INFORMATION RESPONSES
LOWER CHURCHILL PROJECT
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JOINT REVIEW PANEL

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IR# JRP.45 to JRP.75

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IR# JRP.45

The La Grande Hydroelectric Development as a Predictor of Future Reservoir Conditions within the Lower Churchill River

Requesting Organization – Joint Review Panel **Information Request No.: JRP.45**

Subject – The La Grande hydroelectric development as a predictor of future reservoir conditions within the Lower Churchill River.

References:

EIS Guidelines Section 4.4.5 (Component Studies)

EIS Volume IIA, Section 4.0 (Environmental Effects Assessment — Aquatic Environment)

AMEC Earth & Environmental Ltd. & Sikumiut Environmental Management Ltd. 2007. *Lower Churchill Hydroelectric Generation Project Habitat Quantification*. Prepared for Newfoundland and Labrador Hydro, St. John's, NL

Related Comments / Information Requests:

CEAR # 170 (Fisheries and Oceans Canada)

Rationale:

Section 4.4.5 of the EIS Guidelines requires that study methodology and outputs be sufficient to adequately predict the effects on the VECs. DFO has indicated that studies and conclusions based on experiences from the La Grande hydroelectric development are not sufficient to determine impacts on fish and fish habitat and make predictions regarding future reservoir conditions in the Lower Churchill.

The Fish Habitat Quantification report (study 3) (page 93, Section 5.1.6; pages 94-95, Section 5.1.7) explicitly states that the La Grande Hydroelectric Complex (and in particular the Robert Bourassa Reservoir) is used as the main source of information on which to base predictions of future, reservoir conditions for the Lower Churchill. It is not appropriate to rely only on the La Grande complex to make predictions about the Lower Churchill because of significant differences in morphology (i.e., flooded area, shoreline characteristics, surrounding vegetation, etc.), site preparation strategies, reservoir characteristics (i.e., flushing rate) and operating regimes.

Requesting Organization – Joint Review Panel **Information Request No.: JRP.45**

Information Requested:

The Proponent is asked to justify predictions about future fish habitat in the Lower Churchill reservoirs, incorporating information from other large temperate reservoirs that have similar morphological features and flushing rates to those of the Lower Churchill, such as the Williston Reservoir.

Response:

The Existing Environment and Environmental Effects Assessment – Aquatic Environment (Volume IIA, Chapters 2 & 4 respectively) discusses trends documented from existing reservoir developments relatively close to and with similar climates and geologic provinces as the proposed Project. The primary reservoirs that were discussed were the Upper Churchill Development and the La Grande Hydroelectric Development in Quebec (i.e. Robert Bourassa and Caniapisau reservoirs). The information was used to expand our existing knowledge of potential reservoir effects; however, the effect predictions for each aquatic measurable parameter was based on information from the lower Churchill River and not adjusted due to any effects recorded in other reservoirs. The knowledge gained from a review of other existing projects was consistent with the information used to make the effects predictions for the Lower Churchill Project.

The reservoirs that were used in discussions of existing knowledge were all from similar geographic, geologic and climate as that of the proposed Project. While all have much greater drawdowns (at least double) and limited clearing, they provide a conservative estimate of potential effects related to primary production (e.g., phytoplankton, zooplankton). While Williston reservoir is similar in size to the Hydro Quebec reservoirs, it was outside the geographic, geologic and climate zones of the proposed reservoir, and therefore not referenced.

A summary of physical characteristics and recorded trends in various parameters for reservoirs is provided below. Table 1 provides a summary of the physical characteristics and Table 2 a summary of recorded aquatic effects due to reservoir formation.

Table 1 Comparison of Large Reservoirs

Reservoir	Date Impounded	Flooded Area (km^2)	Total Area (km^2)	Maximum Depth (m)	Mean Depth (m)	Flood Level (elevation m asl)	Maximum Drawdown (m)	Water Residence Time	Flow Rate ($m^3 s^{-1}$)	Vegetation Type Flooded	Flood Area Clearing	Trophic Level	Geologic Province
Proposed Gull Island Reservoir	**---**	**85**	**200**	**206**	**21**	**127**	**3.0**	**28 days**	**1780**	**Taiga, bog, coniferous forest**	**Clearing of 3m above max. flood level to 3m below min. flood level**	**Oligotrophic**	**Precambrian Shield**
Proposed Muskrat Falls Reservoir	**---**	**41**	**107**	**69**	**12**	**39**	**0.5**	**10 Days**	**1840**	**Taiga, bog, coniferous forest**	**Clearing of 3m above max. flood level to 3m below min. flood level**	**Oligotrophic**	**Precambrian Shield**
Williston Lake, British Columbia	1968-1973	1430	1773	166	41.7	671	11	26.4 months	550-1500	Forest	Minimal	Oligotrophic	Cordillera
Cat Arm Reservoir, Newfoundland	1984	51.3	52.4	58	18	393	7.3	18 months	20	Boreal forest, fen and bog	None	Oligotrophic	Precambrian Shield
Robert-Bourassa (LG-2), Quebec*	1979-1981	2630	2815	---	22.0	175	7.7	6.9 months	~3400	Taiga, Boreal Forest	None	---	Precambrian Shield
Smallwood Reservoir, Labrador*	1971	~2590	6650	25.9	8.1	471	8.5	---	---	Taiga, bog, spruce forest	None	---	Precambrian Shield
Caniapiscau Reservoir, Quebec*	1985	~3400	4318	49	16.8	535	12	25.8 months	---	Scattered coniferous forest, peat bogs	---	---	Precambrian Shield
Arrow Lakes, British Columbia	1967	---	465	287	~80	432	---	3-7.6 months	1390-1490	---	---	Ultra-Oligotrophic	Cordillera
Southern Indian Lake, Manitoba	1976	414	2391	30	9.8	254	---	11 days-33.6 months	1011	---	---	---	Precambrian Shield
Libby Reservoir, Montana	1972	---	188	46.9	---	749.5	34.2	---	868	Coniferous Forest	---	---	Precambrian Shield

*Examples used in the EIS
--- indicates no data/report for reservoir parameter

Table 2 Trends as documented in North American Reservoirs

Reservoir	Date Impounded	Peak Level Timing			Peak Mercury Levels	Return to Baseline	
		Mercury Concentrations	Primary Productivity	Zooplankton Biomass		Mercury Concentrations	Primary Productivity
Robert Bourassa (La Grande 2), Quebec	1979-1981	Piscivorous – 9 years post-impoundment (Verdon *et al.* 1991) Non-piscivorous – 5 years post-impoundment (Verdon *et al.* 1991)	5 years post-impoundment (Verdon *et al.* 1991)	4 years post-impoundment (Verdon *et al.* 1991)	Piscivorous - ~5x (Verdon *et al.* 1991) Non-piscivorous - ~4x (Verdon *et al.* 1991)	Piscivorous[1] – 20-30 years post-impoundment (Verdon *et al.* 1991) Non-piscivorous[1] – decline noticed after 5 years post-impoundment (Verdon *et al.* 1991)	---
Smallwood Reservoir, Labrador	1971	---	Seasonal pattern changes (unimodal to dimodal), large seasonal diatom blooms reaching ~2x baseline biomass (Campbell *et al.* 1998)	Increase in grazing species due to increased primary production (Campbell *et al.* 1998)	Piscivorous – 2.3x (Anderson *et al.* 1995) Non-piscivorous – 3.2x (Anderson *et al.* 1995)	Piscivorous – 21+ years; estimated return 30 years (Anderson *et al.* 1995) Non-piscivorous – ~16 years; estimated return 20 years (Anderson *et al.* 1995)	---
Southern Indian Lake, Manitoba	1976	Piscivorous – 4-5 years post-impoundment (Hecky *et al.* 1984) Non-piscivorous – 2 years post-impoundment (Hecky *et al.* 1984)	Primary production increased steadily throughout most of lake until 2 year post-impoundment (Hecky *et al.* 1984)	Zooplankton biomass decreased by 30-40% post-impoundment (Hecky *et al.* 1984)	Piscivorous – 6x (Hecky *et al.* 1984) Non-piscivorous – ~4.5x (Hecky *et al.* 1984)	Piscivorous – no decline by 1984 (8 years post-impoundment) (Hecky *et al.* 1984) Non-piscivorous – decline in 2-6 year sampling (Hecky *et al.* 1984)	---
Cat Arm Reservoir, Newfoundland	1984	---	4 years post-impoundment (Campbell *et al.* 1998)	Immediately following impoundment (Campbell *et al.* 1998)	---	Arctic char [Hg] showed decline at 9 years post-impoundment, estimated baseline return at 15 years (Campbell *et al.* 1998)	---
Williston Lake, British Columbia	1968-1973	---	Production 'boom' 5-10 years post-impoundment (Stockner *et al.* 2005)	---	Consumption advisory issued for bull trout due to elevated mercury levels, still in effect as of 1999 (Hill and Baker 1999)	---	Phosphorus became limiting 15-25 years post-impoundment (Stockner *et al.* 2005)

--- indicates no data/report for reservoir parameter
[1] - Piscivorous fish are those that consume other fish. Non-piscivorous fish do not consume other fish.

References:

Anderson, M.R., D.A. Scruton, U.P. Williams, and J.F. Payne. 1995. Mercury in fish in the Smallwood Reservoir, Labrador, twenty one years after impoundment. Water, Air and Soil Pollution. 80:927-930

Campbell, C.E., R. Knoechel, and D. Copeman. 1998. Evaluation of factors related to increased zooplankton biomass and altered species composition following impoundment of a Newfoundland reservoir. Canadian Journal of Fisheries and Aquatic Sciences. 55:230-238

Hecky, R.E., R.W. Newbury, R.A. Bodaly, K. Patalas. And D.M. Rosenberg. 1984. Environmental impact prediction and assessment: the Southern Indian lake experience. Canadian journal of Fisheries and Aquatic Sciences. 41: 720-732

Hill, E. and R. Baker. 1999. 1999 status of mercury studies in British Columbia. 1999 Mercury Workshop, St. John's NL. Hosted by; Labrador Hydro Project, Newfoundland and Labrador Hydro, and Department of Fisheries and Oceans.

Stockner, J., A. Langston, D. Sebastian, and G. Wilson. 2005. The Limnology of Williston Reservoir: British Columbia's largest lacustrine ecosystem. Water Quality Research Journal. 40:28-50

Verdon, R., D. Brouard, C. Demers, R. Lalumiere, M. Laperle, and R. Schetange. 1991. Mercury evolution (1978-1988) in fishes of the La Grande hydroelectric complex, Quebec, Canada. Water, Air and Soil Pollution. 56: 405-417

IR# JRP.46

Changes in Regional Climate

Requesting Organization – Joint Review Panel **Information Request No.: JRP.46**

Subject - Changes in Regional Climate

References:

EIS Guidelines, Section 4.4.4.1 (Atmospheric Environment)

EIS Volume IA, Section 5.2.1 (Climate)

EIS Volume IIA, Section 2.2.4 (Recent Climate Conditions)

Minaskuat Inc. 2008. *Project Area Ecological Land Classification*. Prepared for the Lower Churchill Hydroelectric Generation Project

Related Comments / Information Requests:

CEAR # 184 (Sierra Club Atlantic)

IRs # JRP.7, 27, 85, 99, 100

Rationale:

The EIS states that because of the generally east-west orientation of the Churchill River valley, the topographic features influence the microclimate, particularly at lower elevations. It goes on to explain that the valley exhibits a boreal eco-climatic regime, in contrast to the taiga (sub-Arctic) regime at **higher elevations** within the same watershed (emphasis added). No further information on the effect of the newly created reservoir on microclimate, regional climate or the effect of elevation on the re-establishment of inundated ecotypes is provided.

Requesting Organization – Joint Review Panel **Information Request No.: JRP.46**

Information Requested:

The Proponent is asked to provide:

a. a description of the elevation at which boreal ecozone transitions into taiga ecozone in the Churchill River valley;

Response:

While changes in elevation and latitude affect climate and play a role in defining ecozones, there is no standard elevation that delineates the boundary between the boreal and taiga ecozones in Labrador. Boundaries between ecozones/ecoregions should be considered transitional, rather than rigid lines between adjacent zones/regions. The Boreal Shield Ecozone in Labrador delineates the coastal plain of Hamilton Inlet and valleys of the Churchill, Kenamu, and Naskaupi Rivers, surrounded by the Taiga Shield Ecozone (Environment Canada 2005). The Boreal Shield Ecozone in central Labrador is based on the boundaries of the High Boreal Forest - Lake Melville Ecoregion (Meades 1990), as well as the Perhumid High Boreal Ecoclimatic Region (Ecoregions Working Group 1989) and the Lake Melville Land Region (Lopoukhine et al. 1978). In these publications, the regions are described based on topography, climate, and vegetation (mainly closed-crown, productive forests); no standard elevations are provided as indicators of regional borders.

Since the land base of Labrador is a tilted plateau, highest in the southwest and sloping to the east coast (Lopoukhine et al. 1978), the average elevation of the Boreal Shield Ecozone boundary changes along the east-west length of the ecozone. In the western end of this ecozone, the Winokapau Lake national topographic mapsheet (13E, 1:250,000) shows the 1,300 ft. contour line to correspond approximately with the boundary between the boreal and taiga ecozones, basically the divide between the river valley and higher plateau regions. Near the southern extension of this ecozone, the 1,000 ft. contour line on the Minipi Lake mapsheet (13C) corresponds approximately with the boundary between the boreal and taiga ecozones. At the mouth of the Churchill River, the 300 to 500 ft. contour lines on the Goose Bay mapsheet (13F) correspond approximately with the border between the boreal and taiga ecozones. At the ends of each river valley located within the Boreal Shield Ecozone, the boundary between boreal and taiga ecozones cuts across all contour lines.

References:

Environment Canada. 2005. Ecozones of Canada. Environment Canada, Gatineau, Quebec. [Last updated: 2005-04-11] <http://www.ec.gc.ca/soer-ree/english/ecozones.cfm>

Ecoregions Working Group. 1989. Ecoclimatic Regions of Canada, first approximation. Ecological Land Classification Series, No. 23. Sustainable Development Branch, Canadian Wildlife Service, Conservation and Protection, Environment Canada, Ottawa, Ontario. [118 pp. + map at 1:7.5 million scale].

Lopoukhine, N., N.A. Prout, H.E.Hirvonen. 1978. Ecological Land Classification of Labrador, First Approximation. Ecological Land Classification Series, No. 4. Lands Directorate, Environmental Management Service, Fisheries and Environment Canada, Halifax, NS. [85 pp. + map at 1:1 million scale].

Meades, W.J. 1990. Ecoregions of Labrador: in S.J. Meades. 1990. Natural Regions of Newfoundland and Labrador; pp. 251-321. Protected Areas Association, St. John's, Newfoundland. 374pp. + 101 pp. map appendix.

Requesting Organization – Joint Review Panel **Information Request No.: JRP.46**

Information Requested:

The Proponent is asked to provide:

b. a discussion of any anticipated changes to microclimate (such as precipitation, wind strength and direction, temperature) that might occur as a result of reservoir formation;

Response:

Large lakes and reservoirs are known to have an effect on microclimate, as was illustrated in a study conducted on the Robert-Bourassa Reservoir in Québec (Bégin et al. 1998). The observed effects at this reservoir included a small change in spring thermal conditions, cooler temperatures in the early summer months and slightly warmer fall temperatures (Hydro-Québec 2006). However, it was concluded that these thermal effects had a small effect on the area and were limited to the immediate periphery of the reservoir (Hydro-Québec 2006). Given the surface area of the Robert-Bourassa Reservoir is 2,835 km^2 (Hydro-Québec n.d.), which is approximately 13 and 28 times larger than the Gull Island and Muskrat Falls reservoirs respectively, it is anticipated that the potential microclimatic changes for this Project will be less than that observed for this larger reservoir. Further to this, even if the effects are measureable, the zone of influence rarely encompasses more than 20 km for a 1,000 km^2 body of water (Hydro-Québec 2001). Also, refer to IR# JRP.36 that concluded the formation of the reservoirs would at most cause light breezes on normally calm days but would not alter the frequency, direction or force of wind conditions.

References:

Bégin,Y., L. Sirois, L. Cournoyer and J. Frydecki. 1998. Analyse dendroécologique des effets climatiques du réservoir Robert-Bourassa sur l'environnement forestier, Québec nordique, Centre d'études nordiques, Université Laval pour Hydro-Québec, 125 pp *In* Hydro-Québec. 2006. Hydro-Québec, Complexe de La Romaine; Étude d'impact sur l'environnement. Submitted December 2006.

Hydro-Québec. n.d. Robert-Bourassa Generating Station. Accessed on July 23, 2009 from http://www.hydroquebec.com/generation/hydroelectric/la_grande/robert_bourassa/index.html

Hydro-Québec. 2001. Impacts of Hydroelectric Development: Thoughts, Conclusions and Lessons Learned *In* Summary of Knowledge Acquired in Northern Environments from 1970 to 2000. Accessed on July 23, 2009 from http://www.hydroquebec.com/sustainable-development/documentation/pdf/autres/pop_06_05.pdf

Hydro-Québec. 2006. Hydro-Québec, Complexe de La Romaine; Étude d'impact sur l'environnement. Submitted December 2006

Requesting Organization – Joint Review Panel **Information Request No.: JRP.46**

Information Requested:

The Proponent is asked to provide:

c. a discussion of any elevation and/or microclimate restrictions that would prohibit the reestablishment or continued survival of specific ecotypes after inundation; and

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Response:

Given the limited change in elevation (< 100 m) from the existing shoreline to that of the proposed reservoirs, microlimatic conditions will be similar and are not expected to affect reestablishment of ecotypes that would be inundated. A more important determinant of the ecotypes that would form along the shoreline of the reservoirs will be local soil conditions.

Of the ecotypes described for the Lower Churchill Hydroelectric Generation EIS, only the fluvial ecotypes (Gravel Bars (GB), Riparian Thicket (RT), Riparian Meadow (RM), and Marsh (MA)) within the flood zone will be completely inundated. Since soil erosion and the transport and deposition of gravels, sands and silt, which produced the present gravel bars and river deltas, will continue to occur after inundation, suitable new gravel bars will eventually develop within the flood zone. Once sand gravel bars and deltas re-emerge, new riparian thickets, dominated by alder and willow species, and riparian meadows and marshes, dominated by herbaceous species, will gradually re-establish via seeds/vegetative shoots from adjacent non-inundated populations of the same ecotype. Proximity to flowing water and the presence of a suitable substrate (gravel or sand bars and silty deltas), not elevation, promote the development and re-establishment of fluvial ecotypes.

Fens and Low Shrub bogs that are located in low-elevation areas, such as old slumps, will also be inundated. But as the water level rises, new slumps will likely occur in areas where sands overlie marine clays. These areas will eventually be revegetated with wetland species, as impeded drainage from the underlying clays will promote wetland formation rather than establishment of forest stands.

A temporary increase in Anthropogenic/Disturbed [AN] and Unvegetated (UV) ecotypes is expected following inundation, but once the disturbance has ended, these pioneer successional sites will gradually become vegetated. The resulting ecotypes will depend upon topography, soil type and conditions, and adjacent vegetation.

Since Hardwood Forest (HA) stands dominate in areas where natural disturbance has occurred (edges of slumps, landslides, old blowouts), it is anticipated that new hardwood stands will establish in areas where erosion and slumping occurs due to rising water levels. Hardwood stands are successional stages to conifer forest, so provided disturbance is not continual, many of these stands will eventually succeed to one of the conifer forest ecotypes.

Black Spruce/Lichen Woodland (BL) stands in the lower Churchill River valley are caused by edaphic conditions (well-drained sandy soils, low water table, exposure to repeated burns), rather than climatic factors, which control the distribution of lichen woodland in the Taiga Shield Ecozone. Areas with sandy soils, particularly river terraces along the Churchill River, are dominated by lichen woodland due to their well-drained soils and are maintained through fire; these river terraces will not be inundated by the flooding.

Portions of other forest ecotypes that lie within the flood zone will be inundated and a marginal zone of fluvial ecotypes will likely replace these forest types along the new river margin due to an increase in the water table. Generally, after the disturbance has ended and the habitats have time to stabilize, all ecotypes, forest, riparian, and wetland, will re-establish.

Requesting Organization – Joint Review Panel **Information Request No.: JRP.46**

Information Requested:

The Proponent is asked to provide:

d. a discussion of overall changes to regional climate patterns.

Response:

Similar to large natural lakes, reservoirs affect climate only in their general vicinity and this zone of influence rarely encompasses more than 20 km for a 1,000 km^2 body of water (Hydro-Québec 2001). Given that the Gull Island and Muskrat Falls Reservoirs together represent a total of 315 km^2 at an assumed full supply level, it is logical to expect the formation of these reservoirs would at worst a small negligible effect on climate, and that would be restricted to within a few kilometres of the reservoirs. Further to this, it has been concluded that flow regulation related to hydroelectric development in Atlantic Canada has little to no effect on the North Atlantic climate. In fact, according to Hydro-Québec (2001); "scientific data on reservoirs' effect on climate are sufficiently accurate and reliable for this phenomenon (reservoirs having an effect on North Atlantic climate) to no longer be considered an issue in northern Québec and comparable environments". As a result, there are likely to be no changes to regional climate patterns anticipated as a result of reservoir formation associated with the Lower Churchill Hydroelectric Generation Project.

Reference:

Hydro-Québec. 2001. Impacts of Hydroelectric Development: Thoughts, Conclusions and Lessons Learned In Summary of Knowledge Acquired in Northern Environments from 1970 to 2000. Accessed on July 23, 2009 from http://www.hydroquebec.com/sustainable-development/documentation/pdf/autres/pop_06_05.pdf.

IR# JRP.47

Abundance of Aquatic and Terrestrial Groups

Requesting Organization – Joint Review Panel **Information Request No.: JRP.47**

Subject - Abundance of Aquatic and Terrestrial Groups

References:

EIS Guidelines, Section 4.4.4.2 (Aquatic Environment), Section 4.4.4.3 (Terrestrial Environment), Section 4.4.6 (Data Gaps)

EIS Volume IA, Section 9.0 (Environmental Assessment Approach and Methods)

EIS Volume IIA, Section 2.3.3. (The Lower Churchill River)

Related Comments / Information Requests:

CEAR # 205 (Government of Newfoundland and Labrador – Water Resources Management Division)

Rationale:

In several VECs the guidelines specify that the Proponent is to consider the composition, abundance, distribution, population dynamics and habitat utilization of specific groups (i.e., terrestrial fauna, aquatic species, avifauna, and terrestrial flora) (emphasis added). With the exception of caribou and some avifauna (i.e., forest songbirds) the EIS does not provide information on the abundance of specific key indicator species. With the exception of moose/wolf/caribou interactions little information is provided on population dynamics of those species. Neither the lack of abundance data nor the lack of population dynamics is presented as data gaps. While the EIS provides some discussion as to the range of particular species, it does not clearly indicate where species are on the edge of their range, which often has important implications for productivity and reproduction of the species.

Requesting Organization – Joint Review Panel **Information Request No.: JRP.47**

Information Requested:

The Proponent is asked to provide:

a. **information on the abundance (population estimates) and population dynamics of all species examined in the EIS;**

Response:

A consideration of the population dynamics for various KIs is provided in the context of the discussion of the existing environment. For the Aquatic Environment VEC, information on population dynamics and life history characteristics for fish species considered in the EIS are presented in Volume IIA, Section 2.3 of the EIS as well as in Report 3 of the Aquatic Environment Component studies (AMEC and Sikumiut 2007). IR# JRP.49S also provides additional information regarding fish population estimates and the habitat-based approach used in the EIS. A description of the population for each Key Indicator species comprising the Terrestrial VEC is presented in Volume IIA, Section 2.4 of the EIS. Additional information can be found in the Terrestrial Environment Component Studies and various environmental baseline reports related to the Terrestrial Environment, which supported the EIS.

Consideration of the baseline conditions of each VEC or KI is included in the evaluation of the potential environmental effects (see Volume IA, Section 9.5.1 of the EIS) and ultimately in the determination of significance of environmental effects of the Project on the Aquatic and Terrestrial Environments.

Reference:

AMEC Earth and Environmental Ltd. and Sikumiut Environmental Management Ltd. 2007. Lower Churchill Hydroelectric Generation Project Habitat Quantification. Prepared for Newfoundland and Labrador Hydro, St. John’s, NL. viii + 129 pp. + Appendices

Requesting Organization – Joint Review Panel **Information Request No.: JRP.47**

Information Requested:

The Proponent is asked to provide:

b. **the reasons and an explanation as to how this gap was taken into account when determining if a population was sustainable, where populations estimates cannot be provided; and**

Response:

As discussed in other responses (IR# JRP.116, IR# JRP.123, IR# JRP.126), a habitat-based approach was used during this assessment to determine the significance of potential environmental effects on Terrestrial Environment KIs. Given the nature of the Project a habitat-based approach is appropriate.

The issue of sustainability of populations is addressed in Volume IIB, Section 7.4.2.1 of the EIS wherein it is described, based on the analysis, that the sustainability of populations of Aquatic or Terrestrial VECs will not be compromised.

Requesting Organization – Joint Review Panel **Information Request No.: JRP.47**

Information Requested:

The Proponent is asked to provide:

c. a discussion of which species are at their range edge and how this affects population estimates, as well as significance determinations that are based on maintaining a "sustainable" population.

Response:

Information on the distribution of terrestrial species is provided under the discussion of existing conditions for each VEC/KI. The populations of species at the edge of their range will be variable depending on whether their range is decreasing or increasing as well as species-specific variables. As noted previously, the determination of significance of potential environmental effects is made with consideration of the measurable parameters which, for most Terrestrial Environment KIs, includes consideration of changes in habitat.

IR# JRP.48

Ashkui

Requesting Organization – Joint Review Panel **Information Request No.: JRP.48**

Subject - Ashkui

References:

EIS Volume IIB, Section 5.11.2.2 (Change in habitat during operation and maintenance – Ice conditions and ashkui).

Hatch Ltd. 2008. *Further Clarification and Updating of the 2007 Ice Dynamics* Report. Prepared for Newfoundland and Labrador Hydro, St. John's, NL.

Related Comments / Information Requests:

CEAR # 173 (Environment Canada)
CEAR # 174 (V. Kerby)

Rationale:

The EIS states that "ashkui (such as that which occurs at the confluences of the Metchin River, Elizabeth River, Upper Brook and Lower Brook) will move upstream into the tributary at the interface with the new shoreline (…). Topographic profiles indicate that these confluences will be at least as steep as under existing conditions, and therefore, continue to enhance ashkui formation." (Volume IIB, p. 5-62)

However, Hatch (2008) also states that "[w]hether or not an ashkui will form at a particular location as well as the size of the ashkui is difficult to predict" (p. 3-1).

Furthermore, Hatch (2008) states that "[t]he total area of open water in the post-project conditions is expected to be less than a few kilometres, depending on the size and number of ashkui and the climate condition of the winter (…) There is no model available at this time to predict when an ice cover will form on a reservoir" (p. 3-8)

Ashkui are identified in the EIS as areas of importance for Innu hunting, fishing and trapping.

Requesting Organization – Joint Review Panel **Information Request No.: JRP.48**

Information Requested:

The Proponent is asked to describe:

a. **the biophysical features that make existing ashkui important areas for hunting, fishing and trapping;**

Response:

Ashkui are areas of water that tend to remain open year-round, thereby providing "abundant food and habitat both in and out of water" (M. Penashue, pers. com.). Such areas may exhibit relatively high levels of aquatic productivity that can extend to the surrounding riparian habitats. Ashkui sustain fish, plants and insects which sustain "wildlife such as otter (nitshik), mink (atshikash), geese (nishk), ducks (shishipit), muskrats (utshaskuit), rabbits (uapush), partridge (white and spruce) (uapinea and innineu), beaver (amishk), marten (uapistan), owls (ushu), fish hawks (kushumesheu), eagles (metshu), caribou (atiku), moose (mush), black bear (meusk), porcupine (kaku)" (M. Penashue, pers. com.).

As ashkui attract wildlife, they are logical places to support hunting. Hunting waterfowl at ashkui is common especially early in spring when these areas of open water offer easy access to food (in the water and near shore) for these birds. Larger wildlife such as caribou, moose, and black bear may use ashkui for crossings when the ice on the lakes is unsafe, thus during these periods, the areas can support hunting of such animals. Ashkui can provide good trapping areas for beaver, mink, marten and otter.

The Innu also use ashkui as a readily available source of drinking water or for fishing because of the relatively easy access for fishing gear.

The nearshore vegetation around ashkui can include tamarack or larch, a tree species that is favoured by the Innu for firewood as it produces the most heat.

Reference:

Penashue, M. Apprentice Innu Shaman, Resident of Sheshatshiu, NL.

Requesting Organization – Joint Review Panel **Information Request No.: JRP.48**

Information Requested:

The Proponent is asked to describe:

b. **future conditions at predicted new ashkui sites, including the conditions of the variables that Hatch (2008 p. 3-1) mentions are likely to influence the formation and size of ashkui;**

Response:

Conditions such as water temperature and velocity at new ashkui sites (that would occur at the deltas associated with tributaries) are predicted to be similar to those that are present at the current ashkui sites, resulting in the same open water conditions. The ashkui locations would change, moving further up the tributaries (Figures 5-4 to 5-7 in Volume IIB of the EIS). The limited information on the creation of ashkui led, in 1998, to the establishment of 'The Ashkui Project' with participation by Environment Canada, Innu Nation, the Gorsebrook Research Institute of Saint Mary's University and Natural Resources Canada. Environment Canada (2002) identified the need for further study of the relationship between the hydraulics, hydrology and morphology of water bodies. This insight was considered in the predicted future conditions at selected tributaries to the lower Churchill River in Volume IIB, Figures 5-4 to 5-7.

Based on observations of ashkui on the lower Churchill River, open water occurs in areas of turbulent flow, including at the confluence between tributaries and standing water bodies (reservoirs/lakes). The flowing water occurs at slightly elevated temperatures resulting in open water or reduced ice thickness in a limited zone at the receiving reservoir/lake. The raising of Lake Winokapau by formation of the Gull Island reservoir will move the location of these confluences to points upstream of their current locations. Given that in the post-Project case tributaries will still have higher velocities and higher temperatures than the receiving reservoir, there is confidence in the EIS prediction that ashkui will develop at these new confluences.

Existing ashkui on the lower Churchill River include areas at the confluence of the main stem and tributaries, where deltas are present; hence Hatch (2007) noted that these geologic conditions were 'probably influential' in ashkui formation.

It is notable that the timing, formation and ultimate size of ashkui varies annually as a result of weather variability. Increased air temperatures that could be the result of climate change would likely enhance the formation of ashkui during the operation and maintenance phase of the Project. This uncertainty was addressed by conservative assumptions such as acknowledging the presence of ashkui elsewhere in the lower Churchill River watershed and that the effects will be adaptively managed through the follow-up and monitoring program for waterfowl use of ashkui (Table 7-3 in Volume IIB).

References:

Environment Canada. 2002. The Ashkui Project: Understanding the Landscape of Labrador from Innu and Scientific Perspectives. Available at: http://www.atl.ec.gc.ca/conservation/ashkui_e.html.

Hatch Ltd. 2007. Ice Dynamics of the Lower Churchill River. Prepared for Newfoundland and Labrador Hydro. St. John's, NL.

Requesting Organization – Joint Review Panel **Information Request No.: JRP.48**

Information Requested:

The Proponent is asked to describe:

c. **the level of certainty associated with predictions that ashkui conditions would be restored at new sites;**

Response:

There is a high degree of confidence that ashkui will form at confluences with tributaries in the reservoirs. While, for example, there is a lower level of certainty associated with predicting the size of ashkui and their use by wildlife, appropriate monitoring will be incorporated into the Project Follow-up and Monitoring Program (refer to IR# JRP.112). Additionally, other areas of open water during spring are available in the lower Churchill River watershed and were considered during the completion of the EIS (refer to Figure 5-3 in Volume IIB).

Requesting Organization – Joint Review Panel **Information Request No.: JRP.48**

Information Requested:

The Proponent is asked to describe:

d. **whether predictions regarding post-project formation of ashkuis is based on prior experience elsewhere where re-establishment has proven to be successful. If so, provide details including a description of how prior experiences may compare and/or contrast with current Project conditions;**

Response:

The predictions regarding post-Project formation of ashkui are based on observations of their location and persistence along the lower Churchill River under existing conditions during the environmental baseline program. Similar thermal and hydraulic conditions will exist at the confluence of tributaries with the post-Project reservoirs as indicated in Figures 5-4 to 5-7 in Volume IIB of the EIS.

Requesting Organization – Joint Review Panel **Information Request No.: JRP.48**

Information Requested:

The Proponent is asked to describe:

e. if and how the Precautionary Principle was applied to predictions and significance assessment related to ashkuis for both the biophysical and human (socio-cultural) environments, in light of the apparent uncertainties in the component study regarding the post-project formation of ashkui (size, number and timing of formation);

Response:

The precautionary approach, as described in Volume IA, Section 9.12 of the EIS (and refer to IR# JRP.19), was applied with respect to the future conditions associated with ashkui in the lower Churchill River and the assessment of Project effects. Regardless of the understanding of conditions associated with ashkui (part (b)), a worst-case scenario was assumed that involved a minimal area of open water on the reservoirs during spring conditions. However, other areas of open water in spring exist elsewhere in the Assessment Area including in waterbodies adjacent to the lower Churchill River (Volume IIB, Figure 5-3 in the EIS). To address the lower level of certainty associated with the predictions related to the size and persistence of ashkui, Nalcor is proposing a follow-up plan, as indicated in Volume IIB, Table 7.3, which will be applicable to the waterfowl use of ashkui during the Project.

Requesting Organization – Joint Review Panel **Information Request No.: JRP.48**

Information Requested:

The Proponent is asked to describe:

f. **whether the maintenance of successful hunting, fishing and trapping conditions at new ashkui sites may require remediation and/or rehabilitation work to be conducted; and**

Response:

As indicated in Volume IIA, Section 4.10.2.4 of the EIS, reservoir preparation work will include site preparation at expected ashkui sites at tributary confluences (Volume IIB, Figures 5-4 to 5-7). Follow-up and Monitoring will evaluate waterfowl use of these new sites (Volume IIB, Table 7-3; IR# JRP.65). Ashkui will form at the deltas of tributaries but will move upstream to the new shoreline during operation and maintenance due to the increased velocity of flow and higher temperature of water compared to elsewhere in the reservoirs. Also Nalcor will implement mitigation measures to enhance fish habitat (and therefore ashkui formation) at selected deltas prior to inundation (refer to part (g) of this IR). Thus, any land-use activity that availed of ashkui at these confluences would still be able to pursue activities along the new shoreline as a result of this remediation work.

Requesting Organization – Joint Review Panel **Information Request No.: JRP.48**

Information Requested:

The Proponent is asked to describe:

g. **any mitigation and/or adaptive management measures that could be implemented in order to preserve the ecological and socio-cultural functions of ashkui, if monitoring and/or follow-up programs show that new ashkui areas do not form as expected or do not have the same characteristics.**

Response:

As indicated in Volume IIB, Section 5.11.2.2 of the EIS, characteristics of the Project (e.g., such as steeper inclines at tributaries along the shoreline of the reservoirs (Figures 5-4 to 5-7 in Volume IIB of the EIS)) including mitigation measures will create the conditions associated with ashkui formation. At tributary delta locations selected for fish habitat enhancement could have higher velocity conditions and adjustment of water depths in delta areas at confluence sites through landscaping (Volume IIA, Section 4.10.2.4). Nalcor has committed to conducting a follow-up program to confirm the extent and location of ashkui formation.

IR# JRP.49

Alteration, Disruption or Destruction of Fish Habitat

Requesting Organization – Joint Review Panel **Information Request No.: JRP.49**

Subject – Alteration, Disruption or Destruction of Fish Habitat

References:

EIS Guidelines, Section 4.2.4 (Relationship to Legislation, Permitting, Regulatory Agencies and Policies), Section 4.4.1 (Identification of Issues and Selection of Valued Environmental Components (VECs), Section 4.4.4 (Description of the Existing Environment)

EIS Volume IA, Sections 1.4 (Relationship to Legislation, Permitting, Regulatory Agencies and Policies), Section 6.4 Legislation, Regulations, Guidelines, Policies, Section 9.2 (Valued Ecosystem Component Selection) & Appendix IB-G

EIS Volume IIA, Sections 2.3.7 (Aquatic Environment - Lower Churchill River), Section 4.8.2 (Habitat Utilization)

Related Comments I Information Requests:

CEAR # 170 (Fisheries and Oceans Canada)
CEAR # 180 (D. Steele - Memorial University of Newfoundland, Natural History)
CEAR# 198 (G. Davis)
CEAR # 203 (Hydro-Quebec)
CEAR # 206 (K. Lethbridge)

IRs # JRP.23, 43, 50, 51, 52, 53, 54, 55, 56, 90

Rationale:

The EIS Guidelines (Section 4.2.4) require the Proponent to identify and discuss all relationships between the Project and relevant legislation, regulations and policies. The EIS does not adequately discuss the harmful alteration, disruption or destruction of fish habitat in relation to legislation and regulatory requirements or as a valued ecosystem component (VEC).

DFO has formally written Nalcor to the effect that alteration, destruction, or destruction of fish habitat would occur as a result of the proposed Project, and would require issuance of a subsection 35(2) *Fisheries Act* authorization. DFO has advised that approximately 33 hectares (ha) of fish habitat would be destroyed by the physical footprints of the Gull Island and Muskrat Falls dams arid associated facilities, and that 5,103 ha would potentially be harmfully altered as a result of inundation of existing habitat.

The EIS does not acknowledge this potentially harmful alteration of fish habitat and resultant loss in productive capacity. Rather, it focuses on the increase in wetted area within the newly formed reservoirs and concludes that this habitat will constitute a 'net gain' in productive capacity. The accuracy of this prediction is dependant on a number of factors, including the projected time for stabilization. DFO has expressed reservations regarding the predicted time to achieve reservoir stabilization and the impacts on fish species during this time period. They indicate there is a strong likelihood that fish and other biomass production may be impaired for a number of years after impoundment, particularly during the stabilization period and that the EIS does not adequately acknowledge this.

The EIS alludes to the fact that most existing habitat types will be represented post-impoundment; however, the relative proportions of these habitats will likely be drastically altered. These changes in habitat availability may result in the elimination of certain fish species, or may significantly affect their life processes.

Section 4.4.4 of the EIS Guidelines requires that qualitative and quantitative surveys be completed for each environmental component being impacted and that data be provided to help understand and interpret the impacts of the Project. The overviews provided for life history characteristics of various fish species contain limited information on habitat utilization in the area of the Churchill River to be impacted by the proposed development. This information is required in order to demonstrate how fish species occurring in the Churchill River will be able to carry out their life processes (including spawning, rearing, feeding, migration, and over-wintering) in the habitat types that will be available in the future reservoirs.

Requesting Organization – Joint Review Panel **Information Request No.: JRP.49**

Information Requested:

The Proponent is asked to provide:

- **a. a comprehensive discussion of the alteration, disruption, or destruction of fish habitat and its relation to productive capacity and relevant legislation; and**

Response:

The writing of the EIS and the ongoing submission of fish and fish habitat data to DFO was such that the final HADD determination was not received for incorporation to the EIS. The EIS did therefore focus on the data collected regarding the existing and post-Project utilization predictions, knowing that the destruction of fish habitat under the facility footprints would be included in any HADD determination. It did not speculate on any potential harmful alterations that DFO may also include in the determination. That being said, Nalcor fully acknowledges the determination subsequently provided by DFO. This HADD determination has been the focal point of the Fish Habitat Compensation planning process currently ongoing between Nalcor and DFO. At the request of DFO, the complete HADD determination is provided below as well as supporting text and clarification from DFO as taken from the Fish Habitat Compensation Strategy Framework (the Strategy Framework is appended to the response to IR# JRP.107):

The DFO determination identified a total of 5,135.91 hectares of fish habitat that will be harmfully altered or destroyed, summarized as follows:

- *Destruction of 26.03 ha or riverine fast velocity habitat resulting from the footprint of the Gull Island dam;*
- *Destruction of 7.30 ha of riverine fast velocity habitat resulting from the footprint of the Muskrat Falls dam;*
- *Harmful alteration of 1,264.06 ha of riverine intermediate velocity habitat within the Churchill River Main Stem due to inundation/reservoir creation;*
- *Harmful alteration of 3,549.65 ha of riverine fast velocity habitat within the Churchill River Main Stem due to inundation/reservoir creation;*
- *Harmful alteration of 30.07 ha of riverine intermediate velocity habitat within the Churchill River Tributaries due to inundation/reservoir creation;*
- *Harmful alteration of 19.97 ha of riverine fast velocity habitat within the Churchill River Tributaries due to inundation/reservoir creation;*
- *Harmful alteration of 25.85 ha of riverine habitat within streams of the Churchill River due to inundation/reservoir creation; and*
- *Harmful alteration of 212.98 ha of lacustrine littoral habitat within the Churchill River Main Stem due to inundation/reservoir creation.*

At the time of the determination, Hydro (now Nalcor Energy (Nalcor)) considered it to be excessive given the future habitat and utilization predictions of post-Project habitats. However, it is recognized that future predictions submitted to DFO were based on the information available, which did not include final model results of important post-reservoir parameters such as total suspended sediment (TSS), bank stability and nutrient loading, which were being completed at the time. Due to the remaining uncertainty of future habitat utilization within newly formed reservoirs, DFO considered any harmfully altered fish habitat (in this case, existing intermediate and fast velocity habitat within the footprint of the reservoirs to be created) to constitute the HADD of fish habitat. As such, DFO did not recognize the potential future use of the reservoir as a means of reducing the size of the HADD. While DFO recognizes that the post-Project habitat will be utilized, they considered the determination to be precautionary. As a result, the determination represents a scenario whereby there would be no utilization of future habitat by resident species, no mitigation nor compensation. However, clarification regarding the HADD by DFO indicates that the description of them as harmful alterations reflects the uncertainty of the post-habitat characterization/stabilization of future habitats and does not exclude the potential for future habitats to be utilized by resident fish species and that this habitat, and its utilization, can be incorporated into the Compensation Plan.

A comprehensive data and analysis/discussion of the existing and predicted post-Project habitat quantification as it relates to productive capacity is presented in the Habitat Quantification reports (pages 21-26 in AMEC 2001b and 80-98 in AMEC and Sikumiut 2007) which were submitted within the Aquatic Environment Component Studies as well as in the EIS itself (Volume IIA, page 4-15). The methodology used for the collection and analysis of data is discussed in AMEC (2001a, Section 3.0, pages 6-20) and AMEC and Sikumiut (2007).

Page 4-1 of the EIS (Volume IIA) also presents the relation of the habitat quantification to the *Fisheries Act*. Further clarification as to the HADD determination and *Fisheries Act* is provided within Section 1.0 of the Fish Habitat Compensation Strategy Framework (appended to the response to IR# JRP.107).

References:

AMEC Earth & Environmental Ltd. 2001a. Churchill River Power Project a Proposed Framework for "HADD" Determination (LHP00-07). In Churchill River Power Project (LHP00-07) HADD Determination Methodology Churchill River Labrador. Prepared for Labrador Hydro Project, St. John's, NF.

AMEC Earth & Environmental Ltd. 2001b. Churchill River Power Project: Application of a Proposed Framework for HADD Determination (LHP00-07). In Churchill River Power Project (LHP00-07) HADD Determination Methodology Churchill River Labrador. Prepared for Labrador Hydro Project, St. John's, NF.

AMEC Earth & Environmental Ltd. and Sikumiut Environmental Management Ltd. 2007. Lower Churchill Hydroelectric Generation Project Habitat Quantification. Prepared for Newfoundland and Labrador Hydro, St. John's, NL. viii + 129 pp. + Appendices

Requesting Organization – Joint Review Panel **Information Request No.: JRP.49**

Information Requested:

The Proponent is asked to provide:

b. **a detailed analysis of the existing and predicted post-impoundment habitat and its utilization by all fish species and their different life stages, to the extent possible the Proponent should include Aboriginal Traditional Knowledge from the Innu Nation to complete this analysis and indicate where this has been done;**

   i. **description and explanation of potential habitat use by resident species after reservoir creation, including the type of fish community structures anticipated (i.e., species composition and abundance) needs to be more fully addressed and explained;**

   ii. **explanation of the impacts of this increased habitat availability for large predators on the dynamics of their respective populations and on those of other species; and**

   iii. **determination of the anticipated changes in species diversity, abundance and relative importance for all phases from pre-impoundment through reservoir stabilization;**

Response:

A detailed analysis of the existing and predicted post-impoundment habitat and its utilization by all fish species and their different life-cycle stages has been presented in the Habitat Quantification report which has been submitted within the Aquatic Environment Component Studies. Post-impoundment habitat and its utilization has been described within the Habitat Quantification; however, this was based on habitat once stabilized. It is acknowledged in the EIS and the ongoing fish habitat compensation planning process that stabilization may take some time for certain parameters and this needs to be incorporated into the fish habitat compensation strategy/plan so that anticipated changes in species diversity and abundance can be described.

Discussions have been ongoing between Nalcor and DFO since the submission of the EIS and the HADD determination to assist Nalcor in achieving a mutually agreeable approach to compensation, which incorporates the DFO HADD determination as well as recognition of post-Project habitat utilization. An acceptable fish habitat compensation plan will be based on all phases of the Project, from pre-impoundment through reservoir stabilization, in order to determine the anticipated changes in species diversity, abundance and relative importance. A Fish Habitat Compensation Strategy Framework has been completed which describes the inclusion of the above requested information while the process is ongoing and a plan is being developed. In addition, field investigations are being completed to assist in reducing uncertainty in predictions that will be incorporated into the planning process. Provided below are the relevant portions of the Compensation Strategy Framework related to the above Information Request.

As stated in the Framework, DFO's potential recognition of reduced velocity and flooded areas as contributing towards compensation will require further detailed quantitative and qualitative analysis of post-impoundment habitat (eg. water quality, depths and substrates), and how resident species would use these areas. In addition, any predictions regarding utilization of reservoir habitat would require validation through a long-term monitoring program.

The first component (i.e. Tier 1) of the Compensation Strategy and Plan is Post Impoundment Fish Utilization. This section, as outlined in the Framework, will describe the predicted future habitat within the reservoirs (eg. characterization and quality) and will provide in-depth habitat analysis of the post impoundment environment as well as modelling results. A description of the predicted response to habitat change by species will also be presented. This section will describe the model results used in predicting post-Project habitat and use and will describe the certainty of the predictions. This section will also identify the Habitat Equivalent Units of the post-Project habitat and how these are applied against the HADD.

As stated previously, the Compensation Strategy and Planning process is ongoing. The field validation of parameters used in model results presented in the EIS will be completed in the summer/fall of 2009. It is anticipated that the Strategy will be completed in 2010.

IR# JRP.50

Fish Movement up Tributaries

Requesting Organization – Joint Review Panel **Information Request No.: JRP.50**

Subject - Fish Movement up Tributaries

References:

EIS Volume IIA, Section 4.11 (Environmental Effects Assessment – Change in Habitat Quantity)

Related Comments I Information Requests:

CEAR # 203 (Hydro-Québec)

IRs # JRP. 23,43,49,51,52,53,54,55,56,90

Rationale:

In the EIS, the Proponent predicts an approximately 800 ha increase in fish habitat in the reservoirs' tributaries (Table 4-13 of Volume BA) as a result of the increase in water levels which, for fish in the Churchill River, will push the boundary of tributary access farther upstream. An analysis of the figures presented in the EJS shows that several of the tributaries are fed by higher-elevation lakes, some of them large.

Requesting Organization – Joint Review Panel **Information Request No.: JRP.50**

Information Requested:

The Proponent is asked to:

Indicate whether the increase in tributary water levels will lead to the introduction of fish from the Churchill River into higher-elevation lakes, which could have an impact on resident fish populations (competition, predation, etc.). If introduction is a possibility, the Proponent is asked to explain what measures will be implemented to prevent undesirable species from moving up the tributaries into these higher-elevation lakes.

Response:

An assessment of whether the newly formed reservoirs would inundate existing migratory barriers, such that fish would no longer be restricted from moving from the lower Churchill River to higher-elevation lakes was completed in the early stages of the habitat quantification process. All major tributaries (greater than 4 m wide at their confluence) and a sub-set of smaller tributaries were visually inspected for obstructions both above and below the proposed reservoir elevations (AMEC and Sikumiut 2007 page 16, AGRA 1999 page 17). In addition, all smaller tributaries were assessed using GIS, the digital imagery and Light Detection and Ranging (LIDAR) gathered for the Project. Each tributary was mapped with respect to stream slope and areas with a slope greater than 7 percent were identified. This slope is the minimum slope for a habitat classification of "falls" under the new draft riverine habitat classification for Newfoundland and Labrador and was therefore assumed to be a reasonable reference to identify an existing barrier. These areas were compared to the proposed reservoir levels to assess whether existing barriers remained.

All tributaries retained existing barriers to upstream migration, in particular to high-elevation lakes and habitat.

References:

AGRA Earth & Environmental Ltd. 1999. Churchill River Power Project LHP98-07 Fish and Fish Habitat. Report prepared for Labrador Hydro Project.

AMEC Earth & Environmental Ltd. and Sikumiut Environnmental Management Ltd. 2007. Lower Churchill Hydroelectric Generation Project Habitat Quantification. Report prepared for Newfoundland and Labrador Hydro.

IR# JRP.51

Effects of Entrainment of Fish in Hydroelectric Facilities at the Population Level

Requesting Organization – Joint Review Panel **Information Request No.: JRP.51**

Subject – Effects of Entrainment of Fish in Hydroelectric Facilities at the Population Level

References:

EIS Guidelines, Section 4.4.4.2 (Aquatic Environment), Section 4.5.1 (Environmental Effects - General), Section 4.7 (Residual Effects and Determination of Significance)

Volume IIA, Section 2.3.7 (Aquatic Environment Lower Churchill River), Sections 4.8.3 (Change in Fish Distribution and Abundance - Mortality), Section 4.13.1.2 (Change in Fish Populations — Mortality); and Section 4.15 (Summary of Residual Environmental Effects and Evaluation of Significance)

Volume IIB, Section 7.2.2 (Residual Environmental Effects — Aquatic Environment)

Related Comments / Information Requests:

CEAR # 170 (Fisheries and Oceans Canada)
CEAR # 180 (D. Steele - Memorial University of Newfoundland, Natural History)
CEAR # 192 (E. Davis)

JRs # JRP.23, 43, 49, 50, 52, 53, 54, 55, 56, 90

Rationale:

Section 4.5.1 of the EIS Guidelines specifies that fish mortality resulting from entrainment in hydroelectric facilities needs to be assessed. The significance that this could have on fish populations within the Churchill River depends to a large extent on the type, size and rotational speed of turbines; intake and discharge design features as well as amount of movement/migration through the facilities. In addition, the Gull Island and Muskrat Falls facilities may have significant impacts on fish migration/movement, fish recruitment and feeding ecology in the reservoirs.

DFO has indicated that the EIS fails to:

- sufficiently describe fish movements within the vicinities of the future Gull Island and Muskrat Falls facilities;
- quantify the extent of predicted mortality and disruption to fish migration/movement likely to occur at these sites; and
- analyze the predicted significance of these effects on fish assemblages and population dynamics in the reservoirs.

Requesting Organization – Joint Review Panel **Information Request No.: JRP.51**

Subject – Effects of entrainment of fish in hydroelectric facilities at the population level

Information Requested:

The Proponent is asked to provide:

a. **a comprehensive assessment of the migration/movement of various fish species within the vicinities of the future Gull Island and Muskrat Falls facilities, and the significance of these movements to recruitment of local populations; and**

Response:

A description of the movement of fish within the vicinities of the future Gull Island and Muskrat Falls facilities for the purposes of assessment has been provided in the EIS (Volume IIA, pages 4-51 to 4-52). Additional detailed movement data and analysis can also be found in the component study report titled Fish Migration and Habitat Use of the Lower Churchill River (Jacques Whitford 2000).

The following is a summary of information from the above as well as further assessment of movement to recruitment of local populations.

An intensive radio telemetry monitoring program was implemented through 1998 and 1999 to monitor fish movements and habitat use within the lower Churchill River between Goose Bay and Churchill Falls, with a total of 248 fish tagged and tracked (Jacques Whitford 2000). Species monitored included northern pike, lake whitefish, brook trout (anadromous and resident), lake trout, longnose sucker, white sucker and Atlantic salmon (anadromous and resident).

Vicinity of Muskrat Falls

There have been no recorded migrations across Muskrat Falls either upstream or downstream in any of the radio monitoring studies. Dedicated, fixed telemetry tracking stations located near Muskrat Falls scanned for tagged fish continuously throughout the study. There were two antennae positioned at Muskrat Falls, one which was orientated to a downstream position, the second to an upstream orientation. No fish of any species was recorded passing upstream or downstream over the falls. While very few anadromous Atlantic salmon were captured during the efforts to implant radio tags downriver of Muskrat Falls, the one Atlantic salmon that was captured and tagged below the falls did not approach or attempt to ascend the falls at any time throughout the study. There was also one sea run brook trout tagged below Muskrat Falls, and this individual remained below the falls for the duration of the study.

Muskrat Falls is considered a barrier to migration based on the data collected and presented in the Environmental Assessment and associated component studies (including radio telemetry, isotope analysis and Traditional Ecological Knowledge). In addition, past analysis by researchers have also determined it to be a complete barrier to upstream migration (refer to IR# JRP.52). From these results, it can be determined that there is no significant migration upstream or downstream in the vicinity of Muskrat Falls. Hence movements in this area with respect to recruitment are considered minimal and not significant to the recruitment of local populations.

Vicinity of Gull Island

Several species tagged and monitored during the telemetry study were recorded moving past the vicinity of the proposed Gull Island facility (Jacques Whitford 2000). Provided below is a summary of each species and the significance of these movements to recruitment of local populations.

White Sucker

White sucker were tagged at select sites both upstream and downstream of the proposed Gull Island facility. Regardless of location of capture/implant, no white sucker migrated upstream past the proposed Gull Island facility location (Jacques Whitford 2000).

White sucker tagged just northeast of Upper Brook, in the proposed Muskrat Falls Reservoir area, showed migration between Muskrat Falls to just downriver of Gull Lake (i.e. entirely within the proposed Muskrat Falls reservoir area). None of the tagged fish were recorded passing the proposed Gull Island site.

White sucker tagged at stations 5 km and 10.5 km upstream of Gull Lake showed downstream movements past the proposed Gull Island facility location during the first months (October to November) of tracking, but no movement back upstream (Jacques Whitford 2000). Fish that moved from above the proposed Gull Island facility site down to Gull Lake remained there for the duration of the study.

While not within the vicinity of the proposed Gull Island facility location, white sucker were also tagged at the east and west ends of Winokapau Lake. Most of these fish stayed within the confines of the lake with the farthest downstream migration being to the outflow of Winokapau Lake and the farthest upstream migration being to the Churchill Falls tailrace (Jacques Whitford 2000).

Based on capture data (AGRA 1999; AMEC 2000; AMEC 2001; AMEC 2006), white sucker occur throughout the Lower Churchill River between Happy Valley-Goose Bay and Churchill Falls, as well as in the Goose Bay estuary (AMEC 2000; Jacques Whitford 2001)

It was concluded from the radio telemetry study that white sucker could be divided into two main ecological units:

- Muskrat Falls to Gull Lake; and
- East side of Winokapau Lake to the Churchill Falls Tailrace.

From these results, it can be determined that there is no substantive white sucker migration upstream or downstream of the proposed Gull Island facility location. Hence the important of these movements to the recruitment of local populations is low and not significant.

Brook Trout

In total, 51 brook trout were tagged within the vicinity of the proposed Gull Island facility location, between Gull Lake and Minipi River (km 92 to 131 on the main stem). From the movement data collected, there is evidence of a portion of local brook trout using Gull Lake to overwinter, but there does not appear to be a large-scale (population level) migration to or from Gull Lake from upriver of the proposed Gull Island facility location. For example, of the 42 brook trout tagged upstream from the Gull Island site, five moved downstream into Gull Lake and subsequently moved back upstream. Only two made the migration in consecutive winters.

Capture data from additional fish and fish habitat sampling (AGRA 1999; AMEC 2000; AMEC 2001; AMEC 2006) indicates that brook trout are resident throughout the Lower Churchill River between Happy Valley-Goose Bay and Churchill Falls, as well as in the Goose Bay estuary (AMEC 2000; Jacques Whitford 2001).

From these results, it can be determined that there is no substantive migration upstream or downstream of the proposed Gull Island facility location, and the movement that does occur is limited and local. Hence these movements are not important to the recruitment of local populations. The proposed dam and facility will block access to habitat upriver for those fish below the facility and likewise would reduce survival of fish that did move downstream via the penstock (potential increase in mortality as a result of entrainment is described on pages 4-15 to 4-17 in Volume IIA of the environmental assessment as well as within part (b) of this response). The overwintering habitat being provided to local brook trout that currently migrate downriver to Gull Lake will be available within the Gull Island reservoir.

Longnose Sucker

A total of 22 longnose sucker were tagged, primarily between Winokapau Lake and Churchill Falls. The majority of the fish captured and tagged stayed within the same local area for the duration of the study, with very limited movement up or downstream. However, some traveled considerable distances – in one case more than 200 km.

Within Winokapau Lake, activity in late May and June was centered at the mouths of tributaries where conditions for spawning existed. The study showed that greater than 50 percent of all migration of longnose sucker was during the spawning season with the vast majority of longnose sucker movement recorded in Winokapau Lake. In late August and September about half of the fish tracked returned to areas where they had been earlier in the spring. Some fish remained in the reach where they were tagged.

There was limited movement through the proposed Gull Island facility, however, one longnose sucker moved through the locations of the proposed Gull Island facility from the west end of Winokapau Lake to upriver of Muskrat Falls. This individual remained in this area for the remainder of the study.

Capture data from additional fish and fish habitat sampling (AGRA 1999; AMEC 2000; AMEC 2001; AMEC 2006) indicates that longnose sucker are resident throughout the Lower Churchill River between Happy Valley-Goose Bay and Churchill Falls and are the most abundant species in the lower Churchill River (AGRA 1999) and the Goose Bay Estuary (Jacques Whitford 2001).

From these results, it can be determined that there is no substantive movement upstream or downstream of the proposed Gull Island facility location, and that the movement that does occur is limited. Hence movements past the proposed Gull Island facility location are not important to the recruitment of local populations.

Lake Trout

Lake trout were not included in the initial work plan, however, a total of seven lake trout were captured and tagged during the 1998-1999 telemetry study. Six were captured in Winokapau Lake and another in the Churchill Falls tailrace. Most of the tagged individuals were detected within the same areas as they were initially captured. The movements were minimal, with a median migration distance of 3.7 km, and a maximum of 44.3 km. Only one tagged fish from Winokapau Lake left the lake and traveled approximately 44.3 km downstream. The one lake trout that was tagged near the Churchill Falls tailrace moved as far downstream as the Metchin River in late June but moved back to the tailrace in August. During the course of the study, there were no observable seasonal movements, and no individuals were tracked moving towards the Gull Island facility.

From these results, it can be determined that there is no substantive movement upstream or downstream of the proposed Gull Island facility location, and that the movement that does occur is limited and local. Hence movements of lake trout past the proposed Gull Island facility location are not important to the recruitment of local populations.

Northern Pike

A total of 20 northern pike were tagged throughout this study, with seven tagged in Gull Lake. Pike tagged in Gull Lake, for the most part, remained there. Similar to the longnose sucker, upwards of 50 percent of the migrations were during late May and June, which coincides with the species spawning period. There were four individuals caught in Winokapau Lake, none of which were detected migrating towards the Gull Island facility.

From these results, it can be determined that there is no substantive movement of northern pike upstream or downstream of the proposed Gull Island facility location, and that the movement that does occur is limited and local. Hence movements of northern pike past the proposed Gull Island facility location are not important to the recruitment of local populations.

Ouananiche

A total of 18 ouananiche were tagged, all of which were in the vicinity of the Churchill Falls Tailrace. Approximately 60 percent of the captured individuals moved distances in excess of 10 km, the majority of which were observed during the fall spawning season. Fish movements were from Churchill Falls tailrace either upstream to the Unknown River or downstream to the west end of Winokapau Lake.

Capture data from additional fish and fish habitat sampling (AGRA 1999; AMEC 2000; AMEC 2001; AMEC 2006) indicate that ouananiche are resident throughout the Lower Churchill River between Happy Valley-Goose Bay and Churchill Falls, although lowest abundance is within the lower sections of the river below the proposed Gull Island facility.

From these results, it can be determined that movements of those ouananiche tagged did not occur upstream or downstream through the location of the proposed Gull Island facility location. While it is difficult with the data available to determine whether ouananiche residing in lower reaches of the Churchill River, above Muskrat Falls, move past the Gull Island site, the low number of captures in this area indicates that habitat is less suitable (see AGRA 1999 as an example of catch rates). It could be assumed that ouananiche utilization of the habitat near Gull Island would be similar to that of brook trout; with a portion of the population preferring the faster water near Gull Island and farther upriver to spawn and feed and the lacustrine habitat of Gull Lake and Winokapau Lake to overwinter. However, given the low numbers of ouananiche in the lower reaches of the river, movements past the proposed Gull Island facility location would not be considered important to the recruitment of local populations.

Lake Whitefish

Forty-five lake whitefish were captured in three study sections of the Churchill River; between the Churchill Falls Tailrace and Gull Lake. Approximately half of the individuals that were tagged near the tailrace were observed making downstream migrations of various distances. The individuals that were captured in Winokapau Lake and Gull Lake stayed within the vicinity of the tagging sites. A total of nine fish were tagged and released within Gull Lake, and the maximum recorded migration distance was only 3.7 km. There was no observed migration through the Gull Island site.

Capture data from additional fish and fish habitat sampling (AGRA 1999; AMEC 2000; AMEC 2001; AMEC 2006) indicate that lake whitefish are resident throughout the Lower Churchill River between Happy Valley-Goose Bay and Churchill Falls, as well as in the Goose Bay estuary (AMEC 2000; Jacques Whitford 2001).

From these results, it can be determined that there is no substantive movement of lake whitefish upstream or downstream of the proposed Gull Island facility location, and that the movement that does occur is limited and local. Hence movements of lake whitefish past the proposed Gull Island facility location are not important to the recruitment of local populations.

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AGRA Earth & Environmental Ltd. 1999. Churchill River Power Project LHP98-07 Fish and Fish Habitat. Report prepared for Labrador Hydro Project, St. John's, NL.

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AMEC Earth & Environmental Ltd. 2006. Lower Churchill Hydroelectric Development Fish and Fish Habitat Baseline Study: Catch Based Utilization Index Validation and Additional Habitat Surveys. Report prepared for Newfoundland and Labrador Hydro, St. John's, NL.

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Jaques Whitford Environment Ltd. 2001. Biological Study of the Goose Bay Estuary. Report prepared for Newfoundland and Labrador Hydro; Labrador Hydro Project, St.John's, NL.

Requesting Organization – Joint Review Panel **Information Request No.: JRP.51**

Information Requested:

The Proponent is asked to provide:

b. **an analysis of expected fish mortality and sub-lethal effects resulting from entrainment and/or impingement at the two generating facilities, specifically related to fish species and life stage vulnerability through predictive modeling.**

Response:

Based on the known survival rates of Francis and Kaplan turbines and movements of fish at each potential location, an assessment of potential fish mortality related to fish passage through turbines was conducted as part of the EIS (Volume IIA pages 4-16 and 4-17). Further analysis of expected fish mortality and sub-lethal effects resulting from entrainment or impingement is provided below.

There are several injury mechanisms due to downstream passage of fish through turbines that have been acknowledged by many authors. They include blade strikes, pressure gradients, shear forces and turbulence, and cavitation (the collapse of aqueous gas bubbles creating partial vacuum). Each of these mechanisms has the potential to be fatal. Sub lethal effects as a result of these mechanisms include: lacerations, disorientation, scale loss, damage to swim bladders and internal organs, hemorrhaging and gas bubble trauma (Cada 2001, Cada 1990, Turnpenny 1998, Navarro *et al* 1996, and Coutant and Whitney 2000, Carr 2001, Ruggles and Collins 1981).

Based on the Project Description (Volume IA, Section 4.2) each facility will have different types of turbines in operation. Francis turbines are to be used at Gull Island, while Muskrat Falls will have a combination of Kaplan and Propeller turbines. The rationale and justification is provided in Volume IA, Sections 3.7.6.6 and 3.7.7.5. Table 1 below presents the turbine specifications for the proposed Lower Churchill Facilities for comparison to other studies where fish mortality and injury have occurred.

Table 1 Specifications for the Proposed Lower Churchill Facilities

Location	Turbine Type	RPM	Rated Head (m)	Number of Blades*	Runner Outlet Diameter (m)	Total Discharge (m^3s^{-1})
Gull Island	Francis	100	86.0	13	7.21	586
Muskrat Falls	Kaplan/Propeller	81.8	35.0	5	9.0	665

*Tentative number and may be subject to change upon completion of design process. Numbers based on typical turbines of the same size.

Francis Turbines

As cited in Ruggles and Collins (1981), Bell *et al* (1967) reviewed numerous hydroelectric facilities, equipped with both Francis and Kaplan turbines. Their findings were an average survival rate of 76.8 percent through Francis turbines (with a minimum of 52.2 percent at a test on Cushman No. 2, Washington) (see Table 2).

Table 2 Comparison of Francis Turbines from Bell et al (1967), as seen in Ruggles and Collins (1981)

Plant Name	Wheel Diameter (m)	Rated Normal Head (m)	Elevation of runner to tail water (m)	% survival test fish
Gold Ray		6.10		95.6
Stayton		4.88	1.37	89.7
Leaburg	2.27	27.04		95.2
Cushman No.2 (1960)	2.11	137.16	variable	60.5
Cushman No.2 (1961)	2.11	137.16	Variable	52.2
Shasta (01/1962)	4.67	124.94	0.89	71.0
		124.91	0.69	89.1
		124.94	0.77	59.8
Shasta (11/1962)	4.67	131.55	0.60	82.0
		131.58	0.61	62.8
		131.52	0.54	63.2
Baker Dam	1.65	76.20	variable	66.4
	1.65	76.20	variable	71.7
Lower Elwha	1.49	31.70	4.27	100.0
Glines Canyon	2.34	59.13	2.13	67.0
Seton Creek	3.66	43.28	variable	90.8
Puntledge	2.16	103.63	0.61	67.3
Ruskin	3.78	37.80	variable	89.5
Crown Zellerbach		12.65	7.28	75.9
		12.47	7.35	0.2
Publisher's Paper Co.		12.95	7.13	86.8
			Average	73.2
			Average minus Crown Zellerbach (0.2%)	76.8

Dedual (2007) studied the survival rates of juvenile rainbow trout passing through a Francis turbine at the Hb Dam in New Zealand. He found survival rates to be 95.6 percent, but did state that survival estimates in the study appeared high. Other studies of the survival rates of fish passing through Francis type turbines have produced lower survival estimates. Stornorrfors Power Station, Sweden, equipped with four Francis turbines, produced an estimated survival rate of 72.0 percent for juvenile and adult Atlantic salmon and sea run brown trout (Ferguson *et al.* 2008). Parametrix (2005) related the survival of fish passage through Francis turbines to fish length and operational turbine speed (rpm), at the Spokane Dam in Idaho. They found that survival rates decreased with increases in fish length and increases in turbine speed (rpm).

Kaplan Turbines

As cited in Ruggles and Collins (1981), Bell *et al* (1967) reviewed numerous hydroelectric facilities, equipped with both Francis and Kaplan turbines. Their findings were an average survival rate of 86.0 percent through Kaplan turbines (Table 3).

Kaplan and propeller turbines are seen as more ‘fish-friendly’ turbine designs (Cada 2001). Extensive studies on various species, turbine sizes and operating regimes have shown survival rates to range between 75.8 percent to 98.0 percent for passage through a Kaplan turbine (Schoeneman et al. 1961, Bell and Kynard 1985, Stier and Kynard 1986, Heisey et al. 1992, Mathur et al. 1996, Cada 2001). Table 4 presents the literature review from ALDEN (2001) relating fish survival to fish length, prop speed and number of blades.

Predictive Modeling

ALDEN (2001) conducted a literature review and data analysis on the expected Kaplan-type turbine mortality that would be associated with the construction of Dunvegan Hydroelectric Project. A portion of the analysis included the running of a model that was developed by Headrick (1998). The model was developed for axial type turbines (Kaplan and Propeller), similar to those to be used at Muskrat Falls. The simulations showed that survival rate was negatively correlated with fish length and the number of blades in operation (see Table 4 and Figure 1):

$$S = 109.2 - 0.027(L) - 1.038(b) - 0.045(r) \quad (1)$$

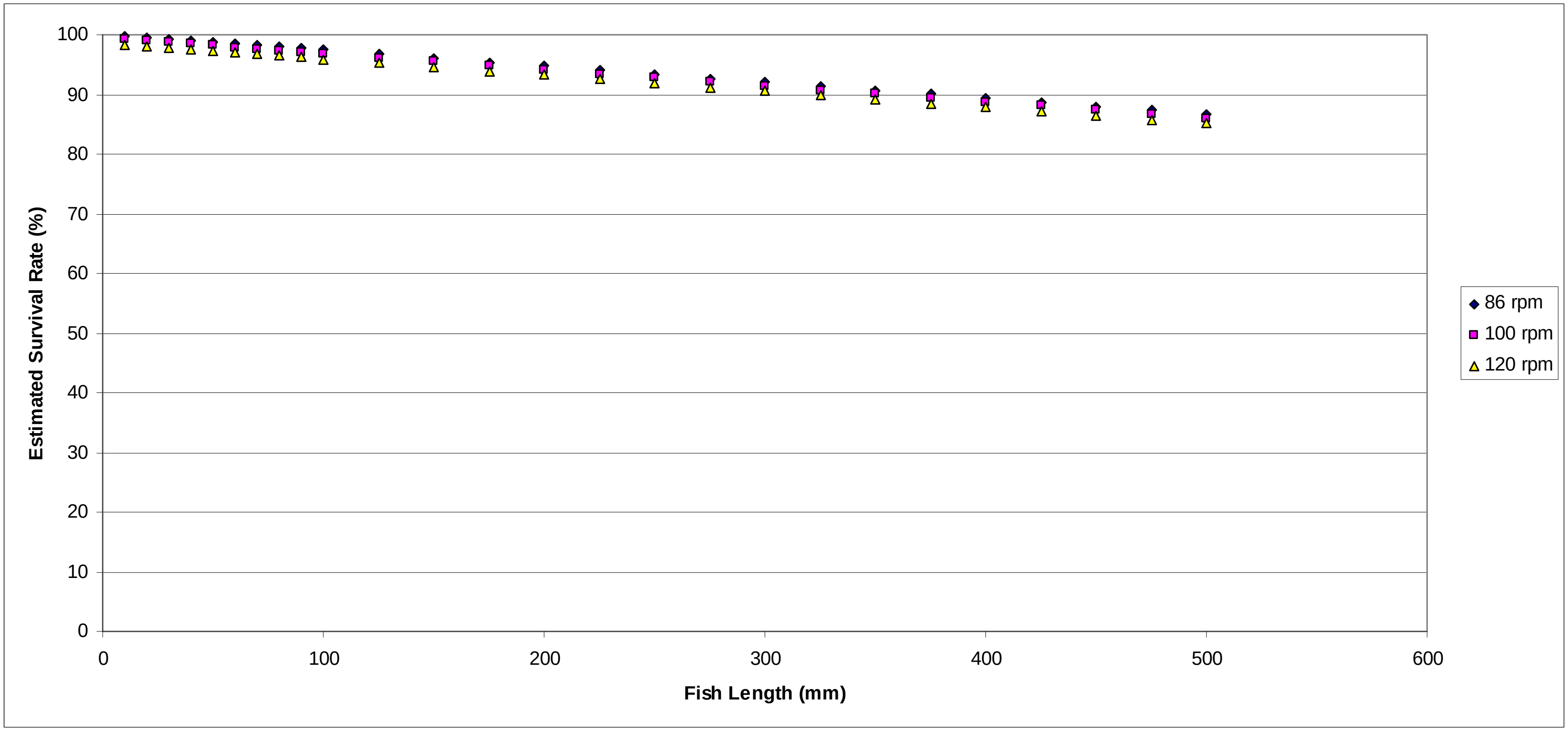
Table 3 Comparison of Kaplan Turbines from Literature Review

Location	Species	Turbine Diameter (m)	Head (m)	Discharge (m^3s^{-1})	RPM	Survival Rate	Reference
Lower Granite Dam - Columbia River	Chinook Salmon	---	---	---	---	96.1	Cada 2001
McNary Dam	Chinook Salmon	---	---	---	---	97.1	Cada 2001
Columbia and Snake Rivers	various species	---	---	---	---	88.0	Cada 2001
Holyoke Dam (1981) - Connecticut River	Atlantic Salmon	---	9.6	---	225.0	88.2	Stier and Kynard 1986
Holyoke Dam (1982) - Connecticut River	Atlantic Salmon	---	9.6	---	225.0	86.3	Stier and Kynard 1986
Holyoke Dam - Connecticut River	American Shad	---	9.6	---	225.0	78.5	Bell and Kynard 1985
Rocky Reach Dam	Chinook Salmon	7.1	30.0	171.0 - 475.0	90.0	94.3	Mathur *et al.* 1996
McNary Dam	Chinook Salmon	7.1	25.9	---	85.7	89.0	Schoeneman *et al*. 1961
Big Cliff Dam	Chinook Salmon	3.7	27.4	---	---	91.0	Schoeneman *et al*. 1961
Safe Harbor Hydroelectric Station	American Shad	5.6	23.0	3143.0	109.0	98.0	Heisey *et al.* 1992
Tobique Narrows	Atlantic Salmon	---	21.5	128.0	225.0	81.6	Carr 2001
Beechwood	Atlantic Salmon	---	15.2	850.0	112.5	90.0	Carr 2001
Mactaquac	Atlantic Salmon	---	36.6	2378.0	112.5	90.0	Carr 2001
					Average	89.85	

Table 4 Estimated Survival Rate for Fish Passed through Axial Flow Turbines (Kaplan and Propeller) as presented in ALDEN (2001)

Fish Length (mm)	RPM	Number of Blades	Estimated Survival Rate
100	150	4	95.6
		5	94.6
		6	93.5
200	150	4	92.9
		5	91.9
		6	90.8
300	150	4	90.2
		5	89.2
		6	88.1
400	150	4	87.5
		5	86.5
		6	85.4
500	150	4	84.8
		5	83.8
		6	82.7

Figure 1 **Estimated Survival Rate for Various Fish Lengths at Muskrat Falls (Kaplan Turbines) using the Headrick (1998) Model. This Model is Not Considered Applicable for Francis Turbines**



The Von Raben model (1957; as cited in Cada 1990; Turnpenny 1998) was developed to predict the probability of a blade strike by turbine passed fish:

$$P = (l * n * R * a * \cos\alpha) * f^{-1} \quad (2)$$

Where;

P = probability of blade contact

l = fish length

n = number of runner blades

R = revolutions per second

a = cross sectional area of water passage (pi [(runner diameter)^2-(hub diameter)^2]/4

α = blade angle

f = discharge

This model was run using the current parameters for the Gull Island and Muskrat Fall facilities. Results are depicted in Figure 2. The model predicts propeller type turbines fairly accurately, however, overestimates the probability of a blade strike through a Francis turbine (Cada 1990).

Predicted Mortality and Injury

With the absence of an anadromous migration above Muskrat Falls, non-anadromous pelagic juveniles will be the most affected life-cycle stage due to potential entrainment (Parametrix 2005). Based on the findings of the literature review, salmonids would be most likely affected by entrainment as they are mobile, pelagic species. This would principally include ouananiche, brook trout, and whitefish.

Muskrat Falls

Within the literature review (Table 4), the mortality shown for configurations close to Muskrat Falls (i.e., Kaplan/propeller, head>25 m, diameter >7 m) showed a mortality range of 5.7-11 percent. ALDEN (2001) found that survival was lower as fish length increased. Table 5 also shows a similar trend in literature values, with mortality showing an increase on 10.8 percent between 100 and 500 mm sized fish. Model results using a five-blade, low RPM Kaplan turbine yielded results of 5.4 - 16.2 percent mortality for a range of 100-500 mm fish length respectively. Most salmonids within the Lower Churchill are less than 500 mm in length and therefore a reasonable mortality range applicable from the ALDEN model would be 5.4 - 13.5 percent.

Based on the analysis of the literature review and model results for similar turbines as those proposed for Muskrat Falls, it is expected that mortality for juvenile and adults will be approximately 6 and 14 percent respectively.

Predicted injury rates for Muskrat Falls based on the Von Raben model is between 2 and 22 percent for fish sized 50 to 550 mm respectively (see Figure 2). Conservatively, this would be applied to those fish not killed by entrainment.

As previously discussed in part (a) of this response, there have been no recorded migrations across Muskrat Falls either upstream of downstream. As per IR# JRP.52, Muskrat Falls offers a complete barrier to the migration of fish, therefore a population based migration would not occur within the vicinity of the facility. From these results, it can be determined that there is no substantive migration upstream or downstream in the vicinity of Muskrat Falls. Hence mortality at the population-level related to entrainment are considered minimal and not significant.

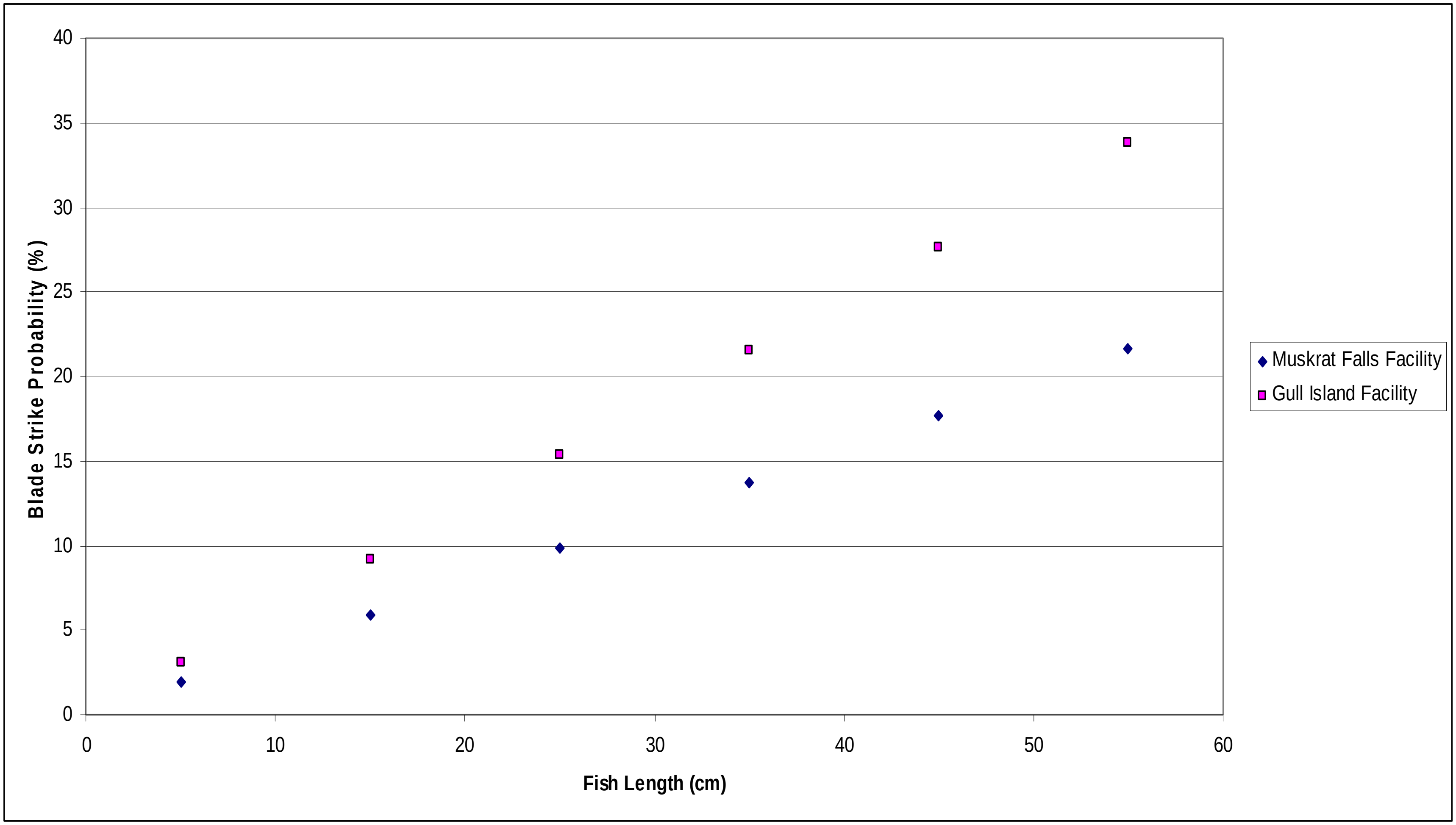
Gull Island

Based on the type of turbine, the Gull Island facility will be expected to have a higher mortality and injury rate than that of the Muskrat Falls facility. Within the literature review (Table 2), the mortality shown for configurations close to Gull Island (i.e., Francis, head>85m, diameter >3 m) showed a mortality range of 32.7-33.7 percent. The ALDEN (2001) model was not applicable for Francis-type turbines and exact specifications regarding the Francis turbines are not yet available. Therefore, uncertainties in applying a model to an estimated turbine configuration would be considered high and unreliable. As a result, the literature values are presented as a reasonable, conservative mortality estimate.

Predicted injury rates for Gull Island based on the Von Raben model are between 3 and 34 percent for fish sized 50 to 550 mm respectively (see Figure 2). Conservatively, this would be applied to those fish not killed by entrainment.

As previously discussed in part (a) of this response, the recorded movements of these species within the vicinity of the proposed Gull Island facility are limited, and local in nature. Hence mortality at the population-level related to entrainment are considered minimal and not significant.

Figure 2 **Estimated Probability of a Blade Strike using the Von Raben Model. Francis Turbine Estimates (Gull Island Facility) are over Estimated using this Model.**



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Turnpenny, A.W.H. 1998. Mechanism of fish damage in low-head turbines: and experimental appraisal. Pages 300-314 *in* M. Jungwirth, S. Schmutz, and S Weiss, editors Fish Migration and Fish Bypass. Fishing News Books, Blackwell Science Ltd., Oxford.

IR# JRP.52

Muskrat Falls as a Complete Obstruction to Upstream Fish Migration

Requesting Organization – Joint Review Panel **Information Request No.: JRP.52**

Subject – Muskrat Falls as a Complete Obstruction to Upstream Fish Migration

References:

EIS Guidelines, Section 4.4.4.2 (g) (Aquatic Environment)

EIS Volume IIA, Section 2.3.1.1 (Aquatic Environment — Environmental Assessment Boundaries), Section 2.3.6 (Fish Distribution and Habitat Use)

Jacques Whitford. 2000. *Fish Migration and Habitat Use of the Churchill River* (LHP98-03). Jacques Whitford Environment Limited report prepared for Labrador Hydro Project, St. John's, NL

Related Comments / Information Requests:

CEAR # 145 (T. Bursey)
CEAR # 170 (Fisheries and Oceans Canada)
CEAR # 184 (Sierra Club Atlantic)
CEAR # 192 (B. Davis)

IRs # JRP.23, 43, 49, 50, 51, 53 , 54 , 55 , 56 , 90

Rationale:

As per Section 4.4.4 and 4.4.4.2 (g) of the EIS Guidelines, the Proponent was to present where appropriate and possible "sufficient information to establish …the extremes of the data" as well as describe "the biological diversity, composition, abundance, distribution, population dynamics, and habitat utilization of aquatic species, including fish..."

This element of the Guideline is important because it determines the biological diversity and distribution of fish within the Churchill River system, necessary for assessing the environmental effects of the Project on fish community structure.

The EIS fails to provide a defensible rationale regarding the claim that there is no upstream migration of fish past Muskrat Falls. This conclusion was based on stable isotope analysis of only land-locked Atlantic salmon (ouananiche) and telemetry studies where only two anadromous fish (one Atlantic Salmon and one Brook Trout) were tagged below Muskrat Falls. To definitively make this claim given the assumptions, limitations, and scientific uncertainty of the isotope analysis and radio-telemetry studies is questionable.

Requesting Organization – Joint Review Panel **Information Request No.: JRP.52**

Information Requested:

The Proponent should reconsider its conclusions that no fish passage is needed in light of the above comments and should properly substantiate the presence or absence of fish passage at Muskrat Falls through additional studies or analysis.

Response:

Based on the information collected and presented as part of the EIS, Muskrat Falls is determined to be a complete barrier to upstream migration. Our conclusions are based on specific studies as well as conclusions of many other scientists, DFO researchers and traditional knowledge. Provided below are specific results from these publications.

1. Anderson (1985) page 163; 'This falls has an overall height of approximately 8m and is a complete barrier to fish migrating upstream.'
2. Bruce et al. (1975) page 9; "Muskrat Falls is considered a natural barrier to migrating anadromous or sea-run fish and as a result only 1.3 percent of the total drainage area is available to anadromous forms of such species as the Atlantic salmon, brook trout and Arctic char."
3. Bruce et al. (1975) page 16; "To date there is no documentation of anadromous species above Muskrat Falls."
4. Ryan (1980) page 79; "Arctic char, American eel, and Atlantic sturgeon, three sea-run species not captured during the survey, are apparently confined to waters downstream of the obstruction at Muskrat Falls as are sea-run brook trout and Atlantic salmon."
5. Lower Churchill Development Corporation (1980) page 171; "Sea run species (salmon, trout, char, smelt) are limited to the region downstream of Muskrat Falls which is a complete obstruction to upstream movement."
6. Lower Churchill Development Corporation (1980) page 323; "At present there are no anadromous species in the Lower Churchill River above Muskrat Falls."
7. AGRA (1999) page 22; "Anadromous forms of all species are restricted by Muskrat Falls."
8. EIA Volume II A, page 2-50; "Beak (1980) reported landlocked populations of Arctic char in both Minipi and Dominion Lakes, where they are believed to be relict from the last glaciation. Although they may be present in other larger water bodies on the plateau, Arctic char are not present in the main stem of the Churchill River (Scruton 1984)."
9. Environment Canada also indicates Muskrat Falls is a complete obstruction to upstream movement on its website (http://map.ns.ec.gc.ca/canal/root/main/station_details_e.asp?envirodat=NF03OE0001).

Aside from scientific evidence, Traditional Ecological Knowledge (TEK), also suggests that Muskrat Falls is a complete barrier to fish passage as provided in the EIS and the appended EIS Report of the work of Innu Traditional Knowledge Committee (Volume IB Appendix IB-H).

1. EIS Volume IIA, Chapter 2. pg 2-33 "Utshashumek (Atlantic salmon) go as far as Manitu-shipu [Churchill River]." "Nipinatamek (sea run trout) goes inland as well. It can be caught just below Manitu-utshu on Mishta-shipu [Muskrat Falls], not above…"
2. EIS Volume. IIA, Chapter 2. pg. 2-36 "Kauapishisht (Atlantic rainbow smelt) are found at the mouth of Mishta-shipu and into Mud Lake, but no further up the river."
3. EIS Volume. IIA, Chapter 2. pg. 2-37 "There are no utshasumek (Atlantic salmon)… in this part of the river".
4. ITKC Report, page 48 "Utshashumek[U] (Atlantic salmon) go as far as Manitu-utshu (Muskrat Falls)."
5. ITKC Report, page 52 "Utshashumek[U] (Atlantic salmon) can go up any small brook as long as there are no major falls. "
6. ITKC Report, page 64 "Nipinatamek[U] (sea run trout) goes inland as well. It can be caught just below Manitu-utshu (Muskrat Falls) on Mishta-shipu, not above, and is found up Manatueu-shipiss (Traverspine River). Where the brooks and rivers meet Lake Melville is where you will find utshashumek[U] (Atlantic salmon) and nipinatemek[U] (sea run trout)."
7. ITKC Report, page 53 "There are no shushashu (Arctic char) up Mishta-shipu although they are caught occasionally at Uhuniau (North west Point)."
8. ITKC Report, page 49 "Utshashumek[U] (Atlantic salmon) goes up Manatueu-shipiss (Traverspine River), as do seals, as far as the rapids."

It should be noted that a report by Thurlow and Associates (1974) which provides an environmental overview of the proposed Lower Churchill Power Development for both the provincial government and Environment Canada, did indicate a personal communication with a "Dugan" (no reference cited in report), who indicated that anadromous fish were now ascending Muskrat Falls as a result of the Upper Churchill Hydroelectric Development. Thurlow and Associates indicated that this was being investigated but no direct follow up report or information from them has been attained. Biologists with the provincial government did report one year later that Muskrat Falls was a complete barrier (Bruce et al. 1975).

In addition to the isotope analysis (27 samples) by the University of Waterloo, one of the main objectives from the Fish Migration and Habitat Use of the Churchill River report, as part of the EIS Component Studies, was to assess fish movement at Gull Island and Muskrat Falls. Fish tagged and tracked upstream of Muskrat Falls showed no migration activity upstream or downstream at Muskrat Falls. As per the IR# JRP.51 response, regarding the movement patterns of fish within the proposed development area; there were no recorded migrations across Muskrat Falls either upstream or downstream. Dedicated, fixed telemetry tracking stations located near Muskrat Falls scanned for tagged fish continuously between 15 October 1998 and 12 November 1999. There were two antennae positioned at Muskrat Falls, one which was orientated to a downstream position, the second to an upstream orientation. No fish of any species was recorded passing upstream or downstream over the falls. While very few Atlantic salmon were captured during the efforts to implant radio tags, the one Atlantic salmon that was captured and tagged below the falls did not approach or attempt to ascend the falls at any time throughout the study. There was one sea run brook trout tagged below Muskrat Falls, and this individual also remained below the falls for the duration of the study. Also important to note is that kelts (anadromous adult Atlantic salmon that have completed spawning) will move downstream to rest in pools, immediately return to the ocean, or overwinter in freshwater, returning to the sea the following spring (Grant and Lee 2004). None of the tagged adult ouananiche or brook trout above the falls migrated downriver over Muskrat Falls toward Goose Bay.

To summarize, no sea run species have been observed upstream of the falls. Repeated studies and investigations have failed to identify sea-run species upstream of the falls. The Traditional Ecological Knowledge is particularly demonstrative, as it provides a long term view of the traditional understanding of where fish can be found. Collectively, no evidence of sea-run species passing upstream of Muskrat Falls can be found.

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IR# JRP.53

Sampling Deficiencies in Baseline Studies (Winokapau Lake)

Requesting Organization – Joint Review Panel **Information Request No.: JRP.53**

Subject: Sampling Deficiencies in Baseline Studies (Winokapau Lake)

References:

EIS Guidelines Section 4.4.4.2 (Description of the Existing Environment — Aquatic Environment) & Section 4.4.5 (Component Studies)

EIS Volume IIA, Section 2.3 (Aquatic Environment), Section 4.11 (Environmental Effects

Assessment — Change in Habitat Quantity, Section 4.12 ((Environmental Effects Assessment — Change in Habitat Quality)

AGRA Earth & Environmental Ltd. 1999. *Fish and Fish Habitat, Churchill River Power Project* (LHP98-07).Prepared for Labrador Hydro Project, St. John's, NL

AMEC Earth& Environmental Ltd. 2001. *Churchill River Power Project: A Proposed Framework for HADD Determination* (LHPOO-07). Prepared for Labrador Hydro Project, St. John's, NL

Jacques Whitford. 1999. *Benthic Invertebrate Study of the Churchill River*. Jacques Whitford Environment Limited report prepared for Newfoundland and Labrador Hydro, St. John's, NL

Jacques Whitford. 1999. *Water and Sediment Quality of the Churchill River* (LHP 98-08) Jacques Whitford Environment Limited report prepared for Labrador Hydro Project, St. John's, Newfoundland

Jacques Whitford. 1999. *Primary Productivity and Plankton Biomass*. Jacques Whitford Environment Limited report prepared for Newfoundland and Labrador Hydro, St. John's, NL

Jacques Whitford. 2000. *Fish Migration and Habitat Use of the Churchill River* (LHP98-03). Jacques Whitford Environment Limited report prepared for Labrador Hydro Project St. John's, NL

Jacques Whitford. 2001. *Water Quality and Chlorophyll Study* (LHP 99-08). Jacques Whitford Environment Limited report prepared for Labrador Hydro Project, St. John's, Newfoundland

McCarthy, J.H., D.A. Scruton and B.R. LeDrew. 2007. *Lower Churchill Hydroelectric Generation Project Habitat Quantification*. Prepared for Newfoundland and Labrador Hydro. 150 pp + appendices

Minaskuat Inc. 2008. *Water and Sediment Quality Modelling in the Lower Churchill River*. Prepared for the Lower Churchill Hydroelectric Generation Project

Related Comments / Information Requests:

CEAR # 170 (Fisheries and Oceans Canada)
CEAR # 184 (Sierra Club Atlantic)
CEAR # 203 (Hydro-Québec)

IRs # JRP.23, 43, 49, 50, 51, 52, 54,55,56,90

Rationale:

Section 4.4.4 of the EIS Guidelines states that a time series of data should be provided as well as sufficient information to establish averages, trends and extremes of the data necessary to evaluate potential environmental and cumulative effects of the Project.

DFO has indicated that in order to make accurate predictions regarding fish and fish habitat within future reservoirs, component studies of the existing environment require standardized and representative baseline sampling programs, spanning as many years as possible prior to development. Due to insufficient baseline sampling, DFO has concerns with using Winokapau Lake as a predictor of fixture conditions within the Gull Island reservoir despite their similarities (long, narrow, deep, steep-sided water bodies).

A number of component studies have small sample sizes, limited spatial and temporal coverage, and/or resolution of organism assemblages that are too broad to be biologically meaningful. In particular:

- during 1999, monthly water quality sampling was conducted during only part of the open water period (July to October), while in 2007 sampling was conducted throughout the entire year, but at a significantly reduced number of stations;
- primary production and plankton biomass studies do not adequately address annual variability either separately or combined and the taxonomic categories used for phytoplankton and zooplankton were too broad;
- level of sampling (number of stations) for benthic invertebrates is inadequate and there is a lack of analyses to determine the number of subsamples required to statistically represent spatial distributions for habitat at each station; and
- insufficient sampling to accurately assess various fish population parameters such as fecundity, age, growth, food and feeding.

For these reasons, DFO has indicated that there is a high level of uncertainty in the descriptions of the existing environment and in predictions of potential impacts and future environmental conditions.

Requesting Organization – Joint Review Panel **Information Request No.: JRP.53**

Information Requested:

The Proponent is asked to provide:

a. **baseline information on the water quality, primary production, and plankton studies in order to properly assess seasonal and annual variability;**

Response:

No additional baseline information is required to properly assess seasonal and annual variability for the effects predictions in the EIS. The measurable parameters used in the EIS had sufficient data to assess the potential effects on the aquatic ecosystem. DFO requirements are based on Harmful Alteration, Damage or Destruction (HADD) to fish habitat. The developed methodology uses catch-based data (i.e. biomass) for fish species from numerous sampling techniques including gillnets, fyke nets, angling and electrofishing. Numerous techniques were necessary due to the challenges associated with both the size of the study area, the variability of the habitats and species being sampled and the capture biases of each method. Biomass has been used in this, and other studies, as a representative value of fish productivity. Catch data were used to quantify the utilization of the distinct habitat types available within the Project area for all species present. This method is also similar to other habitat quantification methods used in the province (Bradbury et al. 2001). This approach is valid for determining predicted effects and for developing appropriate mitigation.

Water Quality - Water quality results were used in the assessment to describe the existing conditions within the Assessment Area as well as for input and comparison to model predictions related to post-Project conditions. Section 4.12.2 (Volume IIA) presents the assessment of change in habitat quality during operation and maintenance of the Project.

Water quality was measured at numerous locations throughout the lower Churchill River since 1998. The results of this water quality monitoring are included in the Jacques Whitford 1999 (Water Quality and Quantity Component Study Report 4 of 5) and Jacques Whitford 2001 (Water Quality and Quantity Component Study Report 5 of 5) reports as well as the Minaskuat 2007 (Water Quality and Quantity Component Study Report 2 of 5) report which are all appended to the EIS. The water quality monitoring in 2006-2007 was completed using the same study area as that of the 1998 program; that being the lower Churchill River from below Churchill Falls Generating Station downstream to the mouth of the river. Sampling in 1998 and 1999 captured water quality during open water conditions but did not provide any information regarding the time when ice-cover was present. This aspect was incorporated as part of the 2006-2007 program which sampled water quality at least monthly for a total of 12 months. A reduced number of sample sites were selected in 2006-2007 to represent the various sections of the river. While the parameters were the same in both sample programs, lower levels of detection were available in 2006-2007, enabling more information to be collected on the many parameters that were present at trace levels (Minaskuat 2007).

The annual mean and range of water quality within the lower Churchill River collected in 2006-2007 were compared with similar data previously collected from 1998. This comparison showed that the mean data values between 2006-2007 and 1998 are similar. The variability between sample years was empirically evaluated by calculating the coefficients of variability for the data. As shown in Table 1, both years are comparable.

Table 1 Comparison of Mean Annual Water Quality Parameters between Years

Parameter	Year	Mean	Std. Dev.	Coefficient of Variability (%)*
Specific Conductance (µS/cm)	1998	19.34	3.38	17.46
	2006	25.75	16.59	62.43
Sodium (mg/L)	1998	0.60	0.28	47.31
	2006	0.61	0.23	38.15
Aluminum (µg/L)	1998	92.61	91.68	99.0
	2006	73.46	68.85	93.73
Magnesium (µg/L)	1998	739.29	134.27	18.16
	2006	840.51	66.69	7.93

* Calculated as: (Std. Dev./Mean) *100

In addition to increasing the sample period to cover a continuous period for many water quality parameters, Nalcor Energy (Nalcor) installed several real time water quality stations throughout the lower Churchill watershed in 2008 to assist in ongoing monitoring. These stations sample a select number of water quality parameters (i.e., temperature, pH, specific conductance, dissolved oxygen, turbidity and total dissolved solids) and are operated continually to assist in gathering additional water quality data on the river. Real time water quality monitoring station data can be located at the following provincial website (http://www.env.gov.nl.ca/wrmd/ADRS/v6/Graphs_List.asp).

Seasonal and Inter-Annual Variability in Primary Production and Plankton Biomass

The lakes within in the lower Churchill River watershed are all at the extreme oligotrophic (low) end of the trophic scale in terms of their primary production and plankton biomass (Minaskuat 2007: Water Quality and Quantity Component Study Report 2 of 5). Oligotrophic lakes are characterized by a lack of distinct seasonal cycles in phytoplankton biomass and, consequently, primary production (Kalff and Knoechel 1978). In this respect, additional seasonal variability has been sufficiently addressed in the EIS.

The seasonal and annual variability of primary production and plankton biomass in these lakes were evaluated through the comparison of the seasonal data collected in 1998 with historical data from four of the lakes collected during 1971-1975 (Duthie and Ostrofsky 1974, 1975; Ostrofsky and Duthie 1975, 1980) and with the same parameters measured elsewhere in Labrador and insular Newfoundland. All data comparisons demonstrate that the collected data is representative of typical conditions and can be used as a direct comparison to any post-Project monitoring requirements (eg. as a potential requirement under the *Fisheries Act*).

Primary Production - The mean and range of daily areal primary production of Atikonak, Gabbro, Lobstick and Michikamau lakes in 1998 were compared with data previously collected from 1971-1975 in Figure 7.2 of the Final Report on Primary Productivity and Plankton Biomass (Jacques Whitford 1999: Fish and Fish Habitat Component Study Report 9 or 11). The expected inter-annual variation among the lakes was empirically evaluated by calculating the coefficients of variability for the data. These coefficients range from 8.4 percent for Atikonak Lake to 34.5 percent for Michikamau Lake with a mean of 25.1 percent among lakes (Table 2). The mean coefficient of variability was used as the best estimate of the standard deviation of historical variation in seasonal mean productivity of the lakes. Thus for any monitoring requirement, future estimates outside ± 50 percent of the historical mean (i.e., two standard deviations) would be judged to be statistically significant at the 5 percent level, provided that one assumes all of the lakes to constitute a 'population' with equal inherent variability.

Table 2 Comparison of Mean Areal Primary Production (mg C/m^3/d) Variability among Years

Lake	N (years)	Mean	Std. Dev.*	Coefficient of Variability (%)**
Atikonak	3	123.67	10.41	8.42
Gabbro	5	146.8	44.49	30.31
Lobstick	4	119.75	32.62	27.24
Michikamau	2	127	43.84	34.52
			Mean	25.12

* Standard deviation calculated using n-1 weighting
** Calculated as: (Std. Dev./Mean) *100

Coefficients of variability calculated for the 1998 seasonal data for the nine study lakes ranged from 20.7 percent to 59.1 percent with a mean of 38.3 percent (Table 3). Using the rationale presented above, this would imply that future means outside a $\pm$ 77 percent range of the 1998 value would be deemed statistically significant.

Table 3 Comparison of Seasonal Areal Primary Production (mg C/m^3/d) Variability among Lakes in 1998

Lake	N (dates)	Mean	Std. Dev.*	Coefficient of Variability (%)
Joseph	3	97	32.3	33.3
Atikonak	3	132.2	29.7	22.5
Ossokmanuan	3	86.2	39	45.2
Gabbro	3	104.6	49.2	47
Lobstick	3	96.4	55.3	57.3
Michikamau	3	96.1	56.8	59.1
Flour	3	80.8	30.2	37.3
Winokapau	3	66.2	15.1	22.7
Gull	3	81.9	17	20.7
			Mean	38.3

* Standard deviation calculated using n-1 weighting.
** Calculated as: (Std. Dev./Mean) *100

The comparison of primary production showed that the data from 1998 broadly overlapped the historical range except in Michikamau where the 1998 mean was below the range measured in 1971, the only previous year of observation. The overall ranges of both years did overlap, however and indicates the collected data is representative of typical conditions.

Phytoplankton Biomass - As noted in the Final Report on Primary Productivity and Plankton Biomass (Jacques Whitford 1999: Fish and Fish Habitat Component Study Report 9 of 11), there are historical values from 1970-1971 reported for peak phytoplankton biomass (Section 7.1.3 and Table 7.2 in Jacques Whitford 1999, Duthie and Ostrofsky 1974, 1975) but no historical values published for seasonal mean biomass. Kalff and Knoechel (1978) noted in their review of temperate zone phytoplankton dynamics that strong seasonal variation in phytoplankton biomass is not to be expected in oligotrophic lakes such as those of the lower Churchill River watershed. This expectation is supported by the data in Figures 6.15 and 6.16 of the Primary Productivity and Plankton Biomass Report (Jacques Whitford 1999).

To confirm, a reanalysis of the data for the four lakes which were sampled during two intermediate trips in addition to the three primary sampling trips reveals that the additional sampling had no consistent effect on the seasonal mean (Table 4).

The five-sample mean was 11.8 percent and 19.3 percent higher than the three-sample mean in the two upper watershed lakes (Joseph and Atikonak) but 2.7 percent and 0.4 percent lower in the two lower-watershed, more fluvial lakes (Flour and Gull, Table 4). Thus seasonal variation was least at the site to be affected most by the proposed Project. The low degree of seasonal variation extrapolates to expectation of low inter-annual variation in the absence of watershed change (Kalff and Knoechel 1978).

A similar comparison of three-sample and five-sample means for chlorophyll data indicates that the five-sample means were from 4.4 percent to 14.3 percent lower than the three-sample means for lakes outside the proposed reservoir area; Joseph, Atikonak and Flour lakes and marginally higher (0.8 percent) in Gull Lake (Table 4).

Similar to primary productivity, sampling is considered sufficient and the collected data is representative of typical conditions.

Zooplankton Biomass – There are no historical annual zooplankton data for the Churchill River watershed lakes, but given the relative consistency of the primary production data noted above it is not likely that there has been any secular change in annual zooplankton composition and biomass over the same time period. Therefore, similar to primary productivity and phytoplankton comparisons above, sampling is considered sufficient and the collected data is representative of typical conditions.

There are seasonal patterns in composition and biomass of the zooplankton in oligotrophic lakes which result from the differing life history patterns of the different taxonomic groups. Copepods typically start out with a relatively high spring biomass consisting of over-wintering adults and late-stage copepodites that reproduce to give way to a new generation(s). Rotifers also start out with high populations in the spring that subsequently decline, presumably due to predation and/or food limitation. Cladocerans start out with very low populations that develop from over-wintering resting eggs (epphipia) and typically increase throughout the summer followed by production of resting eggs in the fall.

Seasonal changes in zooplankton biomass tend to be gradual due to the relatively long, temperature-dependant generation times of several weeks for cladocera and one-two months for copepods. The timing of sampling trips is thus not critical and this is born out by a comparison of three-sample and five-sample means for the four lakes where two intermediate samples were collected (Table 4) in addition to the three regular sampling trips. The five-sample mean ranged from 14.4 percent higher than the three-sample mean in Flour Lake to 16.5 percent lower in Joseph Lake. There was a much larger percentage difference (+78.1 percent) in Gull Lake but this was relative to an extremely low population where the presence or absence of just a few adults in a sample can make a large difference in total biomass. Biomass estimates in these circumstances are subject to high variability resulting from random Poisson sampling error.

Primary production and plankton biomass results were used in the assessment to describe the existing conditions within the assessment area as well as input to post-project conditions. Volume IIA, Section 4.12.2 (page 4-40) presents the assessment of change in habitat quality during operation and maintenance of the Project.

Table 4 Comparison of Three-Sample and Five-Sample Means

Lake	Phytoplankton Biomass (mg/m^3)			Chlorophyll (mg/m^3)			Zooplankton (mg/m^3)		
	3 sample mean	5 sample mean	% difference*	3 sample mean	5 sample mean	% difference	3 sample mean	5 sample mean	% difference
Joseph	323	361	11.8	1.47	1.26	-14.3	212	177	-16.5
Atikonak	300	358	19.3	1.6	1.53	-4.4	179	164	-5.6
Flour	404	393	-2.7	1.94	1.8	-7.2	9	10.3	14.4
Gull	245	244	-0.4	1.06	1.07	0.8	4.1	7.3	78.1

* Calculated as: ((5 sample mean – 3 sample mean) / (3 sample mean)) *100

References:

Bradbury, C., A.S. Power, and M.M. Roberge. 2001. Standard Methods Guide for the Classification /Quantification of Lacustrine Habitat in Newfoundland and Labrador. Fisheries and Oceans, St. John's, NL. 60 pp.

Duthie, H.C. and M.L. Ostrofsky. 1974. Plankton, Chemistry and Physics of Lakes in the Churchill Falls region of Labrador. J. Fish. Res. Bd. Can. 31: 1105-1117.

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Ostrofsky, M.L. and H.C. Duthie. 1975. Primary productivity, phytoplankton and limiting nutrient factors in Labrador lakes. Int. Revue ges. Hydrobiol. 60:145-158.

Ostrofsky, M.L. and H.C. Duthie. 1980. Trophic upsurge and the relationship between phytoplankton biomass and productivity in Smallwood Reservoir, Canada. Can. J. Bot. 58:1174-1180.

Requesting Organization – Joint Review Panel **Information Request No.: JRP.53**

Information Requested:

The Proponent is asked to provide:

b. **baseline information on benthic invertebrates (both seasonally and spatially), particularly during the period prior to major insect emergences;**

Response:

No additional baseline information regarding benthic invertebrates is required for the effects predictions in the EIS. The measurable parameters used in the EIS had sufficient data to assess the potential effects on the aquatic ecosystem. Benthic macroinvertebrates have been shown to be good indicators of habitat health (Reice and Wohlenberg 1993). As such they are typically included in baseline fish habitat characterization and are, on occasion, included in monitoring programs; however, fish habitat classification and quantification required as part of the Fisheries Act Authorization process does not rely heavily upon benthic invertebrate data. As such, the sampling is considered adequate.

The benthic invertebrate study completed in 1999 includes the benthic invertebrate raw data collected during the study period (Jacques Whitford 1999: Fish and Fish Habitat Component Study Report 10 of 11). These data can be found in Appendix 4 of the report. Most of the benthic invertebrates were identified down to genus and many were identified to species. Some insect families, such as the chironomids, are difficult to identify down to species, without destroying the specimen.

As stated previously, the sampling effort with respect to benthic invertebrates is appropriate. This is supported by the series of cumulative species graphs generated from the benthic invertebrate raw data (Figure 1). This type of graph can be a simple indicator of the adequacy of the number of replicate samples collected from sampling stations. The cumulative number of species collected is plotted against the number of replicate samples collected, with the idea that the more replicate samples collected; the fewer new species should appear in each subsequent replicate. Ideally, the graph should show a sharp increase in the number of species, followed by a plateau. The plateau indicates that all species present in that location are represented in the samples taken and more sampling would no longer yield more new species. The figures present the overall sample number taken at each station and the cumulative number of species collected.

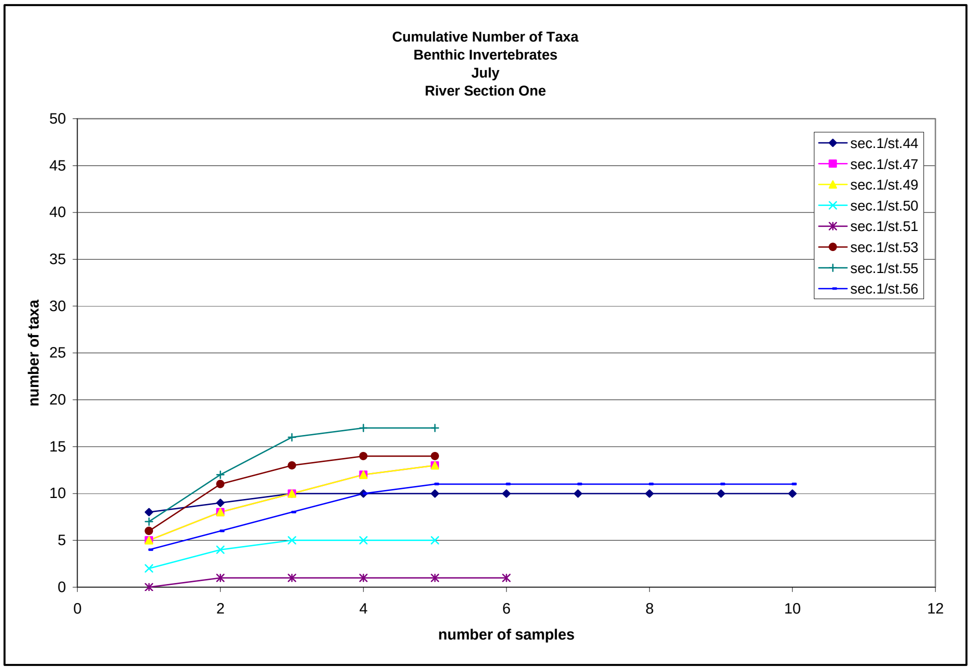

Figure 1a Cumulative Species Graph

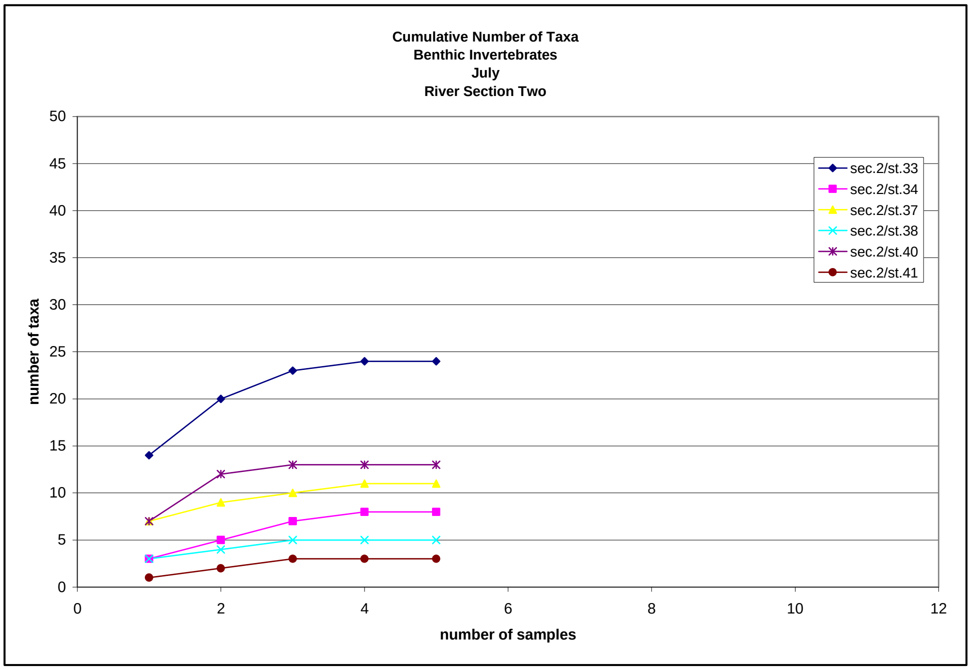

Figure 1b Cumulative Species Graph

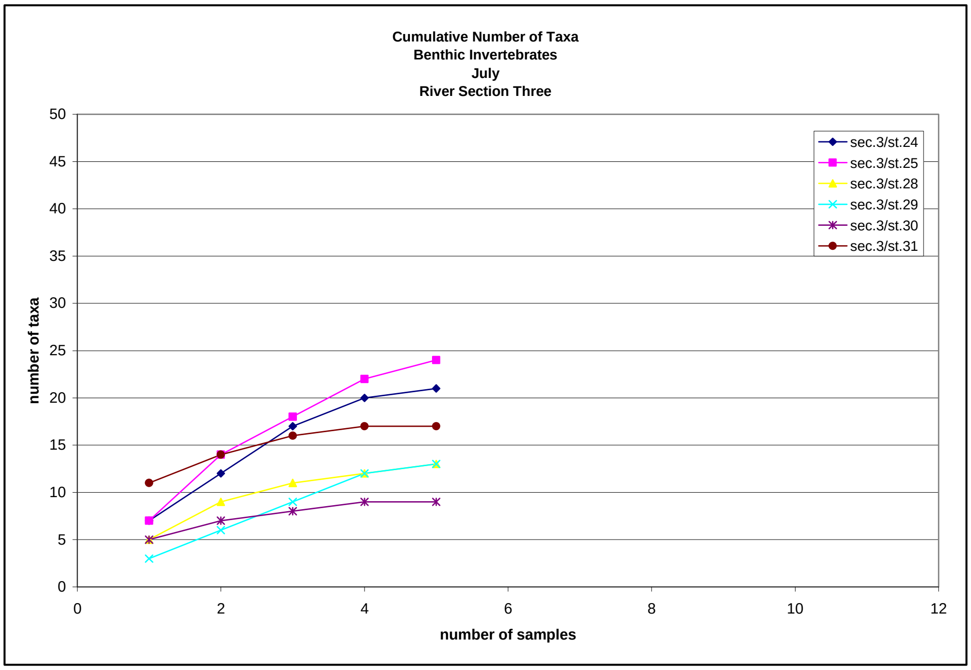

Figure 1c Cumulative Species Graph

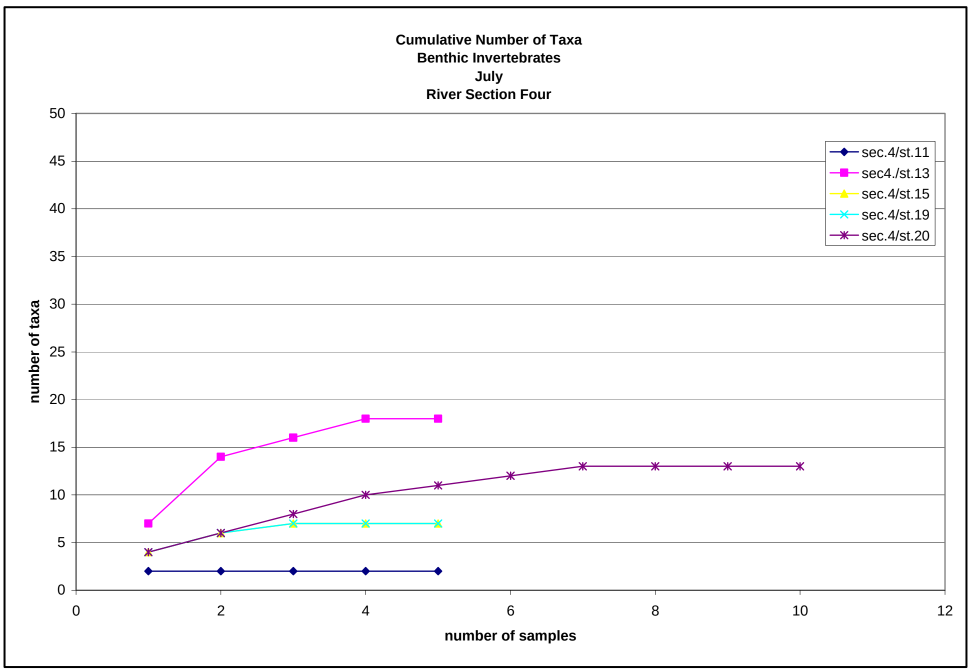

Figure 1d Cumulative Species Graph

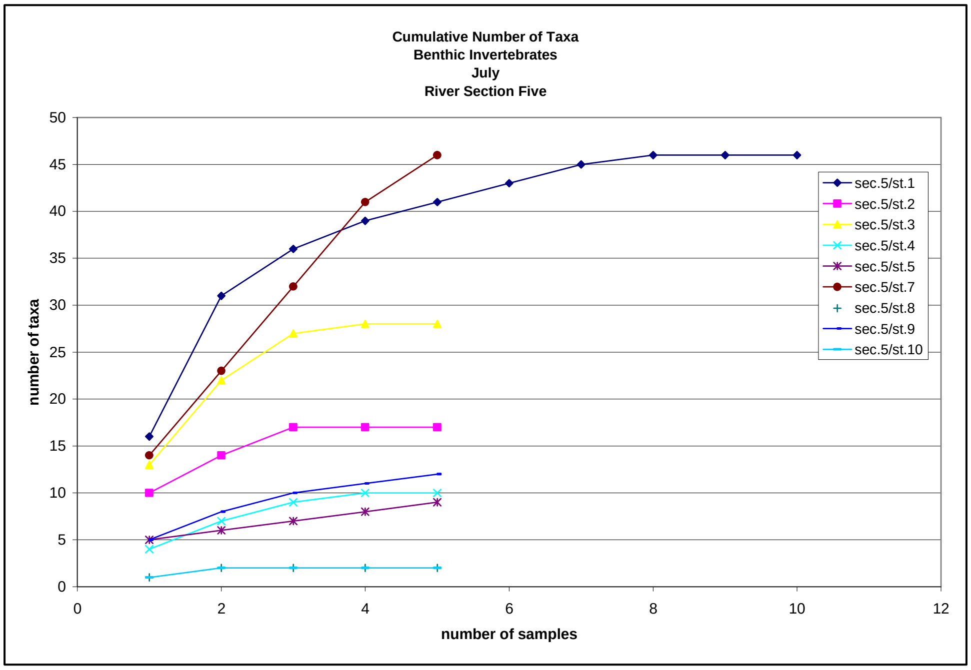

Figure 1e Cumulative Species Graph

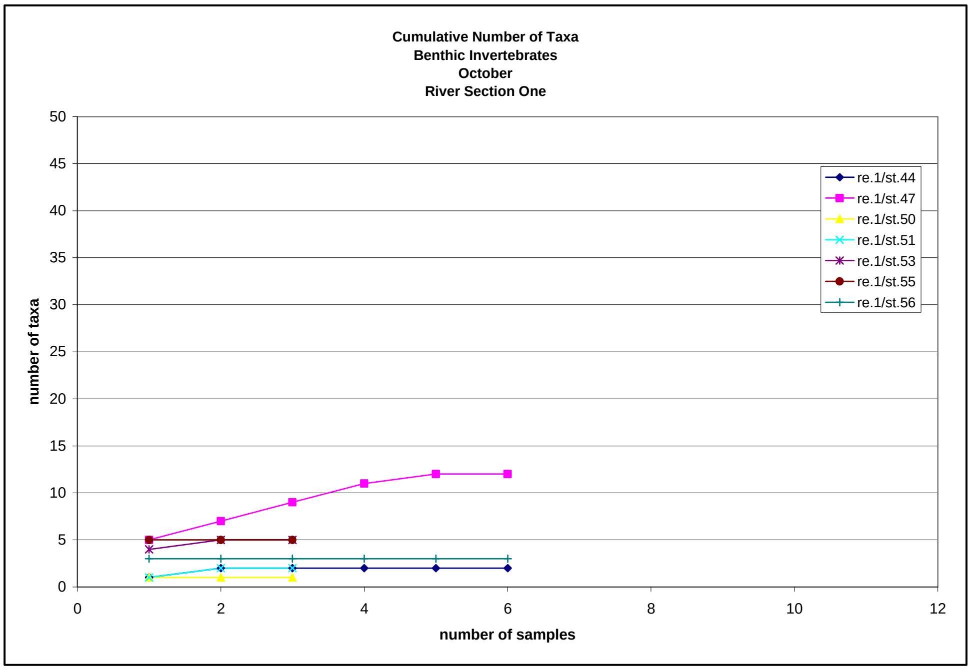

Figure 1f Cumulative Species Graph

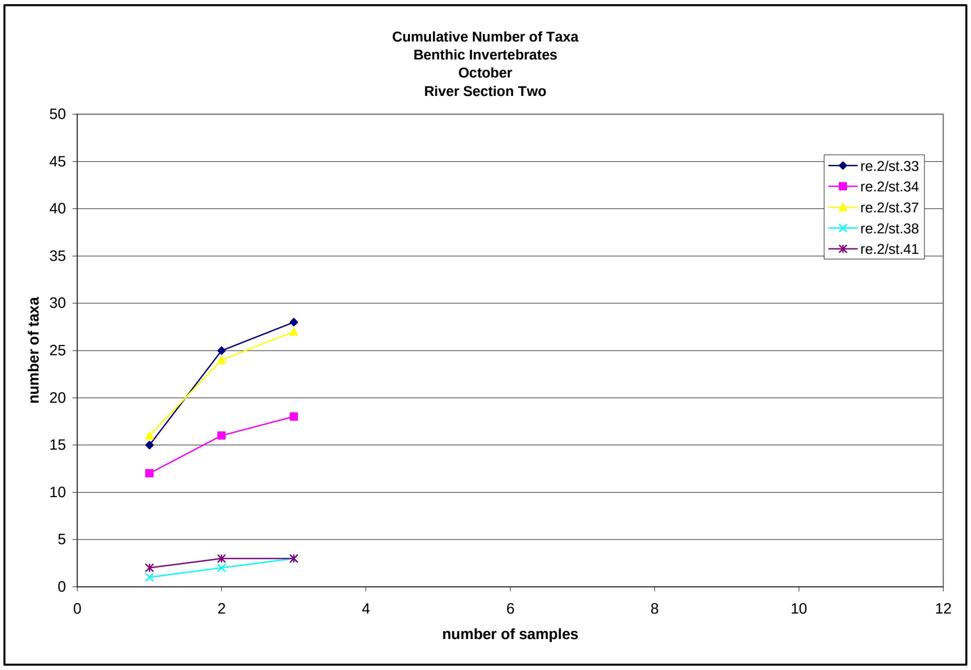

Figure 1g Cumulative Species Graph

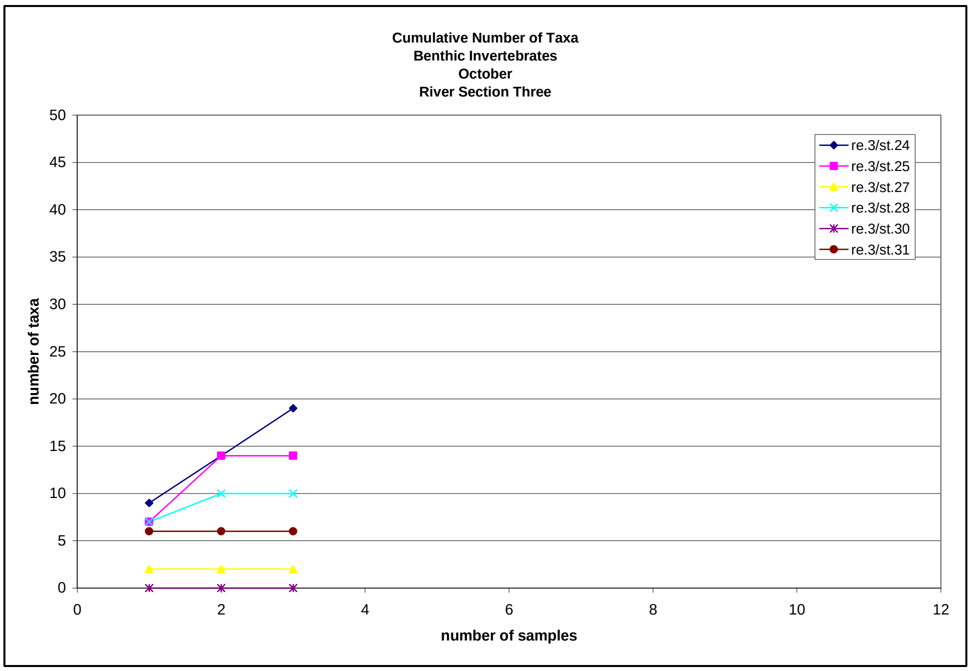

Figure 1h Cumulative Species Graph

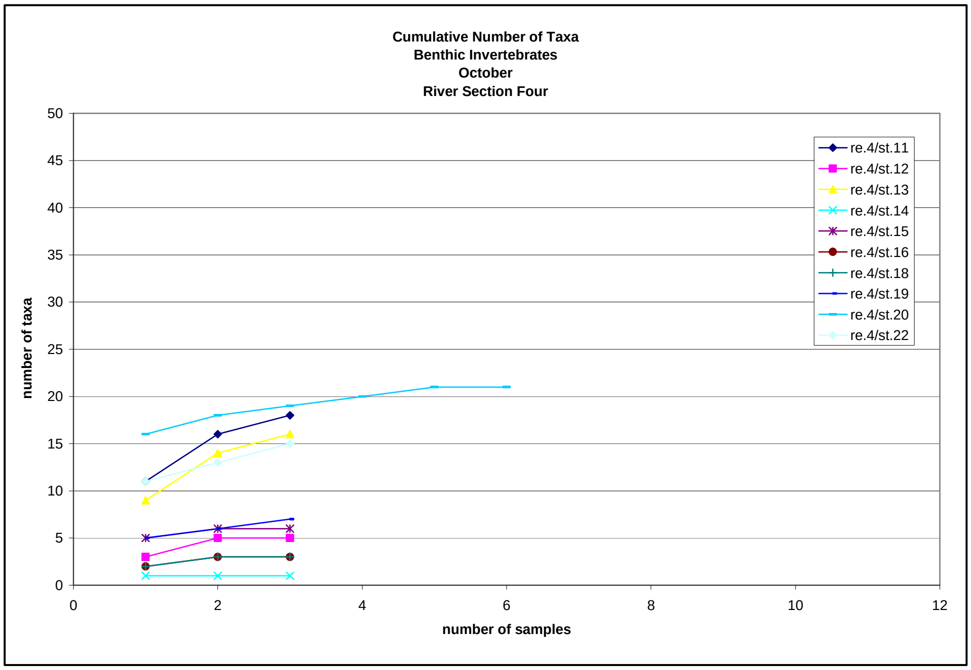

Figure 1i Cumulative Species Graph

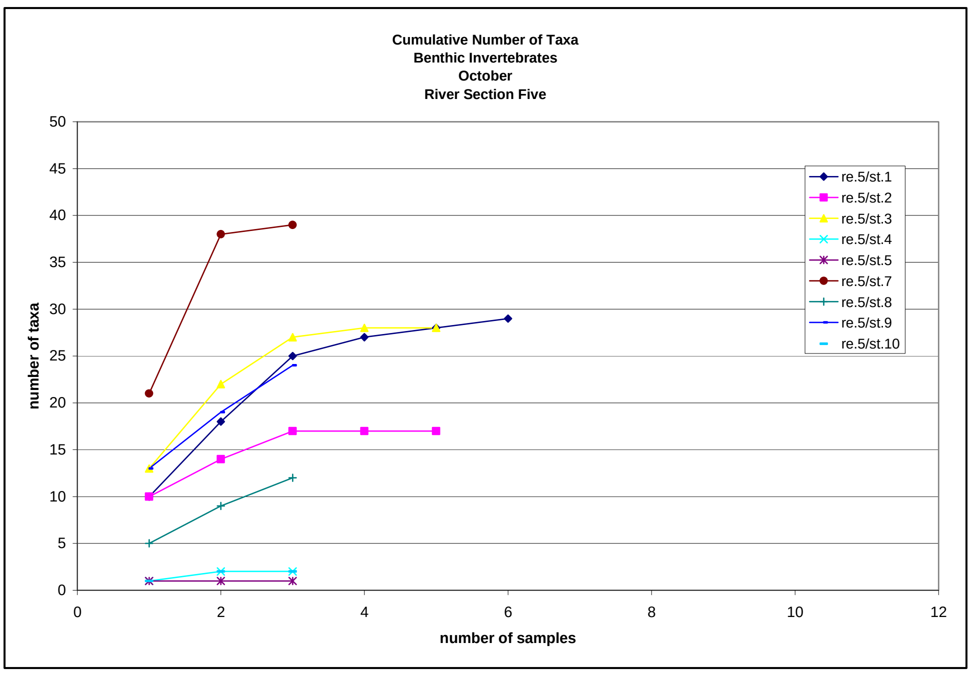

Figure 1j Cumulative Species Graph

References:

Jacques Whitford. 1999. Benthic Invertebrate Study of the Churchill River (LHP 98-09). Prepared for Newfoundland and Labrador Hydro, St. John's, NL.

Reise, S.R. and M. Wohlenberg. 1993. Monitoring freshwater benthic macroinvertebrates and benthic processes: Measurements for ecosystem health. Pages 287-305 In: Rosenberg, D.M. and V.H. Resh (eds.) Freshwater Biomonitoring of Benthic Macroinvertebrates. Chapman and Hall, New York. ix + 488pp.

Requesting Organization – Joint Review Panel **Information Request No.: JRP.53**

Information Requested:

The Proponent is asked to provide:

c. **baseline information on key biological parameters (i.e. fecundity, age, growth, food and feeding) of various fish species in order to meaningfully demonstrate change at the population level;**

Response:

The baseline for the requested key environmental parameters is provided in the following listed component studies. These studies have also consolidated previous data collected on these parameters. The cumulative information available on biological parameters such as fecundity, age, growth, food and feeding is such that any post-project comparison and monitoring will be able to detect meaningful change at the population level.

AGRA (1999): Fish and Fish Habitat Component Study Report 8 of 11.

- Section 3.1 to 3.8 provides the life history of fish caught on the lower Churchill River and interprets it in context to the available knowledge of the study area.
- Section 3.9 presents a brief life history of fish that were found in reduced numbers, have restricted distribution in the lower Churchill River or were not caught during the survey.
- Pages 42 to 47 gives the CPUE of fish collected in the lower Churchill River during the study.
- Pages 48 to 116 lists the fish caught in the lower Churchill River and presents catch rates, growth in length, growth in weight, sex ratios and maturity, stomach contents, gear selection, and mortality rate.
- Table 4.24 on page 117 lists the fish caught within the tributaries of the lower Churchill River and Table 4.26 summarizes the standing stock and biomass estimate for each tributary.
- Section 5.1 and Figure 5.1 show that mainstream sampling of the lower Churchill River in 1998 generally concurs with previous work with respect to parameters such as growth rate (taken from Anderson 1985).

AMEC (2000)

- The study's main objective was to capture a representative sample of fish residing in the lower Churchill River for mercury analysis but to also augment the 1998 freshwater fish sampling program (page 1 Section 1.1).
- Sections 3.3.1.1 to 3.3.1.15 provides information on the catches, growth in length, growth in weight, sex ratios and maturity, stomach analysis, and selection by gear.

Bruce et al. (1975)

- Lists all the species which occur in the lower Churchill River and its watershed.

Bruce (1979)

- An age growth analysis of Brook trout was conducted in the Churchill River watershed. The lower Churchill River area was sampled as part of the survey (Churchill Falls to Muskrat Falls). The report discusses size composition, age composition, growth and mortality, length-weight relationships, mortality, reproductive biology, and food (pages 3 to 5, tables 1 to 5 and figures 1 to 5).

Ryan (1980)

- Figures 8 and 9 illustrate the CPUE (Catch per Unit Effort) for fish caught on the lower Churchill River. The author also summarizes the catches, growth in length, growth in weight, sex ratios and maturity, selection by gear, food study and mortality rate of the fish within the lower Churchill River (pages 17 to 81).

Anderson (1985)

- Pages 165 to 172 the author gives a brief description of the distribution, length versus age, and age or size at which the fish reaches maturity.

References:

AGRA Earth & Environmental Ltd. 1999. Fish and Fish Habitat, Churchill River Power Project (LHP98-07). Prepared for Labrador Hydro Project, St. John's, NL.

AMEC Earth & Environmental Ltd. 2000. 1999 Freshwater fish Mercury Sampling, Churchill River, Labrador (LHP99-07). Prepared for Labrador Hydro Project, St. John's, NL.

Anderson, T.C. 1985 The Rivers of Labrador.Can. Spec. Publ.Fish. Aquat. Sci. 81:389p.

Bruce, W.J., C.J. Morry, L.W. Rowe, and R.J. Wiseman. 1975. An Overview of Fisheries Problems Associated with the Proposed Lower Churchill Hydroelectric Development, Gull Island, Labrador. Internal Report Series No. NEW/1-75-2. Resource Development Branch, Newfoundland Region, Environment Canada.

Bruce, W.J. 1979. Age and Growth of Brook Trout Salvelinus fontinalis, in the Churchill River Watershed, Labrador. Fisheries Marine Service Technical Report 907. Department of Environment, St. John's, NL, Canada.

Ryan, P.M. 1980. Fishes of the Lower Churchill River, Labrador. Fisheries and Marine Service Technical Report No. 922.

Requesting Organization – Joint Review Panel **Information Request No.: JRP.53**

Information Requested:

The Proponent is asked to provide:

d. **additional fish data for all lentic zones in Winokapau Lake, particularly the extreme profundal depths; and**

Response:

No additional baseline information regarding lentic zones in Winokapau is required for the effects predictions in the EIS. The measurable parameters used in the EIS had sufficient data to assess the potential effects on the aquatic ecosystem. The requested data can be found within the Fish and Fish Habitat Component Studies appended to the EIS (AGRA 1999: Fish and Fish Habitat Component Study Report 8 of 11, AMEC 2000: Mercury Component Study Report 5 of 5; AMEC 2007: Fish and Fish Habitat Component Study Report 4 of 11).

The sampling of Winokapau Lake was conducted throughout all lentic zones identified in DFO's Standard Methods Guide for the Classification/Quantification of Lacustrine Habitat in Newfoundland and Labrador (Bradbury et al. 2001). The assessment and associated Fish Habitat Compensation planning process also includes these classifications. The water depth that differentiates the two zones (littoral and non-littoral) was delineated using measured Secchi depth and depth categories as per Bradbury et al. (2001). The depth differentiation was determined to be 5m. With respect to depth of sampling, consideration was given to the estimated maximum bottom depth of the post-project reservoirs and that sampling results would be used, to some degree, to estimate post-project habitat use. The extreme water depths (currently up to 208m) of Winokapau Lake will only exist, post-habitat, in Winokapau Lake. The relative increase in water depth within the lake (approximately 10m) will not alter the near-bottom habitat of Winokapau Lake post-Project. Therefore, sampling effort was focused to what was practical in a remote location and to what would be beneficial in characterizing and assessing post-Project habitats.

The sample data for the non-littoral habitat in Winokapau Lake was submitted to DFO as part of the 1998, 1999 baseline reports (AGRA 1999, AMEC 2000) as well as with the HADD Determination Methodology in 2001 (AMEC 2001).

References:

AGRA Earth & Environmental Ltd. 1999. Fish and Fish Habitat, Churchill River Power Project (LHP98-07). Prepared for Labrador Hydro Project, St. John's, NL.

AMEC Earth & Environmental Ltd. 2000. 1999 Freshwater fish Mercury Sampling, Churchill River, Labrador (LHP99-07). Prepared for Labrador Hydro Project, St. John's, NL.

AMEC Earth & Environmental Ltd. 2001. Churchill River Power Project: A Proposed Framework for HADD Determination (LHP00-07). Prepared for Labrador Hydro Project, St. John's, NL.

Bradbury, C., A.S. Power, and M.M. Roberge. 2001. Standard Methods Guide for the Classification /Quantification of Lacustrine Habitat in Newfoundland and Labrador. Fisheries and Oceans, St. John's, NL. 60 pp.

Requesting Organization – Joint Review Panel **Information Request No.: JRP.53**

Information Requested:

The Proponent is asked to provide:

e. **Analysis of phytoplankton and zooplankton samples and fish food organisms at a finer taxonomic level (down to species where possible) in order to properly assess ecosystem and trophic dynamics.**

Response:

No additional baseline information regarding ecosystem and trophic dynamics is needed for the effects predictions in the EIS. The measurable parameters used in the EIS had sufficient data to assess the potential effects on the aquatic ecosystem. The requested data can be found within the Fish and Fish Habitat Component Studies appended to the EIS (AGRA 1999: Fish and Fish Habitat Component Study Report 8 of 11, AMEC 2000: Mercury Component Study Report 5 of 5, Jacques Whitford 1999: Fish and Fish Habitat Component Study Report 9 of 11). The Fisheries Act HADD determination/Compensation process is habitat-based and as such so is the focus within the assessment method. The baseline data on fish food organisms allows further description of each species in terms of trophic feeding level (i.e. benthic, macroinvertebrate and/or piscivory feeding) and to some extent, an indication as to feeding habitat. It is also used in some instances as a baseline for post-project monitoring of fish habitat utilization. Resolution to a finer taxonomic level was not necessary.

References:

AGRA Earth & Environmental Ltd. 1999. Fish and Fish Habitat, Churchill River Power Project (LHP98-07). Prepared for Labrador Hydro Project, St. John's, NL.

AMEC Earth & Environmental Ltd. 2000. 1999 Freshwater fish Mercury Sampling, Churchill River, Labrador (LHP99-07). Prepared for Labrador Hydro Project, St. John's, NL.

Jacques Whitford. 1999. Primary Productivity and Plankton Biomass. Jacques Whitford Environment Limited report prepared for Newfoundland and Labrador Hydro, St. John's, NL. v + 70 pp + Appendices.

IR# JRP.54

Fluvial Geomorphology - Change in Habitat Quantity

Requesting Organization – Joint Review Panel **Information Request No.: JRP.54**

Subject - Fluvial Geomorphology – Change in Habitat Quantity

Reference(s):

EIS Guidelines, Section 4.4.4.2 (Description of the Existing Environment – Aquatic Environment – Aquatic Environment)

EIS Volume IIA, Section 2.35 (Fish Habitat Characterization (p. 2-24 to 2-28)) & Section 4.11.1 (Change in Habitat Quantity During Construction (p. 4-29 to 4-38)) & Section 4.12.2 (Change in Habitat during Operation and Maintenance (p. 4-39 to 4-44)), and Section 4.15 (Summary of Residual Environmental Effects and Evaluation of Significance (P. 4-57 to 4-59))

Hatch Ltd. 2007. *Ice Dynamics Study of the Lower Churchill River*. Prepared for Newfoundland and Labrador, Hydro, St. John's, NL

Hatch Ltd. 2008. *Hydraulic Modeling of River*. Prepared for Newfoundland and Labrador Hydro, St. John's, NL

Related Comments / Information Requests:

CEAR # 202 (Natural Resources Canada)

IRs # JRP.23, 43, 49, 50, 51, 52, 53, 55, 56, 90

Rationale:

The proponent's conclusions concerning future habitat along the Lower Church River are quantified in Table 4-10 (p 4-35) and 4-13, shown diagrammatically in Figures 4-8 to 4-11 (p. 4-31 to 4-34), and mentioned in the text of section 4.12.2 Change in Habitat during Operation and Maintenance (4-39 to 4-44). There are five classes of habitat that includes littoral, profundal, slow velocity, intermediate velocity and fast velocity in Table 4-10 of which the littoral and profundal are depicted as 'lacustrine' in Figures. 4-8 to 4-11. Definitions for the slow, intermediate and fast velocity classes are listed in Table 2-6 (p. 2-27) and those of littoral and profundal are discussed in the text of section 2.3.5.1 Lacustrine Classification (p. 2-25 to 2-26).

NRCan has indicated that the creation of littoral and profundal habitat (i.e., lacustrine) seems under-estimated in Table 4-10 and Figures. 4-8 to 4-11 for the Churchill Falls tailrace to Gull Island Rapids and Gull Island Rapids to Muskrat Falls reaches. Specifically, the ~27 km reach section of valley below the Winokapau Lake along the Churchill Fall tailrace to Gulf Island Rapids reach is mapped as slow velocity as is the entire Gull Island Rapids to Muskrat Falls reach. In both cases, the category lacustrine seems more appropriate for at least part of these sections of reservoir. The EIS mentions the modeling of velocity and water conditions in the future reservoirs and refers to a report by Hatch (2007). However, the only report in the References attributed to Hatch (2007) is a report on "Ice dynamics of the lower Churchill River" (p. 43 of references), and this report does not contain data on modeling of velocity and water conditions This data is not in the report by Hatch (2008) "Hydraulic Modeling of River" either.

The under-estimation of the post-project lacustrine environment is demonstrated in the table below provided by NRCan (CEAR #202) which was based on rough estimates of the mean velocity along selected cross-sections along these reaches. The estimated mean velocities were derived using discharges of 1500 and 4000 m^3/s (see Figure 2-3 (p. 2-18)) divided by flow depth (scaled from Figure 4-7 (p. 4-30)) and flow width (scaled from the reservoir width from Figure 4-8 to 4-11 (a rectangular cross-section is assumed). All of these mean flow velocities are 7 to 50 percent less than the 0.64 m/s velocity in Table 2-6 where the slow velocity class is defined.

Table 1 Rough estimates of flow velocity within reservoirs

Location	Discharge (m^3/s)	Channel Width (m)	Channel Depth (m)	Estimate Mean Velocity (m/s)
Sill at downstream end of Winokapau Lake	4000	1500	20	0.13
"	1500	1500	20	0.05
~13km below end of Winokapau Lake	4000	400	31.5	0.32
"	1500	400	31.5	0.12
Mid-way along Gulf Island Rapids to Muskrat Falls reach	4000	1400	24	0.12
"	1500	1400	24	0.04

Requesting Organization – Joint Panel Review **Information Request No.: JRP.54**

Information Requested:

The Proponent is asked to provide either:

a. **justification for the "slow velocity" classifications of the above mentioned sections of the reservoir; or**

b. **revisions to the text in 4.12.2, Figures 4-8 to 4-11 and, Tables 4-10 and 4-13, to better portray the resulting distribution of slow and lacustrine habitats along the river resulting from the proposed Project.**

Based on the results above, if necessary, the Proponent is asked to re-evaluate the assessment of the Project's impacts on aquatic habitats and fish communities.

Response:

All classifications of post-Project aquatic habitat within the Project area are based on detailed hydraulic modeling completed by Hatch as part of the Ice Dynamics Study and detailed field measurements within the lower Churchill River system. The hydraulic modeling used in the habitat classifications incorporates detailed cross-section transect and flow survey data measured throughout the lower Churchill River and is not based on rough scaled data from figures and assumptions of rectangular channel form within the lower Churchill River. For example, transect cross-sections and depth/velocity data was collected using georeferenced Acoustic Current Doppler Profile (ADCP) data for use in the modeling (for example, see Section 4.2 of the 2006 Fish and Fish Habitat Baseline Study appended to the EIS). As such, no revisions to the text are required.

Details of the delineation between lacustrine and "slow velocity" habitat types within the reaches identified above is presented in Section 5.1.1.1 (pages 80 to 87) of the Habitat Quantification report included in the Aquatic Environment Component Studies appended to the EIS. The following is a summary.

The determination of what is a lake and what is a river is usually straight forward. The combination of water velocity, depth and width can generally be used to separate the two and within the same system, the differences are usually self-evident. The post-project conditions for both the Gull Island and Muskrat Falls Reservoirs; however, are a gradual change from relatively fast moving water to slower moving with little variation in width and a general deepening of water as it approaches each respective powerhouse. Reservoirs created by the damming of a river such as proposed for the Project may have characteristics of a river for long distances into the reservoir, and include a distinct riverine zone dominated by flow and mixing, followed by a transition zone where flow velocity slows, transported sediments start to settle out, and water clarity increases (Kimmel and Groeger 1984). The distinction between where riverine stops and lacustrine begins within each proposed reservoir is difficult as the flow of water through each is considerable (i.e., 1,780 m^3/s MAF in Gull Island and 1,840 m^3/s MAF in Muskrat Falls) and therefore measurable mean water column velocities will remain throughout each reservoir. However, the Gull Island Reservoir, for example, will approach 97m in depth at the powerhouse and therefore the section of river close to the dam may behave more lake-like than riverine.

While typical definitions of lakes refer to their larger size, relative depth and "static" nature, they do not offer any definitive quantitative criteria or thresholds to easily discriminate between lacustrine and riverine habitat in the post-project situation described above. However, among the various processes that occur within a lake or "static" waterbody is that of potential thermal stratification. Thermal stratification is the arrangement of water masses into separate, distinct horizontal layers as a result of differences in density caused by changes in temperature (Bradbury et al. 2001). A thermocline is a common phenomenon within deep bodies of water and is described as the layer in a thermally stratified body of water where water temperature decreases at a rate of more than 1°C for each meter of depth (Bradbury et al. 2001). It can therefore be assumed that this process does not occur in riverine habitat as higher velocities and/or shallower depths would create turbulence sufficient to disrupt the stable conditions required for thermocline formation. This combination of high flows with sufficiently high velocities and/or shallow water can also therefore disrupt thermocline formation in the proposed reservoirs.

This characteristic (the potential persistence of a thermocline) has been used to provide a reasonable delineation of lacustrine habitat within each of the reservoirs in that the depth and velocities have to be such in each reservoir (i.e., be deep enough and slow enough) that a thermocline can form and persist.

In order to provide a reasonable delineation, field measurements, calculations and modelling results have been completed. As a summary, the Gull Island Reservoir is estimated to be 222 km in length with total water storage of 4.3×10^9 m^3. The water depth just upstream of the dam is estimated at 97 m with a decrease in water depth as the reservoir continues upriver. The exception would be Winokapau Lake which is approximately 120 km upriver from the proposed Gull Island dam site and is an existing deep water lake. Winokapau Lake is approximately 45 km long, up to 1.5 km wide with maximum depths over 200 m. The Muskrat Falls Reservoir is estimated to be 59 km in length with total water storage of 1.5×10^9 m^3. The water depth just upstream of the dam is estimated at 43 m with a decrease in water depth as the reservoir continues upriver toward the tailrace of Gull Island Reservoir. There is also an existing deep water lake in the proposed Muskrat Falls Reservoir (Gull Lake) which is approximately 1km long and has depths in excess of 55 m.

Water quality sampling conducted in 1998 and 2006/07 indicated that most areas of the Churchill River are well mixed with no evidence of thermal stratification (Jacques Whitford 1999; Minaskuat 2007). In 1998, a thermocline (defined as a temperature change of >1°C/m depth) was observed within Winokapau Lake during July and August. No other evidence of thermal stratification was detected at other locations or at other times during the sampling program (Gull Lake does not form a thermocline with pre-project transect depths and velocities between 46-57 m and 0.04-0.05 m/s, respectively). The stratification of Winokapau Lake occurred deep in the water column, typically between 23 and 27 m depth. It should be noted that thermal stratification was also not evident in Winokapau Lake in 2006/07.

In order to provide an indication of the relative volume of the reservoirs and the water retention times for both, the turnover rates (total volume/average inflow) of each were calculated. Muskrat Falls Reservoir has an anticipated turnover rate of 10 days while Gull Island Reservoir has a rate estimated at 28 days.

Thermal simulation modelling of the mean monthly water temperatures for various locations in the existing and future lower Churchill River were conducted by Hatch using a typical pre-project dataset (the year 1983) from Goose Bay and Churchill Falls (Hatch 2007). The results indicate that there is a predicted time lag in warmup (spring) and cooldown (fall) temperatures of a couple of weeks and a slight predicted overall decrease in mean water temperatures of less than 4°C within the period when a thermocline is most anticipated. These conditions would not likely affect the potential for future thermocline formation.

It was estimated that no thermocline will form in the Muskrat Falls Reservoir due to the overall shallow reservoir depths, higher mean velocities, and the short turnover period. In the Gull Island Reservoir, it has been estimated that a thermocline similar to Winokapau (i.e., same time of year and relative depth) will form at the lower end near the dam site. It has also been estimated that while there may be some mixing between the upper and lower thermal layers, the Gull Island Reservoir discharge will be predominantly from the upper layer, due to the location of the intake invert relative to the bottom of the predicted thermocline (M. Rosales, pers. comm.). Existing data can be used to establish the depth at which a thermocline would most likely form within Gull Island Reservoir and hence the approximate reservoir water depth needed to allow it to persist.

Anticipated depths and velocities at each survey transect were computed using a HAC-RAS open water model (a description of the model is provided in the Ice Dynamics Report appended to the EIS – Hatch 2007). The location of each transect is provided in Appendix D of the Habitat Quantification report (AMEC & Sikumiut 2007 – appended to the EIS). Each transect provides a pre-project water depth (m) and velocity (m/s) as well as post-project conditions (see Appendix D of the Habitat Quantification report). These results can be used against thermal results for each reservoir to determine a reasonable water depth and velocity where a stable thermocline may develop and persist.

The information presented above has been used to determine that a thermocline will not form within the Muskrat Falls Reservoir; therefore this reservoir will behave as riverine habitat and has been classified as such.

Based on pre-project information, a thermocline can establish within Winokapau Lake with pre-project transect depths and velocities between 84-216 m and 0.01-0.03 m/s, respectively. It has also been shown that Gull Lake does not form a thermocline with pre-project transect depths and velocities between 46-57 m and 0.04-0.05 m/s, respectively. These conditions have been considered the preliminary basis of requirements for thermocline formation in the lower portion of Gull Island Reservoir (i.e., water depths greater than 50m and mean velocities less than 0.04m/s). Additional information has been used below to refine this prediction.

It has been determined by Hatch that a thermocline will form within the lower portion of Gull Island Reservoir to a depth similar to that which currently forms in Lake Winokapau (i.e., 23-27 m deep). Based on the overall high flows (MAF of 1,780 m^3/s) and high estimated turnover time of 28 days (relative to Muskrat Falls), it can be assumed that adequate water depth will be required to allow a stable thermocline to form and persist. That is, there must be adequate water below the 23 to 27 m thermocline to allow a stable lower water layer to form and persist. With the high flows of Gull Island Reservoir, this water depth could be considerable. Transect data also shows that the water depths directly behind the Gull Island dam will be 97m and therefore ample water depths would be available for thermocline formation.

The modeled depth/velocity data from Muskrat Falls Reservoir outlines two contiguous sections of the reservoir with post-project depths greater than 23 to 27 m where no thermocline is anticipated (Table 1). However, depths greater than 25 m (31 to 69 m) can have mean velocities as low as 0.03m/s and have no thermocline.

Table 1 Summary of Post-Project Transects of the Muskrat Reservoir Greater than 25m Depth with no Thermocline Formation

Reach 1			Reach 2		
Km	Maximum Depth (m)	Mean Velocity (m/s)	Km	Maximum Depth (m)	Mean Velocity (m/s)
43.1	43	0.13	92.5	31	0.06
43.3	42	0.14	92.6	33.3	0.05
43.5	37	0.36	93.1	37	0.05
43.6	27.5	0.36	93.4	69	0.03
43.7	31	0.37	94.1	58	0.03
43.8	31	0.21	94.5	22	0.03
44.8	31.65	0.07			

Due to the relatively short nature of the two Muskrat Falls Reservoir reaches, the use of the maximum depths of 58 to 69m would overestimate the depths needed for a persistent thermocline formation in the Gull Island Reservoir. The relatively short reach lengths may also disrupt thermocline formation even though adequate depths and velocities are present over a relatively short distance. Obviously, the depth and velocity values from each transect are an oversimplification of a complex, dynamic situation, however, the two reaches do suggest that water depths up to 40 m could contain enough flow to disrupt thermocline formation with mean velocities as high as 0.14 m/s.

Based on the transect results in Table 1 above, the MAF through Gull Island Reservoir (1,780 m^3/s) and its turnover rate (28 days), it can be conservatively assumed that at least 35m of water depth (i.e., 8 to 12 m of water below the thermocline) would be needed to establish a stable thermocline within the Gull Island Reservoir as long as this depth is maintained for a considerable distance (i.e., at least 3 km). At 35m water depth, a very conservative upper mean velocity of up to 0.15 m/s over the same contiguous distance could provide stable water conditions for a thermocline to develop. This condition is met between the Gull Island dam location and chainage kilometre 178 on the Churchill River. Upriver of this location, riverine conditions will be maintained.

References:

Personal Communications:

Rosales, M. Hatch Ltd.

Literature Cited:

AMEC Earth & Environmental Ltd. and Sikumiut Environmental Management Ltd. 2007. Lower Churchill Hydroelectric Generation Project Habitat Quantification (TF6110443). Prepared for Newfoundland and Labrador Hydro, St. John's, NL. This document is included in the EIS Component Studies for the Aquatic Environment.

Bradbury, C., A.S. Power, and M.M. Roberge. 2001. Standard Methods Guide for the Classification /Quantification of Lacustrine Habitat in Newfoundland and Labrador. Fisheries and Oceans, St. John's, NL. 60 pp.

Hatch Ltd. 2007. Ice Dynamics of the Lower Churchill River. Prepared for Newfoundland and Labrador Hydro, St. John's, NL.

Jacques Whitford. 1999. 1998 Water and Sediment Quality of the Churchill River (LHP98-08). Jacques Whitford Environment Limited report prepared for Labrador Hydro Project, St. John's, NL.

Kimmel B. L. and A. W. Groeger. 1986. Limnological and ecological changes associated with reservoir aging. In: Reservoir Fisheries Management: Strategies for the 80's. Bethesda, Maryland. 103-109p.

Minaskuat Limited Partnership. 2007. Water and Sediment Quality in the Churchill River. Prepared for the Lower Churchill Hydroelectric Generation Project.

IR# JRP.55

Fluvial Geomorphology - Large-scale Mass Movements

Requesting Organization – Joint Review Panel **Information Request No.: JRP.55**

Subject - Fluvial Geomorphology - Large-Scale Mass Movements

References:

EIS Guidelines, Section 4.4.4.2 (Description of the Existing Environment — Aquatic Environment)

EIS Volume IA, Section 10.4.2 (Slope Stability (p. 10-4 to 10-5))

EIS Volume IIA, Section 4.7.4 (Bank Stability (p. 4-9 to 4-10))

EIS Volume IIB, Section 5.11.2 (Change in Habitat during Operation and Maintenance) & Section 5.11.2.1 (Water Management and Operating Regime (p. 5-61))

AMEC Earth & Environmental Ltd. 2008. *Bank Stability Study for the Proposed Lower Churchill Hydroelectric Generation Project Environmental Baseline Repo*rt. Prepared for Newfoundland and Labrador Hydro, St. John's, NL

Jacques Whitford. 1998. *Sea Level and Geomorphology of the Churchill River and Strait of Belle Isle (LHP 98-23).* Jacques Whitford Environment Limited report prepared for Newfoundland and Labrador Hydro, St. John's, NL

Northwest Hydraulic Consultants. 2008. *Lower Churchill Hydroelectric Generation Project Sedimentation and Morphodynamics Study.* Prepared for Newfoundland and Labrador Hydro, St. John's, NL

NRCan requested more information / additional studies on the recommendations of Jacques Whitford (1988) — in response, NRCan received a 4 pg. text provided by the Proponent's consultant (May 19, 2009)

Related Comments I Information Requests:

CEAR # 202 (Natural Resources Canada)

IRs # JRP.23, 43, 49,50,51,52,53,54,56,90

Rationale:

The EIS report relies on the component study of AMEC Earth & Environmental Ltd (2008) concerning bank stability issues arising from the proposed Project. AMEC Earth & Environmental Ltd (2008) focuses on the shoreline development of the proposed reservoir arising from the effects of waves and currents, and provides maps depicting: terrain stability, soil erosion potential, wave energy, and shoreline erosion potential. However, the component study of Jacques Whitford (1998) mentions that 16 sliding failures having a surface area of > 1 km^2 are seated in glaciomarine silt and clay sediments within the Lower Churchill Valley between Gull Island Rapids and Muskrat Island (see section 6.6.4 Mass Movements, p. 46-47). Several of these failures are considered to have occurred within the last 30 years (relative to the date of the report); Jacques Whitford (1998) indicates that further research is required "to more definitively establish the susceptibility of the glaciomarine silt and clay sediments to failure, the frequency of failure events, and the effects of water saturation and changes in fluvial activity or base level resulting from reservoir formation" (p. 46

The existence of the Jacques Whitford (1998) study and its recommendation for further research is acknowledged in AMEC Earth & Environmental Ltd. (2008) in a review of previous studies (specifically p. 31-33). However, AMEC Earth & Environmental Ltd. (2008) does not address the occurrence of large-scale sliding failures along the reservoir margins.

Requesting Organization – Joint Review Panel **Information Request No.: JRP.55**

Information Requested:

The Proponent is asked to provide:

a. **information that specifically addresses the susceptibility of the glaciomarine silt and clay sediments to failure, the frequency of failure events, and the effects of water saturation and changes in fluvial activity or base level resulting from reservoir formation, as was recommended by the Jacques Whitford (1998) study; and**

Response:

The existing slope failures along the lower Churchill River are predominantly the result of undermining of the river bank and the continuing movement, or creep, of the existing progressive slides. Failures due to undermining are generally instantaneous and will continue to occur until the establishment of a stable beach, inshore and bluff. Localized failures in this soil-type would be common upon initially raising the reservoir, until the formation of a new shoreline and beach/inshore (see Section 6.1 of AMEC 2008 report). The potential presence of layers of differing gradations of soil may also add to its instability. Once a stabilized shoreline has been developed, failures due to undermining of the river bank are anticipated to become minimal. Riemer (1992) reviewed 60 known case histories on reservoirs created during large dam construction and indicated that approximately 85 percent of slope failure events occurred either during construction and/or during reservoir filling, or within 2 years of project completion. The occurrence and magnitude of the sides was also found to increase during periods of prolonged wet conditions, such as intense rainfall and spring conditions.

Slope failures within glacial marine soils are not uncommon; they are due predominantly to the fineness of this soil type, typically silt and clay size particles, and also low consolidation. Published research has indicated that the filling of reservoirs and fluctuations in water levels within the reservoir may promote instability and restart historical slope failures (Zaruba 1979) and that reservoir filing is a major cause leading to bank instability (Riemer 1992). The International Commission on Large Dams indicated that 75 percent of landslides which developed within reservoirs were the reactivation of historical landslides (ICOLD 2002).

Both the Jacques Whitford (1998: Socio-Economic Component Study Report 9 of 9) and the AMEC (2008: Hydrology Component Study Report 1 of 8) reports identify existing slope failures within the glacial marine soils between Gull Island rapids and Muskrat Falls. Documentation of these failures is identified in the Jacques Whitford (1998) report by way of symbols shown on Figure 6.2 of that report (16 failures reported in the text of the report and 22 symbols shown on the figure). The AMEC (2008) report identified 11 known progressive slide failure sites, which were presented in Table 8.2.4 and were also classified as very high on the Terrain Stability Classification maps. A comparison of the mapping between reports indicates that some of the AMEC areas encompass two or more of the Jacques Whitford areas.

References:

AMEC Earth & Environmental Ltd. 2008. Bank Stability Study for the Proposed Lower Churchill Hydroelectric Generation Project: Environmental Baseline Report. Report submitted to Newfoundland and Labrador Hydro. June 2008

ICOLD. 2002. Reservoir Landslides: Investigation and Management, in Bulletin 124 of the International Commission on Large Dams, Committee on Reservoir Stability.

Jacques Whitford. 1998. Sea Level and Geomorphology of the Churchill River and Strait of Belle Isle (LHP 98-23). Jacques Whitford Environment Limited report prepared for Newfoundland and Labrador Hydro, St. John's, NL

Riemer, W. 1992. Landslides and Reservoir, Kenote Paper, Proceedings of the 6th International Symposium on Landslides, Christchurch, 1373-2004.

Zaruba, Q. 1979. The Importance of Slope Movements in Dam Construction. International Association of Engineering Geology Symposium "Engineering Geological Problems in Hydrotechnical Construction", Tbilisi (USSR), 12–19 September 1979

Requesting Organization – Joint Review Panel **Information Request No.: JRP.55**

Information Requested:

The Proponent is asked to provide:

b. an assessment of the effects of the increased mass movements resulting from the Muskrat Falls reservoir formation on fish habitats.

Response:

In the Environmental Effects Assessment – Aquatic Environment section of the EIS (Volume IIA , Section 4.7.4,), an assessment of the bank stability in the lower Churchill River is presented. The new shoreline that will be created by the Muskrat Falls Reservoir will have similar physical characteristics to the present shoreline, with the exception that reservoir creation could increase bank stability. Page 4-9 states that the majority of the shoreline present between Gull Rapids and Muskrat Falls consists of fine sediments composed of mud, sand, and organics. This substrate is of little value to fish, and areas dominated by fine substrate are often characterized by reduced biodiversity and relatively low fish abundances. In regards to the bank stability and how it interacts with the fish habitat, the change between present habitat and post-project habitat is predicted to be minimal.

References:

AMEC Earth & Environmental Ltd. 2008. Bank Stability Study for the Proposed Lower Churchill Hydroelectric Generation Project: Environmental Baseline Report. Prepared for Newfoundland and Labrador Hydro, St. John’s, NL.

Jacques Whitford. 1998. Sea Level and Geomorphology of the Churchill River and Strait of Belle Isle (LHP 98-23). Jacques Whitford Environment Limited report prepared for Newfoundland and Labrador Hydro, St. John’s, NL

IR# JRP.56

Coastal Geomorphology - Churchill River Delta at Goose Bay

Requesting Organization – Joint Review Panel **Information Request No.: JRP.56**

Subject – Coastal Geomorphology – Churchill River Delta at Goose Bay

References:

EIS Guidelines Section 4.5.3 (Operation and Maintenance), Section 4.4.4.2 (Description of the Existing Environment — Aquatic Environment), Section 4.6.1 (Mitigation)

EIS Volume IA (Project Planning and Description)

EIS Volume IIA (Biophysical Assessment)

AMEC Earth & Environmental Ltd. 2008. *Bank Stability Study for the Proposed Lower Churchill Hydroelectric Generation Project: Environmental Baseline Report*. Prepared for Newfoundland and Labrador Hydro, St. John's, NL

Jacques Whitford. 1998b. *Sea Level and Geomorphology of the Churchill River and Strait of Belle Isle (LHP 98-23).* Jacques Whitford Environment Limited report prepared for Newfoundland and Labrador Hydro, St. John's, NL

Northwest Hydraulic Consultants. 2008. *Lower Churchill Hydroelectric Generation Project Sedimentation and Morphodynamics Study*. Prepared for Newfoundland and Labrador Hydro, St. John's, NL

Related Comments I Information Requests:

CEAR # 184 (Sierra Club Atlantic)
CEAR # 198 (G. Davis)
CEAR # 202 (Natural Resources Canada)

IRs # JRP.23, 43, 49, 50, 51, 52, 53, 54, 55, 90

Rationale:

At the outlet of the Churchill River into Goose Bay, a large semi submerged delta comprising sand, silt and clay has formed that extends from map km 1 near Mud Lake to map km -3 at Goose Bay.

Northwest Hydraulic Consultants conducted a sedimentation and morphodynamics study on the lower Churchill River to determine the potential effects of the Project on future sediment transport and associated river morphology (Northwest Hydraulic Consultants 2008). They concluded sediment transported downstream from Muskrat Falls will be much reduced. This will lead to a new equilibrium of erosion and deposition being established within the river below Muskrat Falls. The reach above Muskrat Falls supplies 60% of the total sediment inflow which would be trapped by Muskrat Fails Dam. The remaining 40% of the total sediment inflow enters the river downstream of Muskrat Fails as a result of erosion of terrace and bank sediments along the channel. A sediment deficit downstream, will lead to general downstream bed degradation as there was no evidence of appreciable quantities of coarser gravel-sized sediments for armouring. NW Hydraulics 2008 also concluded a shift in channel pattern from the present braided form to a more meandering form may occur. This change would be associated with increased rates of bank erosion. Increased rates of bank erosion would tend to reduce the extent of bed degradation by increasing the rate of sediment supply. Degradation was predicted to be negligible in the lower 10 km to the river mouth after 100 years.

NRCan has indicated that there are some uncertainties about the volume of sediment reaching the mouth of the Churchill River, given the reduction in sediment supply. The EIS does not discuss the impact of reduced sediment loads on the stability of the Churchill River delta from either the Upper Churchill or from the proposed Project. A decrease in sediment supply and sedimentation at the delta could cause adjustments in delta morphology and stability which in turn could result in increased local shoreline erosion and changes to the adjacent seabed.

Requesting Organization – Joint Review Panel **Information Request No.: JRP.56**

Information Requested:

The Proponent is asked to provide information on:

a. **the anticipated changes in delta morphology and stability as a consequence of reduced sedimentation;**

Response:

The SRH-1D sediment model was used to simulate the long-term channel response downstream of the Muskrat Falls dam. The results represent future anticipated bed material transport (primarily sand) in the lower Churchill River. The model incorporated the lower Churchill River downstream of Muskrat Falls to the head of the delta front at the mouth of the lower Churchill River where backwater effects reduce channel gradient and flow velocity, which in turn promotes sediment deposition (page 10, NHC 2008: Water Quality and Quantity Component Study Report 3 of 5).

Simulations of up to 100 years duration were made for both the “without Project” and “with Project” scenarios. The effect of Muskrat Falls Dam was estimated by the difference between these two scenarios.

Table 1 below summarizes the computed bed level changes at the downstream end of the model near the head of the delta front. Deposition was predicted to occur near the head of the delta after 100 years for both the “without Project” and the “with Project” case. The amount of deposition was slightly greater for Scenario 2 (with lateral sediment inflow occurring along the lower river). The predicted magnitude of deposition was greater for the “without Project” condition than for the “with Project” condition. As a result, the net effect of the Project was to reduce the amount of deposition by 0.2 to 0.3 m over a 100 year period (i.e. an average of 2 to 3 mm per year).

Table 1 Predicted Changes Near Head of Delta Front After 100 Years

Scenario	Assumed Sediment Inflow	Bed change near head of delta front (m)		Net Effect of Project
		Without Project	With Project	
1	No lateral inflow	+0.8	+0.5	-0.3
2	With lateral inflow	+1.0	+0.8	-0.2

These results are generally consistent with the morphology of the lower river observed from the available air photos. Bed material deposition occurs in this area even for the “with Project” condition because sediment is entrained from the river bed downstream of the dam due to bed degradation. As a result, the sediment transport rate near the lower end of the river system is changed much less than further upstream. This change has been determined to be negligible in the lower 10 km to the river mouth after 100 years (NHC 2008).

Reference:

Northwest Hydraulic Consultants. 2008. Lower Churchill Hydroelectric Generation Project Sedimentation and Morphodynamics Study. Prepared for AMEC Earth & Environmental and Newfoundland and Labrador Hydro, February 2008.

Requesting Organization – Joint Review Panel **Information Request No.: JRP.56**

Information Requested:

The Proponent is asked to provide information on:

b. **impacts to local shoreline and seabed stability and sedimentation caused by changes in delta dynamics; and**

Response:

Based on the above rate of change in deposition in this area (2 to 3 mm per year over a 100 year period), there would be no anticipated effects to local shoreline and seabed stability and sedimentation caused by changes in delta dynamics.

Requesting Organization – Joint Review Panel **Information Request No.: JRP.56**

Information Requested:

The Proponent is asked to provide information on:

c. **anticipated effects on the benthic community and aquatic habitats at or in the vicinity of the delta.**

Response:

Based on the above rate of change in deposition in this area over a 100 year period, there are no anticipated effects on the benthic community and aquatic habitats at or in the vicinity of the delta.

IR# JRP.57

Special Areas

Requesting Organization – Joint Review Panel **Information Request No.: JRP.57**

Subject - Special Areas

References:

EIS, Volume III, Section 2.8.11 (Existing Environment – Special Areas)

Related Comments / Information Requests:

CEAR # 151 (G. Sabau)

Rationale:

The EIS mentions that "[t]wo special sites were identified under the 1970s International Biological Program (IBP) due to the presence of Common Wood Sorrel at the western end of Gull Lake and the presence of sand dunes along the river approximately 10 km downstream from Gull Island. These sites are yet to be designated as protected" (p. 2-74).

Requesting Organization – Joint Review Panel **Information Request No.: JRP.57**

Information Requested:

The Proponent is asked to:

a. **provide a map of these two sites in relation to the expected maximum floodzone;**

Response:

See Attachment A to this IR, IBP Sites in the Project area, with the original site delineation from the IBP sheets along with predicted future reservoir limits. Note that the information available for site 48 does not delineate an eastern boundary.

Requesting Organization – Joint Review Panel **Information Request No.: JRP.57**

Information Requested:

The Proponent is asked to:

b. identify the significance of these two sites from a biological and ecological perspective; and

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Response:

As indicated in the EIS (Volume IIA page 2-78), the two sites as documented by the International Biological Programme (IBP) are referenced in their report (IBP 1974) as sites 48 and 50. Northland Associates (1979) completed additional field work related to these two sites and provided detailed site descriptions including photographs of the areas. Both reports include a listing of the major plant communities found at each location.

Site 48 is called the lower Churchill River site (50^0 05' N, 61^0 6-12' W). The 30 km^2 site is described as a lichen forest (black spruce – cladonia) on stabilized sand dunes that are considered representative of the sand dunes and dune vegetation indigenous to the Churchill valley (Northland Associates 1979). Elevation ranges from 16.6 m asl (above sea level) along the Churchill River to 100 m asl at the top of the terraces which support lichen-black spruce forest. The Goose Bay-Churchill Falls road runs in an east-westerly direction along the north end of the site. Site 48 is bordered on the north side by hills and on the south side by the lower Churchill River. It is also bisected in several places by permanent running streams similar to the Pinus River. Old stream beds are now eroded valleys in the sand ridges. Two string bogs are present between the terrace and the lower Churchill River. As noted by Northland Associates (1979), alternate sand dune sites do exist on both sides of the Churchill River east of the site.

Site 50, known as Gull Island lake (53^0 00' N, 61^0 17' W) is an area of 73 km^2 and is described by Northland Associates (1979) as a rich black spruce forest on sandy alluvial soil, with the only known records of Common Wood Sorrel (*Oxalis montana)* in Labrador. Elevations range from 16.6 m asl along the Churchill River to a maximum 316.6 m asl in the southwest corner of the area. As in Site 48 the shoreline consists of slumped and eroded sand and clay-gravel banks, scarified by ice. In the case of Site 50, Northland Associates (1979) provided documentation of additional locations of Common Wood Sorrel on an island in Gull Lake and the adjacent (south) shore of the lake.

As noted in the EIS Volume IIA, Section 2.4, rare plant surveys in the lower Churchill River watershed (and nearby Goose River) occurred during July 2006 and July 2007 as part of the environmental baseline program for the Project (Minaskuat 2008). None of the plant species listed under the *SARA* or under *NLESA* were found in these surveys (Minaskuat 2008). Common Wood Sorrel was found on the previously reported IBP site, as well as at three additional locations (farther west and upstream) of the proposed Gull Island dam site. At each site, Common Wood Sorrel occurred in colonies scattered throughout the understorey. Of the four locations where this species was found, two will be inundated and two will be partially inundated; one of which will have 2,300 plants above the reservoir level. The subsequent vegetation surveys done in the area have indicated that Common Wood Sorrel, although not commonly found, is more widely distributed than believed in the early 1970s when the site was identified as an IBP site.

References:

International Biological Programme. 1974. Conservation of Terrestrial Communities. Report of Region 8 (Newfoundland and Labrador).

Northland Associates Ltd. 1979. Lower Churchill Hydroelectric Development Reservoir and Transmission Line – Wildlife Reconnaissance. Prepared for the Lower Churchill Development Corporation. St. John's, NL.

Minaskuat Inc. 2008. Rare Plant Survey in the Lower Churchill River Valley. Prepared for the Lower Churchill Hydroelectric Generation Project.

Requesting Organization – Joint Review Panel **Information Request No.: JRP.57**

Information Requested:

The Proponent is asked to:

c. **assess the effects of the Project on the integrity of the natural features that the designation by the International Biological Program was intended to protect, or provide an explanation as to why this wasn't done.**

Response:

Between 1964 and 1974 Canada participated in a planned program of research known as the International Biological Program (IBP), a worldwide endeavour involving 58 nations. A subcommittee for the Conservation of Terrestrial Communities (IBP-CT) was created, aimed at the establishment of a system of representative terrestrial and aquatic ecosystems around the world. Canada organized regional inventories of relatively undisturbed ecological areas having valued biological attributes. Newfoundland and Labrador comprised Region 8 of the Canadian IBP initiative. The idea was that this would encourage their protection both for these biological values, and for possible use of the sites as "benchmark" areas for research and monitoring. Altogether, some 1,534 sites were identified, and about 1,000 of them documented, but there was no special legal or policy provisions for their protection unless they happened to be situated within a national park or other area with formal protection. Many of these "IBP sites" were too small to be designated as national or provincial parks or major wildlife areas, and a number of them were under private ownership.

When the program ended in 1974, two provinces (British Columbia and Quebec) had legislation for "ecological reserves", a legal designation deemed appropriate for most IBP sites. Neither site 48 nor site 50 have been designated or received any special status by the Government of Newfoundland and Labrador subsequent to their identification as IBP sites in 1974.

IBP sites were not identified as Valued Environmental Components or Key Indicators in the Guidelines. The areas were assessed in relation to potential effects in both the biophysical and socioeconomic environment in the context of the discussion on rare and uncommon plants, as habitat for various Key Indicator species, and in the context of special areas - in relation to the impoundment of the Muskrat Falls Reservoir. Based on calculations, approximately 18 percent and 16 percent of the area delineated for sites 48 and 50 will be inundated with the projected reservoir levels.

In the case of site 48, although some of the site will be flooded, none of the black spruce-lichen forest complex associated with the stabilized sand dunes, for which the site was designated, will be affected. As part of the ELC, the same landscape (i.e., black spruce –lichen forest on stabilized sand dunes) has also been identified outside of the site 48 boundary. In total, 3,569 ha of that particular land feature has been identified within the Project Area ELC. Of that amount, less than one hectare is within the flood zone.

With respect to site 50, some locations of Common Wood Sorrel will be flooded, based on more recent surveys, alternate locations for this species occur outside the area of the flood zone.

INFORMATION RESPONSES
LOWER CHURCHILL PROJECT
CEAA REFERENCE NO.07-05-26178

JOINT REVIEW PANEL

Attachment A
IBP Sites in the Project Area

IR# JRP.57

October 5, 2009

nalcor energy
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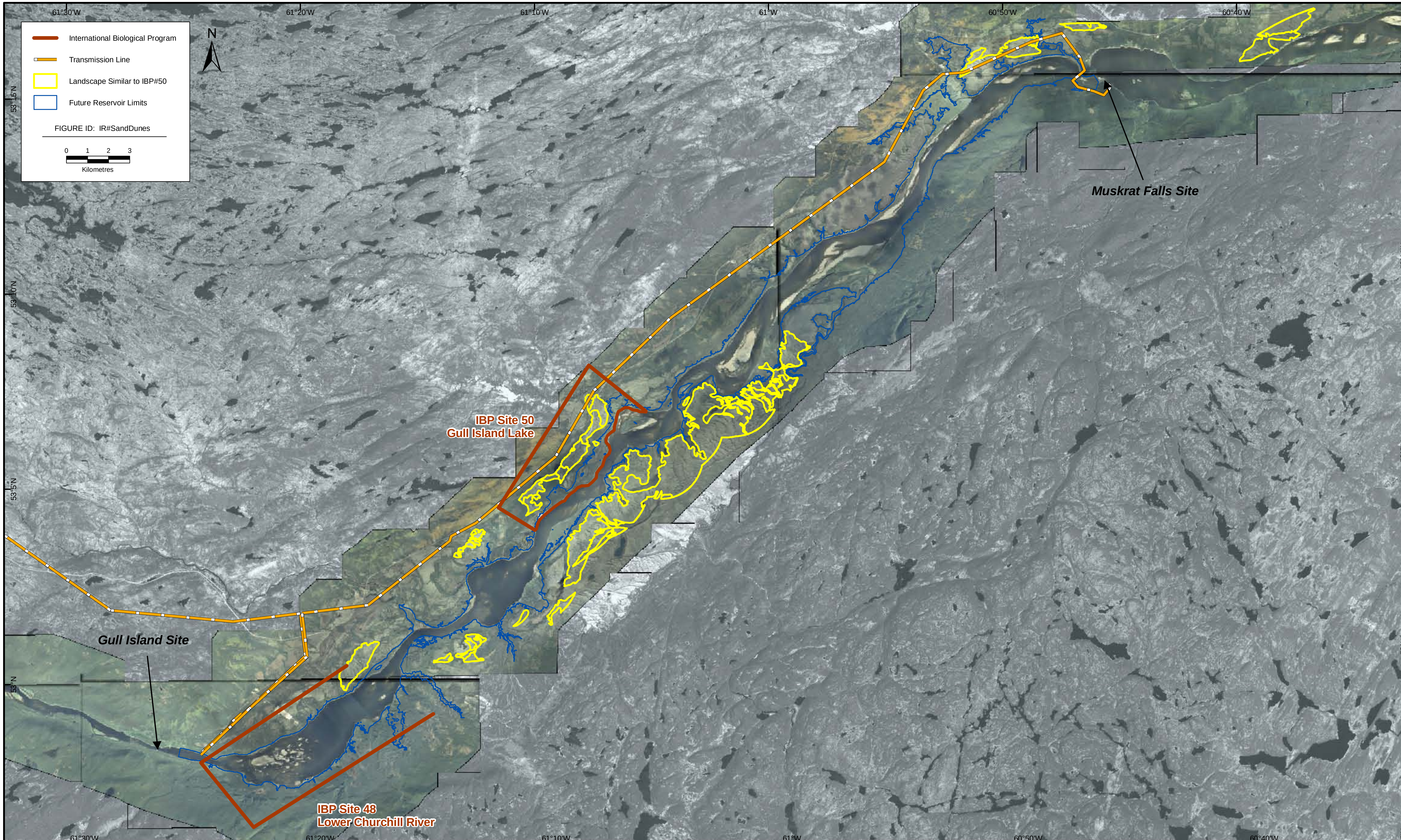

FIGURE NO:		DRAFT DATE: 23/07/2009
1	**IBP Sites in the Project Area**	REVISION DATE: 1/10/2009

IR# JRP.58

Acid Rock Drainage

Requesting Organization – Joint Review Panel **Information Request No.: JRP.58**

Subject - Acid Rock Drainage

References:

EIS Guidelines, Section 4.3.4 (Construction)

EIS, Volume IA, Section 4.4.1.1 (Gull Island, Construction Infrastructure) & Section 4.4.2.1 (Muskrat Falls, Construction Infrastructure)

Related Comments / Information Requests:

CEAR #205 (Government of Newfoundland & Labrador – Mines Branch)

Rationale:

The EIS Guidelines require that "[i]f quarrying/excavating/using rock with the potential for acid generation" the EIS should "provide an assessment of the potential for and the impacts of metal leaching and acid rock drainage" (p. 20).

The EIS states "[t]he modified acid/base accounting was determined by the Sobek method and yielded a Neutralizing Potential to Acid Potential ratio of less than 0.2 for the composite samples tested, indicating that the rock material is not a net acid producer" (Volume IA, p. 4-41). However, the EIS later states "[t]he Sobek method yielded a neutralizing potential to acid potential ratio of 2.3, indicating that the rock material is not a net acid producer" (Volume IA, p. 4-50).

Requesting Organization – Joint Review Panel **Information Request No.: JRP.58**

Information Requested:

The Proponent is asked to:

a. **provide the technical report on which these results are based in order to determine if samples taken and analyzed are sufficiently representative of the rock to be used for the Project; and**

Response:

The technical reports in which the results of the acid-base accounting results are presented, are titled as follows:

- Gull Island: Technical Report, GI1010 – Gull Island 2007 Site Investigation, Volumes I & VIB; and
- Muskrat Falls: Technical Report, MF1020 – Muskrat Falls 2007 Site Investigation.

Extracts from the above reports showing the acid-base accounting results are included in Attachment A. The same table is shown in both reports, as the acid-base testing was completed for both Gull Island and Muskrat Falls under a single assignment to the testing laboratory.

The borehole locations from which samples were taken is also included for both Gull Island and Muskrat Falls.

Requesting Organization – Joint Review Panel **Information Request No.: JRP.58**

Information Requested:

The Proponent is asked to:

b. **clarify the discrepancy in values as provided for the Neutralizing Potential to Acid Potential ratio in the EIS.**

Response:

To clarify the discrepancy in values for the neutralizing potential to acid production potential ratio (NP/AP) provided in the EIS, Volume IA, pages 4-41 and 4-50:

- the NP/AP on page 4-41 is in reference to Gull Island (SNC Lavalin) and the value provided of "less than 0.2" is incorrect. As shown in the above referenced report for Gull Island, the AP is 0.2 or less. The NP/AP is greater than 23.1.
- the NP/AP on page 4-50 is in reference to Muskrat Falls (SNC Lavalin) and the value of 2.3 is correct, as shown in the above referenced report for Muskrat Falls.

References:

SNC Lavalin, Gull Island: Technical Report, GI1010 – Gull Island 2007 Site Investigation, prepared for Newfoundland and Labrador Hydro, April 2008

SNC Lavalin, Muskrat Falls: Technical Report, MF1020 – Muskrat Falls 2007 Site Investigation, prepared for Newfoundland and Labrador Hydro, April 2008.

INFORMATION RESPONSES
LOWER CHURCHILL PROJECT
CEAA REFERENCE NO.07-05-26178

JOINT REVIEW PANEL

Attachment A

Technical Report GI1010 – Gull Island 2007 Site Investigation
Technical Report MF1020 – Muskrat Falls Site Investigation

IR# JRP.58

October 5, 2009

nalcor energy
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HYDRO
THE POWER OF COMMITMENT
Newfoundland & Labrador Hydro

LOWER CHURCHILL PROJECT

TECHNICAL REPORT
GI1010 – GULL ISLAND 2007 SITE INVESTIGATION

VOLUME 1 – GENERAL REPORT
Document No: 722850-GI 1010-40ER-0001-00

April 2008

FINAL

Prepared by: Carlos Baisre

Verified by: Pierre de Courval

Approved by: Bert Peach

SNC·LAVALIN

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Six (6) samples retrieved from borehole GS-V2-07 were tested. All of the tests were performed with strain measurements. The compressive strength varied between 75.64 MPa (failure along a structural feature) and 240.40 MPa, with an average value of 178.42 MPa. Young's modulus values ranged from 47.58 GPa and 65.08 GPa , while Poisson's ratio ranged from 0.177 and 0.278.

Finally, four (4) samples collected from borehole GN-S-07 were tested. All of the tests were carried out with strain measurements. The tested samples yielded compressive strength values of 181.43 MPa (through intact rock), 118.96 MPa (along a structural feature and intact rock), 118.90 MPa (along a structural feature and through intact rock) and 227.29 MPa (through intact rock). Young's modulus values were 47.32 GPa, 33.29 GPa, 36.23 GPa and 65.91 GPa , while the Poisson's ratios were 0.158, 0.148, 0.171 and 0.261.

A complete description of the test procedures with results and post-failure photographs of the tested samples is given in Volume 9.

2.8.2.2 Acid Rock Drainage Testing

Modified acid-base accounting was carried out on rock samples in order to evaluate the risk of acid rock drainage associated with the exposure of rock spoil to air and water. Composite samples, each comprising rock from three separate cores, were used. Sample 76976-01 contained rock from boreholes GS-R-07, GS-E-07 and GS-M-07. Sample 76976 contained rock from boreholes GN-P3-07, GN-S-07 and GN-U-07.

The tests were carried out at the RPC Laboratories in Fredericton, New Brunswick. The modified acid-base accounting was determined by the Sobek Method and yielded Neutralizing Potential to Acid Potential ratios of 23.1 or greater, indicating that the rock material is not a net acid producer. The detailed test reports are contained in Volume 6B.

RPC
921 College Hill Rd.
Fredericton, N.B. E3B 6Z9
Report No.: 76976-IAS

SNC Lavalin Inc.
455 Boul. René Lévesque Ouest
Montreal QC H2Z 1Z3
Attn: Karine Champagne

January 11, 2008

Modified Acid-Base Accounting
Results based upon Sulfide

RPC ID	Client ID	Paste pH	Total Sulfur	Sulfate†	Sulfide	Acid Production Potential	Neutralizing Potential pH 8.3	Net NP pH 8.3	NP/AP
			%	%	%	Kg $CaCO_3$/tonne			
76976-01	Composite GS-R, GS-E, GS-M	9.3	< 0.005	< 0.005	< 0.005	< 0.2	3.4	3.4	-
76976-02	Composite GN-P3,GN-S,GN-U	9.5	0.012	< 0.005	0.007	0.2	5.1	4.8	23.1
76976-03	Composite M5, C7, M6	9.7	0.083	0.005	0.078	2.4	5.6	3.2	2.3

Each sample consisted of 3 cores. These were crushed and composited. Respesentative sub-sabples were pulverized and used for all subsequent analyses.

The modified acid/base accounting was determined by the Sobek method.
A negative value for Net Neutralizing Potential indicates that the material is a net acid producer.

† Acid soluble, non-volatile sulfur species (sulfate).
Sulfide was determined by difference.

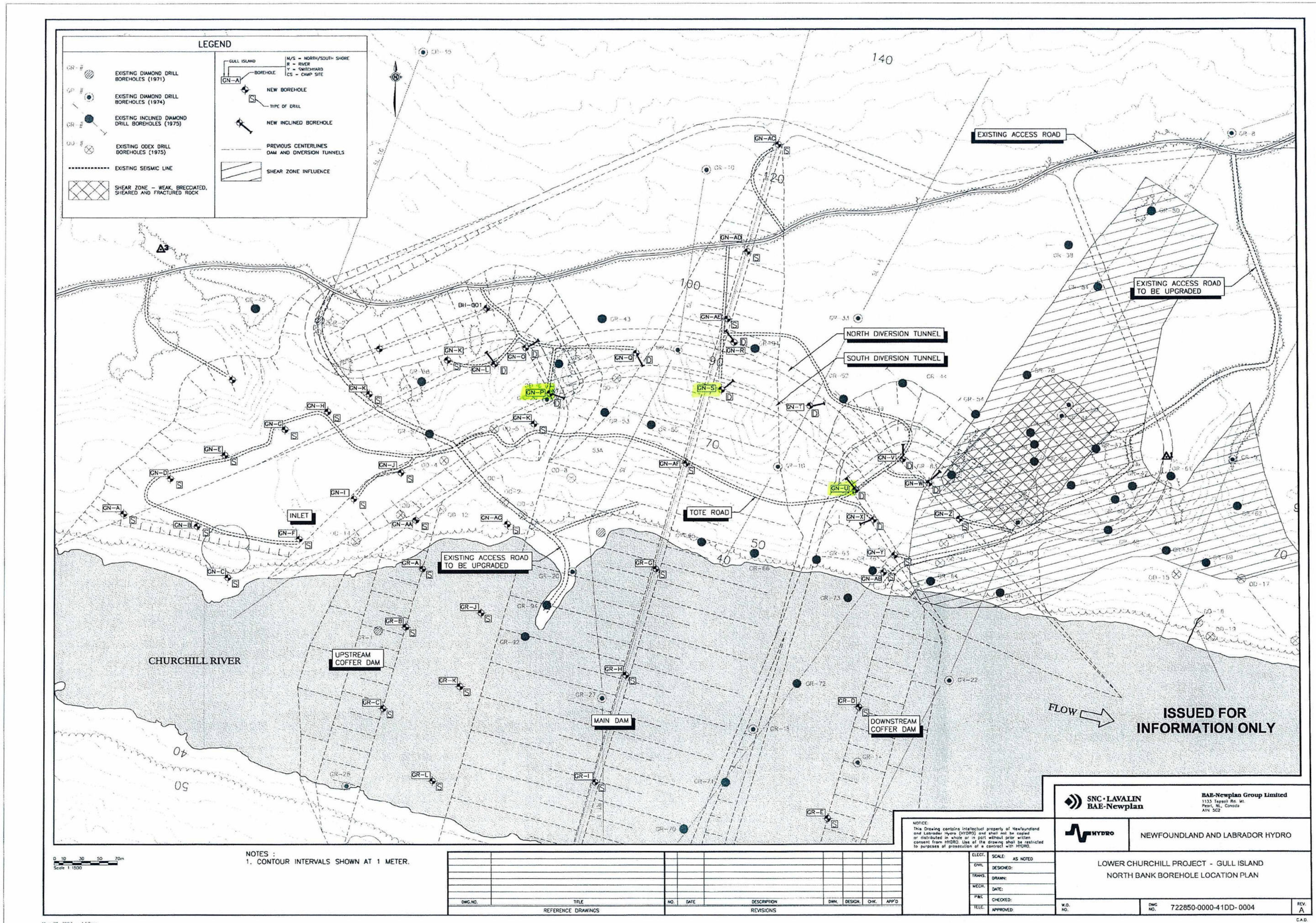
NP = Neutralizing Potential
AP = Acid Production Potential

<original signed by>

A. Ross Kean, M.Sc.
Department Head
Inorganic Analytical Chemistry

<original signed by>

Peter Crowhurst, B.Sc., C.Chem.
Analytical Chemist
Inorganic Analytical Chemistry


LEGEND
EXISTING DIAMOND DRILL BOREHOLES (1971)
EXISTING DIAMOND DRILL BOREHOLES (1974)
EXISTING INCLINED DIAMOND DRILL BOREHOLES (1975)
EXISTING ODEX DRILL BOREHOLES (1975)
EXISTING SEISMIC LINE
SHEAR ZONE - WEAK, BRECCIATED, SHEARED AND FRACTURED ROCK
NEW BOREHOLE
TYPE OF DRILL
NEW INCLINED BOREHOLE
PREVIOUS CENTERLINES DAM AND DIVERSION TUNNELS
SHEAR ZONE INFLUENCE
EXISTING ACCESS ROAD
EXISTING ACCESS ROAD TO BE UPGRADED
NORTH DIVERSION TUNNEL
SOUTH DIVERSION TUNNEL
TOTE ROAD
INLET
UPSTREAM COFFER DAM
MAIN DAM
DOWNSTREAM COFFER DAM
CHURCHILL RIVER
FLOW
ISSUED FOR INFORMATION ONLY
NOTES :
1. CONTOUR INTERVALS SHOWN AT 1 METER.
REFERENCE DRAWINGS
REVISIONS
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NORTH BANK BOREHOLE LOCATION PLAN
DWG NO. 722850-0000-41DD-0004
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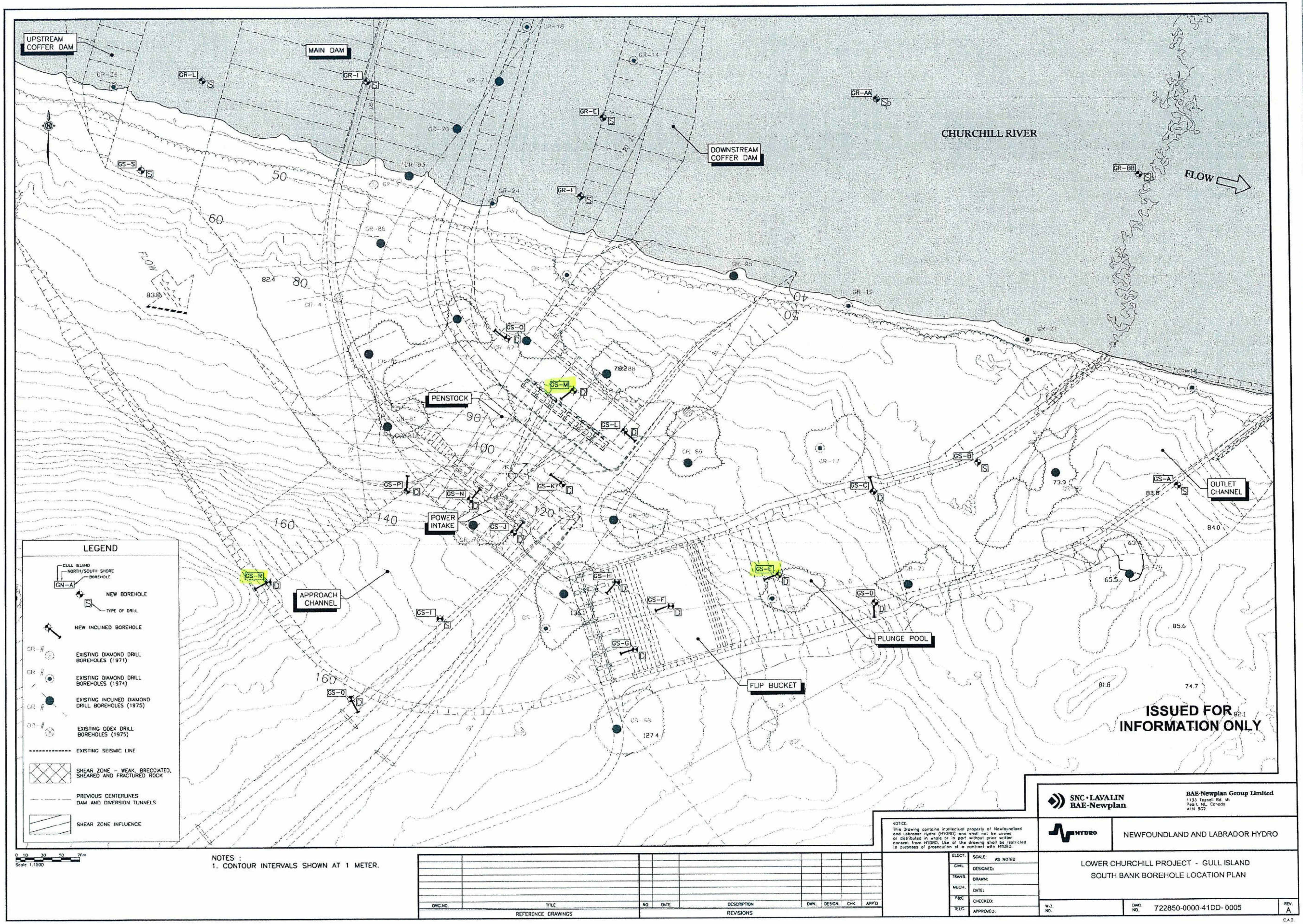
C.A.D.


UPSTREAM COFFER DAM
MAIN DAM
DOWNSTREAM COFFER DAM
CHURCHILL RIVER
FLOW
PENSTOCK
POWER INTAKE
APPROACH CHANNEL
PLUNGE POOL
FLIP BUCKET
OUTLET CHANNEL
GS-A
GS-B
GS-C
GS-D
GS-E
GS-F
GS-G
GS-H
GS-I
GS-J
GS-K
GS-L
GS-M
GS-N
GS-O
GS-P
GS-Q
GS-R
GS-S
GR-L
GR-I
GR-E
GR-F
GR-AA
GR-BB
LEGEND
NEW BOREHOLE
TYPE OF DRILL
NEW INCLINED BOREHOLE
EXISTING DIAMOND DRILL BOREHOLES (1971)
EXISTING DIAMOND DRILL BOREHOLES (1974)
EXISTING INCLINED DIAMOND DRILL BOREHOLES (1975)
EXISTING ODEX DRILL BOREHOLES (1975)
EXISTING SEISMIC LINE
SHEAR ZONE - WEAK, BRECCIATED, SHEARED AND FRACTURED ROCK
PREVIOUS CENTERLINES DAM AND DIVERSION TUNNELS
SHEAR ZONE INFLUENCE
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LOWER CHURCHILL PROJECT - GULL ISLAND
SOUTH BANK BOREHOLE LOCATION PLAN
SCALE: AS NOTED
722850-0000-41DD-0005
REV. A

Newfoundland & Labrador Hydro

LOWER CHURCHILL PROJECT

TECHNICAL REPORT

MF1020 – MUSKRAT FALLS SITE INVESTIGATION

Document No: 722850-MF1020-40ER-0001-00

FINAL **April 2008**

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SNC·LAVALIN

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Appendices

Appendix A Drawings:
Plate 1: Site Location Plan
Plate 2: Borrow Area GR-5
Appendix B Test Pit Log Reports and Gradation Curves
Appendix C Laboratory Test Results

2.3.2 Acid Rock Drainage Testing

A modified acid-base accounting was carried out on rock samples in order to evaluate the risk of acid rock drainage associated to the exposure of rock spoil to air and water. A total of three (3) tests were performed on composite samples produced from cores retrieved in boreholes M5 and M6, which were drilled during the1998 investigation program, and in borehole C7, drilled in 1979.

The modified acid/base accounting was determined by the Sobek method and yielded a Neutralizing Potential to Acid Potential ratio of 2.3, indicating that the rock material is not a net acid producer.

Figure 2-1 illustrates the location of boreholes M5, M6, and C7. The test results are given in Appendix C.

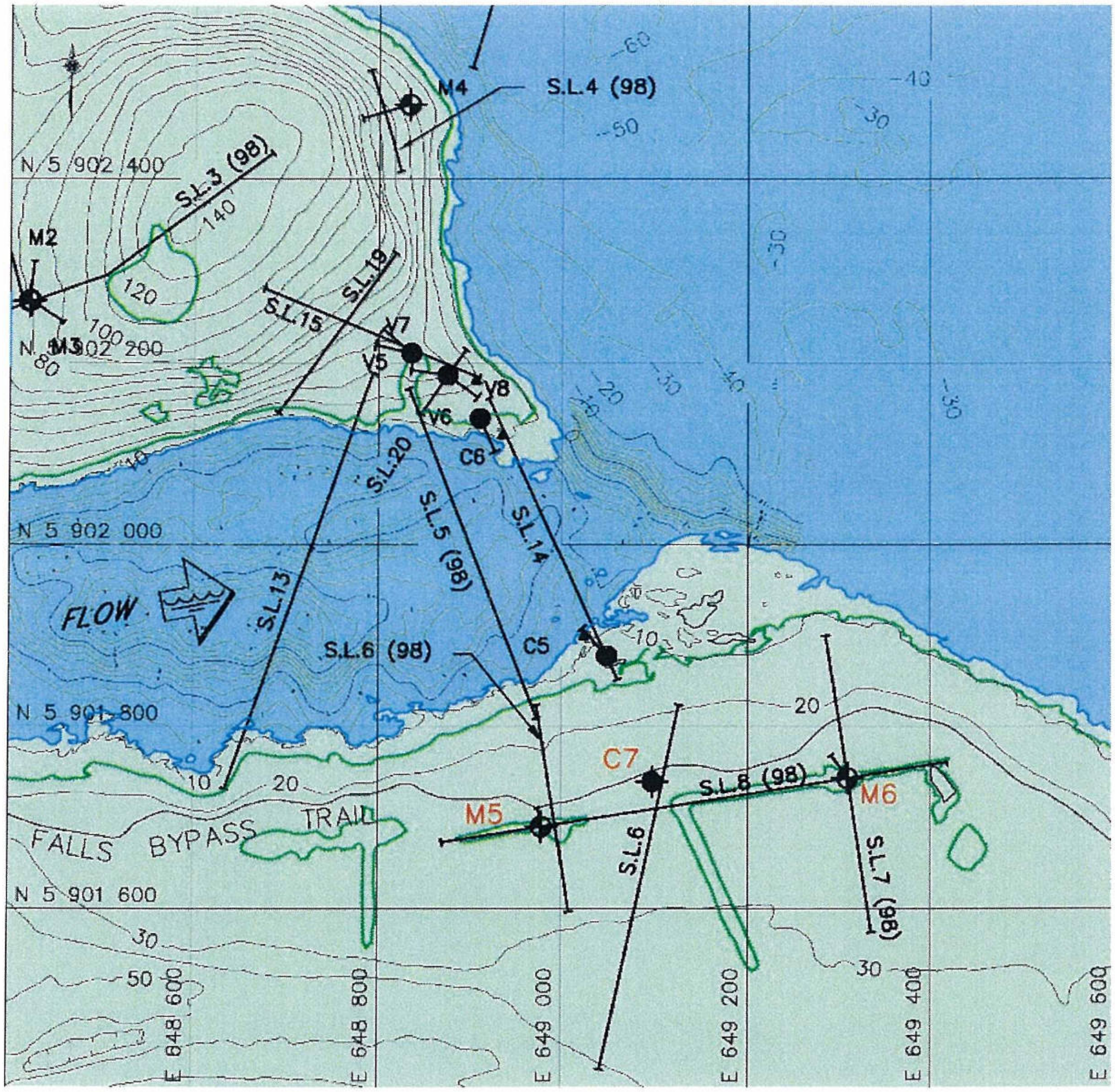

Figure 2-1: Acid Rock Drainage Testing - Location of Boreholes M5, M6 and C7

Note: Figure 2-1 was cropped from Plate 7 of the January 1999 report prepared by SNC-Agra[1].

[1] SNC-Agra Joint Venture, "Muskrat Falls Hydro Electric Development – Final Feasibility Study", January 1999.

APPENDIX C

Laboratory Test Results

RPC
921 College Hill Rd,
Fredericton, N.B. E3B 6Z9
Report No.: 76976-IAS

SNC Lavalin Inc
455 Boul. Rene Levesque Ouest
Montreal QC H2Z 1Z3
Attn: Karine Champagne

January 11, 2008

Modified Acid-Base Accounting

Results based upon Sulfide

RPC ID	Client ID	Paste pH	Total Sulfur	Sulfate[†]	Sulfide	Acid Production Potential	Neutralizing Potential pH 8.3	Net NP pH 8.3	NP/AP
			%	%	%	Kg $CaCO_3$/tonne			
76976-01	Composite GS-R, GS-E, GS-M	9.3	< 0.005	< 0.005	< 0.005	< 0.2	3.4	3.4	-
76976-02	Composite GN-P3,GN-S,GN-U	9.5	0.012	< 0.005	0.007	0.2	5.1	4.8	23.1
76976-03	Composite M5, C7, M6	9.7	0.083	0.005	0.078	2.4	5.6	3.2	2.3

Each sample consisted of 3 cores. These were crushed and composited. Respesentative sub-sabples were pulverized and used for all subsequent analyses.

The modified acid/base accounting was determined by the Sobek method.
A negative value for Net Neutralizing Potential indicates that the material is a net acid producer.

[†] Acid soluble, non-volatile sulfur species (sulfate).
Sulfide was determined by difference.

NP = Neutralizing Potential
AP = Acid Production Potential

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