.

Vascular Plants Recorded in the 2001 Survey	Additional Species Reported in Previous Records, and Synonyms for Species with Name Changes	MTD	GRB	DB	BH	2001 Survey
Equisetaceae (Horsetails)						
Equisetum arvense L.		x	x	x	x	*x*
Equisetum fluviatile L.		x				*x*
Equisetum palustre L.						*x*
Equisetum pratense Ehrh.						*x*
Equisetum sylvaticum L.		x				*x*
Isoëtaceae (Quillworts)	*Isoetes echinospora* Dur. syn. *I. muricata* Dur.	x				

Vascular Plants Recorded in the 2001 Survey	Additional Species Reported in Previous Records, and Synonyms for Species with Name Changes	MTD	GRB	DB	BH	2001 Survey
Lycopodiaceae (Clubmosses)						
Diphasiastrum complanatum (L.) Holub						*x*
Huperzia selago (L.) Bernh. ex Schrank & Mart						*x*
Lycopodium annotinum L.						*x*
Lycopodium dendroideum Michx.						*x*
Lycopodium lagopus (Laest. *ex* C. Hartm.) G. Zinserl. *ex* Kuzen.						*x*
Selaginellaceae (Spikemosses)	*Sellaginella selaginoides* (L.) Link	x				
Dryopteridaceae (Wood Ferns)						
Athyrium filix-femina (L.) Roth *ex* Mertens var. *angustum* (Willd.) G. Lawson		x		x		*x*
Dryopteris carthusiana (Villars) H.P. Fuchs		x			x	*x*
Dryopteris campyloptera Clarkson	syn. *Dryopteris spinulosa*					x
Gymnocarpium dryopteris (L.) Newman		x				*x*
Onoclea sensibilis L.		x				*x*
Ophioglossaceae (Adder's Tongues)						
Botrychium multifidum (S.G. Gmel.) Rupr.						*x*
Osmundaceae (Flowering Ferns)	*Osmunda claytoniana* L. [interrupted fern]	x				
Thelypteridaceae (Marsh Ferns)						
Phegopteris connectilis (Michx.) Watt		x				*x*
Cupressaceae (Cypress)	*Juniperus communis* L. [common juniper]	x				
Pinaceae (Pines)						
Abies balsamea (L.) Mill.		x	x	x	x	*x*
Larix laricina (DuRoi) K.Koch		x	x	x	x	*x*
Picea glauca (Moench) E.G. Voss		x	x	x	x	*x*
Picea mariana (Mill.) B.S.P.		x	x	x	x	*x*

Vascular Plants Recorded in the 2001 Survey	**Additional Species Reported in Previous Records, and Synonyms for Species with Name Changes**	**MTD**	**GRB**	**DB**	**BH**	**2001 Survey**
Taxaceae (Yews)	*Taxus canadensis* Marshall (reported by Pien and Nishet Penashue)					
Colchicaceae (Autumn Crocuses)						
Streptopus amplexifolius (L.) DC. var. *amplexifolius*		x	x			*x*
Convallariaceae (Lily-of-the-Valley)						
Maianthemum canadense Desf. subsp. *canadense*					x	*x*
	Maianthemum trifolium (L.) Sloboda syn. *Smilacina trifolia* (L.) Desf. [three-leaved false Solomon's seal] (MTD)	x				
Cyperaceae (Sedges)						
Carex aquatilis Wahlenb. var. *aquatilis*		x				*x*
Carex cf. *arcta* Boott						*x*
Carex atratiformis Britt.			x			*x*
	Carex canescens L.	x				
	Carex bigelowii Torr.	x				
Carex brunnescens (Persoon) Poiret var. *sphaerostachya* (Tuckerman) Kalela		x				*x*
Carex disperma Dewey						*x*
	Carex echinata Murray subsp. *echinata* syn. *Carex angustior* Mackenz. (MTD) [little prickly sedge] [syn.Carex cephalantha (L.H. Bailey) E.P. Bicknell] (BH)	x			x	
* *Carex hostiana* de Candolle						x
Carex cf. *interior* L. H. Bailey						*x*

Vascular Plants Recorded in the 2001 Survey	**Additional Species Reported in Previous Records, and Synonyms for Species with Name Changes**	**MTD**	**GRB**	**DB**	**BH**	**2001 Survey**
Carex lenticularis Michx. var. *lenticularis*						*x*
Carex leptalea Wahlenb.						*x*
Carex leptonervia (Fernald) Fernald						*x*
Carex limosa L.						*x*
Carex magellanica Lam. subsp. *irrigua* (Wahlenb.) Hultén						*x*
	Carex mainensis Porter (DB, otherwise only reported for STPM)			x		
* i *Carex panicea* L.						x
Carex projecta Mackenzie						*x*
	Carex rostrata Stokes	x			x	
Carex saxatilis L.						*x*
Carex stipata Muhl. *ex* Willd. var. *stipata*						*x*
	Carex stylosa C.A. Meyer var. *nigritella* (Drej.) Fern.	x	x			
Carex trisperma Dewey						*x*
Carex utriculata Boott in W.J. Hooker						*x*
Carex vesicaria L.						*x*
Eleocharis acicularis (L.) Roem. & Schult.						*x*
Eriophorum angustifolium Honckeny subsp. *angustifolium*		x				*x*
Eriophorum chamissonis C.A. Meyer (syn. *Eriophorum russeolum*)						*x*
Eriophorum scheuchzeri Hoppe						*x*
Scirpus atrocinctus Fernald						*x*

Vascular Plants Recorded in the 2001 Survey	Additional Species Reported in Previous Records, and Synonyms for Species with Name Changes	MTD	GRB	DB	BH	2001 Survey
Scirpus microcarpus J. & C. Presl (syn. *S.rubrotinctus*)	*Scirpus rubrotinctus* Fern.	x				*x*
Trichophorum alpinum (L.) Pers.						*x*
Trichophorum cespitosum (L.) Hartm.	syn. *Scirpus cespitosus* L. var. *callosus* Bigel.	x	x			*x*
Iridaceae (Irises)						
Iris versicolor L.		x			x	*x*
Juncaceae (Rushes)						
Juncus alpinus Villars						*x*
* *Juncus articulatus* L.						x
Juncus arcticus Willd. var. *balticus* (Willd.) Trautv.						*x*
Juncus brevicaudatus (Engelm.) Buch.		x				*x*
Juncus filiformis L.		x				*x*
Luzula parviflora (Ehrh.) Desv.		x				*x*
Liliaceae (Lily)						
Clintonia borealis (Aiton) Raf.		x				*x*
Orchidaceae (Orchids)						
Corallorhiza trifida Châtelain		x				*x*
	Platanthera dilatata (Pursh) Lindl. ex L.C. Beck var. *dilatata* syn. *Habenaria dilatata* (Pursh) Hook. [white bog orchid] (scent bottle orchid, white bog orchid, bog candle)	x	x			
**Listera borealis* Morong						x
	Listera cordata (L.) R. Br. [northern listera]	x				

Vascular Plants Recorded in the 2001 Survey	Additional Species Reported in Previous Records, and Synonyms for Species with Name Changes	MTD	GRB	DB	BH	2001 Survey
Poaceae (Grasses)						
Agrostis mertensii Trin.						*x*
Agrostis scabra Willd.		x				*x*
	Alopecurus aequalis Sobol. var. natans (Wahlenb.) Fern. [short-awned foxtail]	x				
Bromus ciliatus L. var. *ciliatus*						x
	Bromus hordeaceus L. syn. B. *mollis* L. [soft chess, brome grass]				x	
Calamagrostis canadensis (Michx.) P.Beauv. var. *canadensis*		x		x	x	*x*
Calamagrostis stricta (Timm) Koeler subsp. *stricta* var. *borealis* ©. Laest.) Hartman						*x*
Deschampsia cespitosa (L.) P.Beauv. subsp. cespitosa						x
Deschampsia flexuosa (L.) Trin.						*x*
Elymus trachycaulus (Link) Gould *ex* Schinners subsp. *trachycaulus*						*x*
Festuca rubra L. s.l.						*x*
Glyceria striata (Lam.) A.S. Hitchc. var. *stricta* (Scribn.) Fernald					x	*x*
Hierochloë odorata (L.) P.Beauv.						*x*
Phleum alpinum L.						*x*
	Poa alpina L. [alpine blue grass]	x	x			
i *Poa annua* L.						x
Poa arctica R.Br. subsp. *arctica*						*x*
i *Poa compressa* L.						x

Vascular Plants Recorded in the 2001 Survey	**Additional Species Reported in Previous Records, and Synonyms for Species with Name Changes**	**MTD**	**GRB**	**DB**	**BH**	**2001 Survey**
Poa glauca Vahl						*x*
Poa palustris L.						*x*
Poa pratensis L. subsp.?						*x*
Schizachne purpurascens (Torr.) Swallen subsp. *purpurascens*						*x*
Trisetum spicatum (L.) K. Richter	syn. *Trisetum spicatum* (L.) K. Richter ssp. *molle* (Michx.)	x				x
Potamogetonaceae (Pondweeds)						
Potamogeton cf. *alpinus* Balbis						*x*
Potemogeton sp.						*x*
	Potamogeton richardsonii (Benn.)	x				
Scheuchzeriaceae (Scheuchzeria)						
Scheuchzeria palustris L. subsp.*amer*		x				*x*
Sparganiaceae (Burreeds)						
Sparganium sp.						*x*
Adoxaceae (Viburnum)						
Viburnum edule (Michx.) Raf.						*x*
Apiaceae (Parsley)						
Cicuta bulbifera L.						*x*
Araliaceae (Ginseng)	*Aralia hispida* Vent. [bristly aralia] (MTD)	x				
Asteraceae (Daisy)						
Achillea millefolium L. subsp. *lanulosa* (Nutt.)Piper	*Achillea millefolium* L. [common yarrow] (BH)				x	*x*
	Anaphalis margaritacea L. [pearly everlasting] (MTD)	x				

Vascular Plants Recorded in the 2001 Survey	Additional Species Reported in Previous Records, and Synonyms for Species with Name Changes	MTD	GRB	DB	BH	2001 Survey
Artemisia campestris L.	*Artemisia borealis* (Pall.) (MTD) syn. *A. campestris* L. s.l. [wormwood]	x				*x*
Aster radula Solander *in* Aiton						*x*
Petasites frigidus (L.) Fries var. *palmatus* (W.T. Aiton) Cronquist	syn. *Petasites palmatus* (Ait.) Gray. (MTD)	x				x
	Petasites frigidus (L.) Fries var. *xvitifolius* (Greene) D.M. Cherniawsky (pro sp.) *(frigidus var. palmatus x var. sagittatus)*, syn. *Petasites vitifolius* Greene. (MTD)	x				
Senecio c.f. *congestus* (R.Br. ex Parry) DC.						*x*
Solidago macrophylla Pursh				x		*x*
Solidago multiradiata Aiton		x			x	*x*
Solidago cf. *uliginosa* Nutt.						*x*
Symphyotrichum novi-belgii var. *novi-belgii* (L.) Nesom						*x*
Symphyotrichum puniceum (L.) Á & D. Löve var. *puniceum*	*Aster puniceus* L. [purple stemmed aster] (BH)				x	*x*
Taraxacum c.f. *lapponicum* Kihlm.		x				*x*
Betulaceae (Birch)						
Alnus viridis (Chaix) DC. *in* Lam. & DC. subsp. *crispa* (Dryand. *ex* Aiton) Turrill *ex* Aiton		x				*x*
Alnus incana (L.) Moench subsp. *rugosa* (DuRoi) R.T. Clausen				x	x	*x*
Betula cordifolia Regel						*x*
Betula glandulosa Michx.		x				*x*
Betula papyrifera Marshall		x			x	*x*

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Betula pumila L. var. *pumila*	syn. *Betula borealis* Spach. (MTD)	x				*x*
Brassicaceae (Cruciferae) (Mustard)	*Arabis alpina* L. subsp. *alpina*	x	x			
Barbarea orthoceras Ledeb.						*x*
Cardamine pratensis L. var. *angustifolia* Hook.						*x*
Rorippa palustris (L.) Besser	*syn. Rorippa islandica (Oeder) Borb·s var. Fernaldiana*	x				*x*
Caprifoliaceae (Honeysuckle) (excluding Adoxaceae)						
Linnaea borealis L. subsp. *americana* (J. Forbes) Hultén					x	*x*
Lonicera villosa (Michx.) Roem. & J.A. Schult.						*x*
Caryophyllaceae (Pink)						
Sagina nodosa (L.) Fenzl subsp. *borealis* G.E. Crow		x				*x*
Lychnis alpina L.var. *american* Fernald						*x*
Stellaria borealis Bigelow subsp. *borealis*						*x*
Stellaria crassifolia Ehrh. var. *crassifolia*						*x*
Cornaceae (Dogwood)						
Cornus canadensis L.						*x*
Cornus stolonifera Michx.		x			x	*x*
Elaeagnaceae (Oleaster)						
Shepherdia canadensis (L.) Nutt.						*x*
Ericaceae (Heath)						
c.f. *Andromeda polifolia* L						x
Chamaedaphne calyculata (L.) Moench		x				*x*
Empetrum nigrum L. subsp. *nigrum*						*x*

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Gaultheria hispidula (L.) Muhl. *ex* Bigelow						*x*
Kalmia polifolia Wangenh.						*x*
Moneses uniflora (L.) A. Gray		x				*x*
Orthilia secunda (L.) House						*x*
Pyrola asarifolia Michx. subsp. *asarifolia*						*x*
Pyrola minor L.					x	*x*
Rhododendron groenlandicum (Oeder) Kron & Judd					x	*x*
Vaccinium angustifolium Aiton						*x*
Vaccinium cf. cespitosum Michx. var. cespitosum						*x*
Vaccinium myrtilloides Michx. *non* Hook						*x*
Vaccinium c.f *ovalifolium* Smith						*x*
Vaccinium uliginosum L.		x				*x*
Vaccinium vitis-idaea L. subsp. *minus* (Lodd.) Hultén		x				*x*
Fabaceae (Pea)						
Astragalus cf. *robinsii* (Oakes) A. Gray						*x*
i Trifolium aureum Pollich						*x*
i Trifolium hybridum L.						*x*
Grossulariaceae (Currant)						
Ribes glandulosum Grauer		x				*x*
Ribes lacustre Pers. (Poir)						*x*
Ribes triste Pallas						*x*
Lamiaceae (or Labiatae) (Mint)						
Lycopus uniflorus Michx.						*x*

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Mentha arvensis L. subsp. *borealis* (Michx.) Roy L. Taylor & MacBryde	*Mentha arvensis* L. (BH) var. *villosa* (Benth.) S.R. Stewart f. *glabrata* (Benth.) [field mint] (MTD)	x				*x*
	Prunella vulgaris L. var. *lanceolata* (Bart.) Fern. f. *iodocalyx* Fern. (MTD)	x				
cf. *Scutellaria galericulata* L	*Scutellaria epilobiifolia* A. Hamilton. syn. *S. galericulata* L. var. *pubescens* Benth. (MTD)	x				*x*
Lentibulariaceae (Bladderwort)						
	Pinguicula vulgaris L. [common butterwort]	x				
	Utricularia vulgaris L.	x				
Menyanthaceae (Buckbean)						
Menyanthes trifoliata L.		x	x			*x*
Myricaceae (Wax-Myrtle)						
Myrica gale L.		x			x	*x*
Nymphaeaceae (Waterlily)	*Nuphar variegatum* Engelm. [bullhead lily] (in a floodplain pond behind a dune MTD lower river)	x				
Onagraceae (Evening-Primrose)						
Chamerion angustifolium (L.) Holub		x			x	*x*
Chamerion latifolium (L.) Holub		x				*x*
Circaea alpina L. subsp. *alpina*						*x*
Epilobium ciliatum Raf. subsp. *glandulosum* (Lehm.) Hoch & P.H. Raven	syn. *Epilobium glandulosum* Lehm. var. *adenocaulon* (Haussk.) Fern. (GB1, MTD)	x	x			x
* *Epilobium* cf. *leptophyllum* Raf.						x
Epilobium palustre L.						*x*
Oxalidaceae (Oxalis)	*Oxalis acetosella* L. subsp. *montana* (Raf.) Hultén				x	

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Castilleja septentrionalis Lindl.						*x*
Papaveraceae (Poppy) (including Fumariaceae)	*Capnoides sempervirens* (L.) Borkh. [syn. *Corydalis sempervirens* (L.) Pers.] . [pale corydalis]	x				
Parnassiaceae (Grass-of-Parnassus)						
	Parnassia kotzebuei Cham. & Schlecht.		x			
	Parnassia parviflora DC.	x				
	Parnassia palustris L. var. *neogaca* Fern.	x				
Plantaginaceae (Antirrhinaceae) (Snapdragon) (including the Callitrichaceae, Hippuridaceae, and non-hemiparasitic genera of the former Scrophulariaceae).						
Callitriche verna L. *emend.* Kutz						*x*
Hippuris vulgaris L.		x				*x*
Veronica scutellata L.	*Veronica scutellata* (L.) [marsh speedwell, skullcap speedwell]	x				*x*
Polygonaceae (Buckwheat)	*Persicaria vivipara (L.) Ronse-Decr.* syn. *Polygonum viviparum* L. [alpine bistort]	x	x			
Primulaceae (Primrose)						
Lysimachia c.f. *thyrsiflora* L.						*x*
Trientalis borealis Raf. subsp. *borealis*						*x*
Ranunculaceae (Buttercup or Crowfoot)						
Actaea rubra (Aiton) Willd. subsp. *rubra*						*x*
Coptis trifolia (L.) Salisb.	[syn. Coptis groenlandica (Oeder) Fernald]	x	x			x
Ranunculus abortivus L.	*Ranunculus abortivus* L. var. *acrolasius* Fern. [small-flowered buttercup] (MTD)	x				*x*

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Ranunculus aquatilis L. var. *diffusus* With.	*Ranunculus trichophyllus Chaix var. eradicatus (Laestad.) W.B. Drew (MTD) syn. Ranunculus aquatilis L. var. eradicatus Laest.*	x				*x*
Ranunculus flammula L.var. *reptans* (L.) E. Meyer	*Ranunculus reptans* L.	x				*x*
Ranunculus cf. *pennsylvanicus* L.f [P.C.] or *R.macounii* Britton						*x*
Thalictrum pubescens Pursh var. *pubescens*	*Thalictrum polygamum Muhl.* [meadow rue] (MTD), *Thalictrum* sp. [meadow rue] (BH)	x			x	*x*
Rosaceae (Rose)						
Amelanchier bartramiana (Tausch) M. Roem		x				*x*
Comarum palustre L.	*Potentilla palustris* L. [marsh fivefinger, marsh cinquefoil] (BH, DB, MTD)	x		x	x	*x*
Fragaria virginiana Mill. subsp. *glauca* (S.Watson) Staudt						*x*
Potentilla norvegica L. subsp. *monspeliensis* (L.) Asch. & Graebn.						*x*
	Potentilla tridentata Ait. [three-toothed cinqfoil] (MTD)	x				
Prunus pensylvanica L.f. var. *pensylvanica*		x				*x*
	Rubus arcticus L. subsp. acaulis (Michx.) Focke syn. [*Rubus acaulis Michx.]*	x				
Rubus chamaemorus L.					x	*x*
Rubus idaeus L. subsp. strigosus (Michx.) Focke	*Rubus ideas* L. var. *canadensis* Richards (MTD)	x				*x*

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Rubus pubescens Raf.		x	x		x	*x*
Sanguisorba canadensis L. subsp. *canadensis*		x	x	x	x	*x*
Sibbaldiopsis tridentata (Solander) Rydb. [syn. *Potentilla tridentata*]						*x*
* Sorbus cf. americana Marsh						x
Sorbus decora (Sarg.) C.K. Schneid.	*Sorbus decora* (Sargent) Schneider (BH) syn. *Pyrus decora* (Sargent) Hyland var. *groenlandica* (MTD)	x			x	*x*
Rubiaceae (Madder)						
	Galium boreale L. [northern bedstraw] (BH) (likely *G. labradoricum*)				x	
Galium labradoricum (Wiegand) Wiegand						x
Galium trifidum L. subsp. *trifidum*		x				*x*
Galium triflorum Michx.		x			x	*x*
Galium sp. [P.C.]						*x*
Salicaceae (Willow)						
Populus balsamifera L. subsp. *balsamifera*		x			x	*x*
Populus tremuloides Michx.		x			x	*x*
Salix cf. arctica Pallas						*x*
Salix cf. arctophila Cockerell ex A. Heller		x	x			*x*
	Salix argyrocarpa Andersson Labrador willow, silver willow; Fr: saule argenté. Boreal-subarctic eNA; nwNfld., N to nLab. (Bowdoin Harbour); snowbeds.	x				
Salix bebbiana Sarg.		x				x
Salix cordata Michx.						*x*

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Salix discolor Muhl.						*x*
Salix humilis Marshall var. *humilis*	*Salix humilis* Marsh. var. *keweenawensis* Farw.	x				*x*
Salix lucida Muhl. subsp. *lucida*	*Salix lucida* Muhl. var. *angustifolia* Anderss.	x				*x*
	Salix glauca L. var. callicarpaea (Trautv.) Argus syn. *Salix cordifolia* Pursh var. *callicarpaea* (Trautv.) Fern. (MTD)	x				
	Salix pedunculata Fernald (DB, otherwise only reported for Newfoundland)			x		
Salix pellita Andersson		x				*x*
Salix planifolia Pursh						*x*
Salix pyrifolia Andersson		x			x	*x*
	Salix vestita Pursh var. *erecta* Anderss.	x				
Sapindaceae (Soapberry) (including Aceraceae, Hippocastanaceae)	*Acer spicatum* Lam. [mountain maple] (MTD)	x				
Saxifragaceae						
Mitella nuda L.		x	x			*x*
	Saxifraga aizoides L. (MTD)	x				
Violaceae (Violet)						
Viola macloskeyi F.E. Lloyd subsp. *pallens* (Banks ex Ging.) M.S. Baker		x		x		*x*
	Viola labradorica Schrank syn. Viola adunca Sm var. minor (Hook.) Fern. syn. V. labradorica Schrank [hook-spur violet] (MTD)	x				
Viola renifolia A. Gray					x	*x*