

5 Muskrat Falls Project

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5.1 Introduction

The Muskrat Falls Project comprises the hydropower generation facility proposed on the Lower Churchill River. The main project elements include: a 824 MW power station with four turbine-generator units, a concrete gravity dam, spillway, abutment stabilization works, a substation, and facilities for interconnection with the high voltage transmission links.

Planning and development of the Project has progressed during a long time span with studies performed initially in the mid 1960's and continuing to 2011. The characteristics of the project have changed and evolved during this period in response to circumstances and differences in the assumed market for connection of the Project.

The history of the development includes the following main steps:

- The first assessment of power sites on the Lower Churchill River was prepared for development of the Upper Churchill Falls project during the 1960's. The studies at that time were limited in scope with only reconnaissance surveys and some field investigations.
- A review was commissioned in 1975 for the Gull Island Power Company Limited that suggested changes to the layouts and identified a program of more detailed field investigations.
- In 1977, Newfoundland and Labrador Hydro commissioned further field work and an update of previous preliminary layouts and cost estimates.
- Additional work was carried out in 1979 as part of engineering studies for the full Lower Churchill project development. The work included definition for a detailed exploration program at Muskrat Falls, study of alternative intake and powerhouse designs, review of ice studies and diversion works, review of the design floods and additional studies on schedule and support requirements.
- Subsequently in 1979, the Lower Churchill Development Corporation arranged for completion of the detailed field investigation program and an engineering study for the potential development of Muskrat Falls. As a result of this study, it was established that development of the Muskrat Falls site with a capacity of 618 MW was technically feasible. The engineering report was completed in March, 1980. Alternative project layouts were developed and a recommended variant was selected.
- The 1979 study also included an investigation into the stabilization requirements for the north spur at the Muskrat Falls site, which was identified as a geotechnical formation requiring careful consideration for the project. Recommendations were made to resolve any concerns for the north spur.
- In 1989, a supplemental development layout study of the Muskrat Falls site was prepared with a total installed capacity of 824 MW. The higher installed capacity resulted from a project

optimization study that considered Muskrat Falls as part of an integrated development of the Lower Churchill, leaving the Upper Churchill Project for energy exports.

- In 1998, Newfoundland and Labrador Hydro commissioned the preparation of a final feasibility study which comprised a review of the previous studies, further site investigations and the determination of the preferred solution for development of the Muskrat Falls site.
- In association with the feasibility study, a companion study was prepared in 1999 to optimize the installed capacity of the project as part of a Lower Churchill River development. This study verified the selection of the 824 MW installed capacity.

All of the preceding studies were performed on the basis of the Muskrat Falls project being constructed after completion of the Gull Island hydroelectric project upstream.

The program for development was changed subsequent to the completion of the feasibility study with the main rationale being the requirement for commercial sales to the Island. The project development scheme is now based on implementation of the Muskrat Falls project as a first stage, with power sales to Newfoundland and Labrador rather than using the Hydro Quebec transmission system to sell power. This important change required that many aspects of the project be updated. A series of studies were carried out in 2010 and 2011 to establish the new engineering and technical basis for the project. Nalcor Energy has also adapted many aspects of the project to suit long term operating conditions and internal preferences for some aspects of the development. The following sections describe the proposed project in more detail.

5.1.1 Muskrat Falls Development

The Muskrat Falls development was originally conceived as one element of the overall development of the Lower Churchill River and associated expansions upstream. The configuration included expansion of the Upper Churchill project, upstream Quebec river diversions that would supplement the inflow to the Upper Churchill reservoir, and the Muskrat Falls and Gull Island projects on the Lower Churchill. The Muskrat Falls project was originally selected for development following completion of the Gull Island project, and as result, some design and construction conditions were changed to accommodate proceeding with Muskrat Falls first.

The Muskrat Falls project was ultimately selected in 2010 to be completed as the first stage of the Lower Churchill River development, with the Gull Island Project to follow when market conditions permit. Nalcor conducted a series of supplemental studies as necessary to reconfigure the project for development as the first stage before undertaking the Gull Island project. The studies updated information such as the design flood, ice conditions, dam break, firm and average energy, construction planning, and design variant. The characteristics such as the powerhouse, the spillway and the non-overflow dam of the power facilities have been modified slightly as part of the updates. Changes have largely been related to details of the dam, ice management, and sequencing of construction that affect the Muskrat Falls project. Of three variants considered for the project, the one selected was primarily the result of a bridge project spanning the Churchill River, which made access to the south shore possible.

Engineering and design of the project is reported to be in progress with the final configuration selected by Nalcor. The Project, as now envisaged, differs in some respects from the configuration presented in the technical studies. Selected deviations were discussed with Nalcor and explanations

were provided during the review process. Further discussion of these results is provided in the following paragraphs.

5.1.2 Scope of Review

MHI's technical review of the proposed Muskrat Falls development included:

- Review the proposed project layout and characteristics to identify any factors that might preclude successful development of the site;
- Confirmation that the scope of work for the project is comprehensive as a basis for planning and cost estimates;
- Assessment of the methods used for preparation of the project cost estimates and confirmation that the estimates are reasonable;
- Evaluation of the time period allocated for construction; and
- A review of the values derived for the generating capacity and energy.

Where appropriate, the outcomes from the above tasks have been used as input to the CPW analysis. The following sub-sections summarize the review of the Muskrat Falls project.

The review was not intended to be exhaustive but is sufficient to ensure that the decisions and recommendations reached for development of the project are well founded on factual and appropriate information.

5.1.3 Methodology

The documents listed in Table 20 were provided by Nalcor and examined for this review.

With respect to the project cost estimate and the project control schedule, the information collection was performed largely by interviews with Nalcor staff. The details relating to the cost, contract strategy, and scheduling of the project are considered by Nalcor to include commercially sensitive information that could affect the contracting process and accordingly have not been included in detail in this document.

Table 20: Muskrat Falls Documents Reviewed

Exhibit	Title	Prepared by	Date
17	Churchill Falls Water Management Agreement	Nalcor Energy	2009
19	Muskrat Falls Final Feasibility Study	SNC-Agra	1999
31	Lower Churchill Project Cost Estimate Progression 1998 to 2011, Technical Note	Nalcor Energy	July 2011
38	Lower Churchill Falls Project, Muskrat Falls North Spur, 1999 to 2011	Nalcor Energy	July 2011

Exhibit	Title	Prepared by	Date
39	Lower Churchill Falls Project, MF 1260, Assessment of Existing Pumpwell System	Hatch in association with RSW and Statnett	July 2008
40	Lower Churchill Project, MF 1271 – Evaluation of Existing Wells, Pumps and Related Infrastructure in the Muskrat Falls Pumpwell System	Hatch	March 2011
41	Lower Churchill Project, MF 1272 – Installation of New Piezometers in the Muskrat Falls Pumpwell System	Hatch	April 2010
CE-15 Rev.1 (Public)	Muskrat Falls Hydroelectric Project, MF 1010 – Review of Variants	SNC Lavalin	March 2008
CE-16 Rev.1 (Public)	Muskrat Falls Hydroelectric Project, MF 1050 – Spillway Design Review	SNC Lavalin	December 2007
CE-17 (Public)	Lower Churchill Project, MF 1130 – River Operations During Construction and Impoundment	Hatch in association with RSW and Statnett	January 2008
CE-18 (Public)	Muskrat Falls Hydroelectric Project, MF 1250 – Numerical Modeling of Muskrat Falls Structures	SNC Lavalin	May 2008
CE-19 (Public)	MF 1300 – Muskrat Falls 2010 Site Investigation, Volume 1	SNC Lavalin	June 2011
CE-20 Rev.1 (Public)	MF 1310 – Muskrat Falls Site Access Review	SNC Lavalin	February 2011
CE-21	Lower Churchill Project, MF 1320 – Estimate of Firm Energy Potential of the Muskrat Falls Development	Hatch	June 2011
CE-22 (Public)	Lower Churchill Project, MF 1330 – Hydraulic Modeling and Studies, 2010 Update, Modeling of the River, Report 1	Hatch	October 2010
CE-23 (Public)	Lower Churchill Project, MF 1330 – Hydraulic Modeling and Studies, 2010 Update, Muskrat PMF and Construction Design Flood Study, Report 2	Hatch	December 2010
CE-24 (Public)	Lower Churchill Project, MF 1330 – Hydraulic Modeling and Studies, 2010 Update, Dam Break Study, Report 3	Hatch	December 2010
CE-25 (Public)	Lower Churchill Project, MF 1330 – Hydraulic Modeling and Studies, 2010 Update, Muskrat Falls Ice Study, Report 4	Hatch	March 2011
CE-26	Lower Churchill Project, MF 1330 – Hydraulic Modeling and Studies, 2010 Update, Muskrat Falls Regulation Study, Report 6.	Hatch	May 2011
CE-27 Rev.1 (Public)	CE 202-120142-00007, Muskrat Falls Hydroelectric Development, Summary of Studies on Firm and Average Energy Production	Nalcor Energy	June 2011
CE-28 Rev.1 (Public)	Churchill River Complex: Power and Energy Modeling Study	Acres International Limited	July 1998
CE-29 Rev.1 (Public)	Churchill River Complex Optimization Study, Optimization Study, Volume 1, Main Report	Acres International Limited	January 1999
CE-30 Rev.1 (Public)	Churchill River Complex: Power and Energy Modeling Study, Final Report. Optimization Study, Detailed Models, Volume 2	Acres International Limited	July 1998
CE-52 Rev.1 (Public)	Technical Note – Strategic Risk Analysis and Mitigation	Nalcor Energy	2010

Exhibit	Title	Prepared by	Date
CE-54 Rev.1 (Public)	GI1141 –Upper Churchill PMF and Flood Handling Procedures Update	Hatch in association with RSW Inc, and Statnett	August 2009
CE-51 Rev.1 (Public)	Muskrat Falls Generating Facility and Labrador-Island Transmission Link, Overview of Decision Gate 2 Capital Cost and Schedule Estimates, Technical Note	Nalcor Energy	August 2011

5.2 General

Detailed design of the Project has now been assigned to an EPCM (Engineering, Procurement and Construction Management) consultant that is working to prepare for project sanction (DG3). A Technical Note¹²¹ was prepared by Nalcor which summarizes the main changes from completion of the feasibility study and contains a list of the key characteristics to be used by the EPCM consultant.

The following paragraphs summarize the Project as interpreted from the available reference documents and discussions with Nalcor staff.

5.3 Project Design and Construction Considerations

5.3.1 Project Site

The Muskrat Falls site is described in the Final Feasibility Study¹²² with access details updated in the Muskrat Falls Site Access Review¹²³. Topographic features of the site include the two stage waterfall in the main river channel, a high rock knoll on the north shore, and a clay spur extending from the rock knoll to the valley slope.

Topographic investigations for the site appear to be complete and include site mapping, bathymetric surveys, and feature location surveys. The surveys performed, as well as the hydraulic and ice studies, all support the site layout and design.

The general geotechnical and geological characteristics of the site are described in the Muskrat Falls Final Feasibility Study. Additional studies have also been carried out following the feasibility study to supplement data in areas where specific issues were identified. A significant investigation effort has

¹²¹ Exhibit 30, Nalcor, "Technical Note: Lower Churchill Design Progression 1998 to 2011", July 2011

¹²² Exhibit 19, SNC-Agra, "Muskrat Falls Hydroelectric Development, Final Feasibility Study Volume 1 – Engineering Report", January 1999

¹²³ Exhibit CE-20 Rev.1 (Public), SNC-Lavalin, "Technical Report, MF1310 – Muskrat Falls Site Access Review", February 2011

been undertaken for the north spur zone as described in the Technical Note: Muskrat Falls North Spur.¹²⁴

All investigation programs have been carried out using qualified consulting engineering firms. The programs were defined to allow for the collection of data and supplemental investigations were undertaken to clarify conditions found in the field.

During the geotechnical investigations, the site was reviewed in sufficient detail to allow for feasibility assessment, preliminary design, and cost estimates, which support the decisions required. Additional investigations may be undertaken for detailed design; however, there is no reason to believe that the site conditions would preclude successful development of the hydropower station.

Access to the site is available from the Trans Labrador Highway and with completion of a bridge across the Churchill River, access is now possible to both banks of the river.

Topographic and geotechnical conditions have been identified and site construction can begin as planned.

5.3.2 Installed Capacity

The installed capacity and arrangement of the Muskrat Falls and Gull Island projects were most recently optimized for the Final Feasibility Study as part of an integrated system plan, including the Upper and Lower Churchill River.

The selected installed capacity of 824 MW is associated with firm energy of about 4.5 TWh/yr and average energy of 4.9 TWh/yr. The plant capacity factor is about 68% for the arrangement selected and this is consistent with run of the river hydro power projects. The power station can, therefore, operate primarily as a base and intermediate load energy producer with peaking power to be provided by other plants on the island. Details of the utilization of the available power and energy from the Project are incorporated in the power systems studies reviewed in other sections of this Report.

The installed capacity of the Project was originally¹²⁵ optimized for the Lower Churchill Falls development, comprising Muskrat Falls and Gull Island, integrated with Upper Churchill Falls and other projects in Quebec, to supply power and energy to the Hydro Quebec system.

5.3.3 Site Layout and Access

The Final Feasibility Study provided a comprehensive review of the conditions affecting the layout of the site. However, an important update of this study was conducted in 2010, which was based on the original plan and several adjustments to suit conditions that had changed from the end of the Feasibility Study. The most important of these adjustments are summarized in the following paragraphs.

¹²⁴ Exhibit 38, Nalcor, "Technical Note: Lower Churchill Project - Muskrat Falls North Spur 1999 to 2011", July 2011

¹²⁵ CE-29 Rev.1 (Public), Acres International, "Churchill River Complex Optimization Study", January 1999

Each of the studies to date have adopted similar water level criteria. The downstream water level is governed by the natural water level of the Churchill River below Muskrat Falls. The upstream water level is limited by the assumed tailwater level for the future Gull Island development. With Muskrat Falls developed in isolation, the upstream water level could be higher. However, this would restrict the possible future output from the Gull Island project. The decision to restrict Muskrat Falls to a maximum level consistent with future Gull Island development is considered to be appropriate.

Diversion of the river during construction in the Final Feasibility Study considered the use of tunnels. However, more recent studies have demonstrated that an open channel river diversion can be used effectively at a lower cost. The water flow is initially left in the existing river channel, while the spillway is constructed behind a cofferdam; the river is then diverted through the spillway while the main gravity dam section is completed. The powerhouse is constructed outside of the existing river bed where it can be isolated by cofferdams for the full construction period.

The project is being developed with a small reservoir for run of river operation. The reservoir level at the site will fluctuate within a range of 500 mm as needed to accommodate small variations in river flow or turbine-generator loading.

The studies carried out to select the general arrangement of the permanent works appear to be comprehensive and to provide a reasonable conclusion for the optimum development in terms of cost and construction duration. Topographic, geotechnical, hydrologic, and hydraulic conditions have been considered to select the optimum site layout. The studies have been performed by consulting engineering firms with extensive relevant experience with similar projects and in accordance with good utility practice. The selected arrangement of the site is consistent with common hydroelectric power project layouts.

5.3.4 Dam and Spillway

Concrete dams were selected to close the river to the north and south of the powerhouse block. A spillway structure is included between the north dam and the powerhouse block.

The north dam is configured as a concrete gravity section with a free overflow spillway located along part of the crest. Roller compacted concrete construction is planned to allow for rapid completion of the structure within two summer seasons. Roller compacted concrete construction methods are appropriate for modern concrete dams although careful preparation of the site and mobilization of the necessary production facilities will be required. Planning activities by Nalcor appear to recognize the requirements and are believed to provide a good foundation for project development and construction.

The south dam is located outside of the existing river valley and closes the valley from the south end of the powerhouse block. The south dam will also be a concrete gravity structure that will be constructed with roller compacted concrete. The dam is now designed as a non-overflow section that will retain water levels up to the probable maximum flood. The south dam can be constructed without any diversion of the existing river channel.

Spillway facilities comprise a gate controlled structure located between the north dam and the powerhouse and a free overflow spillway on the crest of the north dam. The gate controlled spillway will be used for the release of river flow in excess of the amount required for power generation. The

free overflow spillway will be used during floods exceeding the discharge capacity of the spillway and possibly in the event of unusual conditions such as unavailability of a gate or full load rejection of the power station.

The main spillway has four submerged radial gates located in a structure adjacent to the north end of the powerhouse. The spillway arrangement selected for the final design differs from the Final Feasibility Study, as described in a final optimisation study completed in 2011.

The diversion scheme proposed appears to be practical and consistent with the construction program. Studies have been undertaken to assess the effect of ice on the cofferdams and water levels at the construction site. The ice analysis has been updated to represent the final arrangement of structures proposed.

The layout and dimensions of the structures were selected as part of the Final Feasibility Study and the subsequent project optimization update studies. The layout of the dam has been prepared by experienced consulting firms and appears to be consistent with the conditions at the site and hydropower industry practice. The north spur structure at the site is a natural dam that extends from the rock knoll adjacent to the main river channel northwards across the valley. The spur comprises a soil and rock formation derived from the geological history of the site. The bedrock foundation is deep and extends below the river bed level. The Final Feasibility Study focused on the stability and water tightness of the north spur.

The possibility of instability of the north spur under reservoir loading was identified early and analysed to develop a remedial works program. This consisted of installation of dewatering wells that reduce the phreatic surface in the soil, with the result that the factors of safety are increased. The well program has been examined during subsequent technical studies, and the consultants have confirmed the satisfactory operation of the pump wells¹²⁶ to date. Stability of the north spur relies on the well system to manage the phreatic surface through the structure along with remodelling of the topography to reduce the loading on the slopes. The Final Feasibility Study included an analysis to substantiate the design concept but the detailed design studies must demonstrate the long term viability of this concept¹²⁷. The long term viability of this scheme is subject to further analysis and detailed design of the necessary stabilization works.

Design for the permanent works includes the extension of the de-watering well system by increasing the number and extent of the wells. Some local excavation will be undertaken to lower the height of the ridge, thereby reducing the loading on slopes.

The consultants involved have undertaken a comprehensive review of the stability of the north spur including the response of the structure to changes in water levels. There is no reason to believe that the north spur would not be stable during the life of the project.

¹²⁶ Exhibit 40, Hatch, "Lower Churchill Project, MF1271 – Evaluation of Existing Wells, Pumps, and Related Infrastructure in the Muskrat Falls Pumpwell System", March 2010

¹²⁷ Exhibit 38, Nalcor, "Technical Note: Lower Churchill Falls, Muskrat Falls North Spur 1999 to 2011", July 2011

Based on the information provided, the design and construction of the Muskrat Falls works is consistent with good engineering and construction practices and should not pose any unusual risks for the construction or operation of the facilities.

5.3.5 Powerhouse Arrangement

The powerhouse is designed with four turbine-generator units using a concrete spiral case arrangement. The structure integrates the intake, turbine and draft tubes. The arrangement proposed is a conventional approach for low head hydropower stations. Precedents for the use of this arrangement with similar sized turbines were provided as part of the Feasibility Study.

The powerhouse arrangement considered provisions for the erection and operation of the turbine generator units. Several adjustments to the arrangement were made in the various update studies (see Table 1) performed after the completion of the Final Feasibility Study. Updates were prepared between 2007 and 2010. Adjustments included selection of four Kaplan turbines in place of the original arrangement with three propeller turbines and one Kaplan. Other adjustments were to details of the powerhouse layout, spillway, ice management, site access, and river diversion, which influenced the powerhouse location and layout. The final arrangement of the powerhouse will be determined during the ongoing design studies by the selected EPCM consultant. However, there is no evidence to suggest that the powerhouse arrangement represents any unusual risks or incorporates any abnormal features.

5.3.6 Generating Equipment

Four Kaplan turbine-generator sets are proposed for the development, which is a deviation from the arrangement of three propeller and one Kaplan proposed in the Final Feasibility Study. The turbine arrangement was selected by Nalcor as an optimization considering long term reliability, maintenance, powerhouse structure design, shipping dimensions, and other factors. The use of the four Kaplan units has a slightly higher capital cost than the propeller units but this is compensated by savings in the civil works, improved energy yield, and the other factors examined.

The selection of Kaplan units is a conventional choice for the head and discharge conditions at Muskrat Falls. The arrangement is not believed to pose any unusual design, construction, or operating risks. Several well qualified manufacturers are available for this equipment, which should allow for competitive pricing for equipment procurement.

5.3.7 Switchyard and Transmission Interconnection

A switchyard will be located at the Muskrat Falls site for interconnection of the power station with the transmission system. The system comprises a 345 kV switchyard at the Muskrat Falls station, a 345 – 138 kV substation located about five kilometers from the station, 245km of 345 kV ac transmission to the Upper Churchill Falls substation, the 345 kV ac – dc converter station, and the 1100 km dc link to the island and inverter station at Soldiers Pond. In addition to the Island Link, the Project reinforces the existing transmission system in Labrador.

The transmission and stations proposed are believed to be consistent with the requirements for the project. There is no reason to expect any unusual risks or difficulties with the arrangement when the final design is prepared by the EPCM consultants.

5.3.8 Project Construction

The studies performed to date have identified sources for construction materials in the vicinity of the site. Access routes have been identified and assessed for materials and equipment, including for the movement of large scale components such as transformers, generator components, and turbines. Nalcor has assessed the equipment and labour required for construction and planned the site development activities to accommodate the required facilities and accommodations. The schedule has been modified to recognize that some construction works will be sensitive to the winter weather conditions.

Work has been scheduled for construction of facilities using conventional and proven methods. There is no reason to believe that the construction of the facilities proposed would result in unusual risks for cost escalation or time extensions.

5.4 Construction Schedule

A Project Control Schedule was used to plan the implementation of the works and as a basis for the detailed cost estimate prepared for the project by Nalcor. The cost of the works will be directly affected by the project schedule, which will determine the time available for each task, flood risk exposure, the need for any winter season work and other details influencing work productivity, such as labour force loading, and equipment utilization. Resource levelling through the construction schedule can have a significant effect on cost.

The Final Feasibility Study schedule was prepared on the assumption that access would only be available from the north bank of the river during the first year. However, the Final Feasibility Study was substantially superseded when access across the Lower Churchill River downstream from the site allowed for a new site layout variant to be selected.¹²⁸ The selected variant allowed for a substantial reduction in the duration of construction by making use of the access along the south bank of the river to expedite the powerhouse construction.

The final project variant was selected on the basis of the improved construction schedule, lower construction risks, and the comparative cost of the works. A final project control schedule was prepared by Nalcor for the works¹²⁹ on the basis of the selected project arrangement. The project control schedule updates the assumptions about the sequence of the construction works by including the selected contract strategy and the work breakdown structure adopted for the base construction estimate. MHI finds that the project control schedule is appropriate for DG2.

¹²⁸ Exhibit CE-15 Rev.1 (Public), SNC Lavalin, "Newfoundland and Labrador Hydro Lower Churchill Project Pre-feed Engineering Services, Muskrat Falls Hydroelectric Project - MF1010 – Review of Variants", March 2008

¹²⁹ Exhibit CE-51 Rev.1 (Public), Nalcor, "Technical Note: Muskrat Falls Generation Facility and Labrador – Island Transmission Link - Overview of Decision Gate 2 Capital Cost and Schedule Estimates", August 2011

5.4.1 Work Breakdown Structure and Contract Packaging

The Project Control Schedule was determined from a Work Breakdown Structure (WBS) that is reported to include all elements of the scope of work. During an interview, Nalcor outlined the contract strategy including separation of the scope of work into contract packages. The WBS allows for the construction activities to be divided into logical packages for planning and cost estimating.

The preliminary contract packaging has been prepared by Nalcor based on the WBS, the character of the works, and the anticipated capacity of contractors. The contracts identified appear to be logical and consistent with the strategy devised by Nalcor for construction.

The WBS appears to be sufficiently detailed to allow for a comprehensive assessment of the project schedule and cost. The WBS has taken into consideration activities necessary for construction of the project.

5.4.2 Project Control Schedule and Construction Duration

The Project Control Schedule provides a basis for the detailed project cost estimate. The schedule was developed from the WBS and considers the site conditions, climactic conditions, site access, constraints, and other factors relevant to the works. The schedule updates the work presented in the previous Study – Review of Variants, which included the comparative schedules described above.¹³⁰ The final project control schedule is adequate for construction planning, management of the works, and for the cost estimating activities. The schedule will be updated as contract packages are awarded and the final construction schedules are established.

An effort has been made to level activities through the construction period to reduce variations in the work load, to minimize interface difficulties among contractors, and to balance the labour force. The activity leveling process affects the cost estimate by reducing indirect costs for items such as labour camps and equipment.

The resulting project control schedule has about 750 activities and is structured according to the proposed contracting strategy. The activities selected appear to represent the full scope of work and to constitute a logical sequence of work.

Based on the information available, the overall construction duration is believed to be reasonable. Work is planned by contract packages with awards being timed as required and in consideration of site conditions.

¹³⁰ Exhibit CE-15 Rev.1 (Public), SNC Lavalin, "Newfoundland and Labrador Hydro Lower Churchill Project Pre-feed Engineering Services, Muskrat Falls Hydroelectric Project - MF1010 – Review of Variants", March 2008

5.5 Base Cost Estimate

The final Base Cost Estimate was prepared by Nalcor Energy as described in a confidential detailed estimate report¹³¹. Nalcor considers these estimates to be commensurate with an Association for the Advancement of Cost Engineering (AACE) Class 4 estimate (Exhibit 31).

Nalcor concluded that, since the increase in costs between the interim and final Base Cost estimates for Muskrat Falls was essentially offset by a decrease in the Base Cost for the Labrador – Island Transmission Link, the change in Base Costs for Muskrat Falls was not material.

The absolute value of the construction cost estimate has been determined by using the procedure adopted by Nalcor to determine the Base Cost Estimate.

Nalcor's DG2 capital cost estimate was prepared as a "bottom up" estimate considering the construction productivity and schedule along with the cost of materials, equipment and labour required for construction. The WBS was used as basis for the estimate. The procedure defines work activities for each element of the construction, assigns crews and equipment for the activities, and then determines the cost by estimates of the crew productivity for each activity.

A review of the Nalcor estimate was prepared by examining some of the inputs to the analysis and by comparison with similar projects within the experience of the reviewer. The review was not performed as an independent cost estimate, nor was it performed as a peer review of the Nalcor estimating procedures. The review outlined in the following paragraphs considers the main elements of the estimating procedures. The cost estimate was prepared using an appropriate methodology that was applied in a comprehensive manner with relevant input data and assumptions. The resulting estimate of costs is believed to provide a reasonable valuation for the Project cost.

5.5.1 Cost Estimate Methodology

The overall methodology for the cost estimate derives a detailed Work Breakdown Structure that includes all elements of the scope of work. The WBS was then used to allocate costs to either equipment procurement or civil works construction activities. The approach adopted is in accordance with the recommended estimating practices of the AACE.

Equipment procurement costs were estimated by reference to supplier quotations, estimator's experience, and industry benchmarking. These costs were defined by the cost estimator according to the WBS structure.

The civil cost elements were determined by considering the construction method and costs associated with each of the WBS items. The procedure involved identification of the construction crew, labour productivity, material inputs, and other costs required to complete the work identified. Detailed construction quantity takeoffs were required to measure the amount of work to be performed within the time allocated in the project control schedule.

¹³¹ Exhibit CE-51, Nalcor, "Technical Note: Muskrat Falls Generation Facility and Labrador – Island Transmission Link Overview of Decision Gate 2 Capital Cost and Schedule Estimates", August 2011

Nalcor has adopted the use of cost estimating software packages that facilitate the handling and management of the information required for the analysis. The procedure requires the estimation of a large number of parameters and the formulation of assumptions that pertain to the valuation. Importantly, the strategy for construction of the project must be determined and a construction schedule developed.

A general description of the cost estimate methodology is presented in a technical note by Nalcor¹³². The overall cost estimate methodology is appropriate for a major construction project and would allow for a reliable estimate provided that the inputs to the analysis are meaningful. The following paragraphs provide further information on the assessment of the Nalcor cost estimates.

5.5.2 Construction Labour Rates

Labour rates are an important part of the overall construction costs. The WBS included with the Project Control Schedule was used to determine the labour force loading for the construction period. The tradesmen required for construction were then determined along with the man hours allocated and their scheduling. Identification of the required trades provides the basis for the evaluation of labour costs.

Nalcor determined the cost of labour inputs to the estimate based on other large projects in the region with adjustments for the anticipated site conditions. The labour rates assumed were discussed during meetings with Nalcor staff. A detailed listing of trades was provided with reasonable direct and indirect cost allowances. Labour rates were extended to account for payroll overheads, benefits, shift allowances, travel, and other costs.

Labour rates were developed for the full set of trades identified as necessary for the works. Indirect costs were derived by estimating the cost basis of the anticipated expenses. Indirect costs for accommodations, meals, site services, and travel were determined from the estimated construction schedule. Workers are assumed to work on a rotation basis with a reasonable estimate of travel costs included for home leave during each rotation.

Historical as built productivity rates for the main elements for the civil construction works were considered in the development of the estimate. Productivity rates were based on the experience of Nalcor estimators, norms obtained from SNC-Lavalin, and other cost estimating specialists. The approach used to estimate construction labour costs is considered to be reasonable.

5.5.3 Construction Materials

Construction materials such as fuel, reinforcing steel, cement, fly ash, etc. were determined using a combination of supplier quotations and local estimating expertise. Materials costs were determined to include the cost for shipping, handling, and storage at the project site.

The approach adopted by Nalcor focussed on the largest elements of the construction materials costs including fuel, cement, fly ash, and steel. Indices for each of these were developed for the cost

¹³² Exhibit 31, Nalcor, "Technical Note: Lower Churchill Project Cost Estimate Progression, 1998 to 2011", July 2011

estimate. The consumption of the materials was determined from quantity estimates for the permanent construction works and for the general construction works.

Estimates for material costs and escalation were obtained from vendor intelligence with consumption based on estimator norms. An allowance was included for contractor overhead and profit. Detailed benchmarking of the cost estimate was not possible within the available time. However, fuel costs were noted to be consistent with current market conditions although this item is highly variable. Steel fabrication costs are somewhat higher than anticipated from a similar project.

Based on the information available, the cost of construction materials used for the cost estimate appears to be reasonable.

5.5.4 Construction Equipment

The cost of construction equipment was obtained from supplier budget quotations and local estimating expertise.

Construction equipment was determined from an estimate of the major fleet composition to complete the works identified in the WBS within the time available in the Project Control Schedule.

Hourly equipment rates were derived from the purchase cost of equipment (trucks, excavators, bulldozers, cranes, etc.) with allowances made for depreciation, maintenance and operating costs, down time, and salvage value. Depreciation was assumed over a five year term in determining the operating costs. A salvage value of about 20% was included in the rate estimation. The actual value of salvage would depend on the condition and utilization of the construction fleet. The values adopted by Nalcor are believed appropriate for the purpose.

Construction equipment productivity was developed from industry fleet productivity norms and adjusted to local conditions by benchmarking with external construction advisors. The approach adopted for the cost estimate is reasonable.

5.5.5 Permanent Equipment Packages

The cost of permanent equipment was obtained from supplier's budget quotations for the main turbine-generator package and the principal electrical systems. The quotations were adjusted to account for escalation from the bid date and to correct for known changes in the market conditions.

The major permanent equipment is the turbine-generator package, which would be supplied by one of a small number of qualified manufacturers internationally. The cost of this equipment is related to international commodity pricing for steel, copper, fuel, and other indices. However, prices are subject to variation depending on the number of orders manufacturers have in hand for projects.

5.5.6 Owner's Management and Engineering

The cost for owner's management and engineering was derived for the anticipated project organization with costs built up from the anticipated salary rates, expenses, and other costs. The estimate has allowed for the cost of the engineering studies and design based on the value of contracts already awarded. The owner's management organization structure was developed and used

as a base of the estimate by including salary and overhead costs for the anticipated management, engineering, and support staff positions.

Indirect costs were included for salary uplifts, travel to site, accommodations and allowances, vehicles, provision of offices, and other details. The cost of project permits is included.

Based on the information available, Nalcor's process for developing an estimate of costs for the owner's management and engineering is reasonable for an AACE Class 4 estimate.

5.5.7 Summary of Base Cost Estimate

The overall cost estimate was derived from the WBS, project control schedule and cost inputs using the Prism and Chief Estimator software packages. The use of this software has allowed Nalcor to apply a detailed and structured approach to the cost estimate that should allow for a reliable valuation of the overall cost of the Project.

Nalcor has prepared a very detailed estimate for the work. There is no reason to believe that the scope of work identified for the estimate is incomplete. The resulting cost estimate appears to be consistent with the nature of the works proposed for construction, local conditions, and construction market conditions.

5.5.8 Capital Cost Estimate and Risks

The overall capital cost of the Muskrat Falls project comprises the base cost estimate plus allowances for contingencies, cost escalation, and interest during construction. The following paragraphs provide comments on the methods adopted by Nalcor to establish estimate contingencies and an allowance for cost escalation during construction.

The estimate contingency makes provision for uncertainties, risks, and changes within the project scope. Nalcor has defined these as "tactical" risks that are within the project domain and, as such the cost is part of the capital cost for the Project. Tactical risks are assumed to be those elements that are within the control of the Owner's project management team. Tactical risks arise from uncertainties in the information available for the cost estimate. An example can be differences in the valuation of cost elements or variation in the estimate of work quantities for work carried out within the project scope.

Nalcor reported that contingencies were estimated through examination of the cost estimate to identify factors most likely to cause variation in the project costs. The potential change in these factors was then assessed through a combination of analytical tools and estimator's experience. Risk analysis using Monte Carlo simulation was adopted to evaluate the potential range in the cost estimate given the identified risk elements.

Cost escalation allowance makes provision for changes in price levels that are driven by economic conditions. Nalcor determined an escalation analysis from the Base Cost Estimate model by adjusting the value of the various input costs using published cost indices that were escalated through the construction period to provide input cost forecasts. When combined with the project control estimate, the escalation allowances illustrate the increase in project cost as part of the cash flow.

The approach adopted for the project cost contingencies and escalation is reasonable. Both elements are part of the capital cost estimate for the development, with the total number represented by the expected capital cost expenditure. Note however, that the project cost estimate (sum of Base Estimate, plus contingency, plus escalation allowance) does not include any provision for changes to elements such as the project scope, or unexpected events such as strikes, abnormal weather, etc. A financial contingency would normally be established to allow for such factors in creating the project budget.

MHI finds that the capital cost estimate provided by Nalcor is within the accuracy range of an AACE Class 4 estimate appropriate for DG2.

5.6 Muskrat Falls Project Cost Increases

After examination of the relevant documents, it was noted that the cost estimate for the Muskrat Falls development had increased by 104% between 1998 and 2010. This substantial increase was reviewed and it was determined that it can largely be explained by inflation and a change in scope. The change in scope is the addition of the 2 – 345 kV transmission lines from Muskrat Falls Generating Station to Churchill Falls Generating Station, associated switchyards, environmental costs, and other items such as insurance. While the cost increase cannot be fully explained by these factors, MHI considers the current cost estimate to be within the accuracy range of an AACE Class 4 estimate (+50%/-30%) which is representative of a feasibility level study.

5.7 Conclusions and Key Findings

The Muskrat Falls Generating Station feasibility studies, cost estimates, and schedule were examined by MHI's technical experts to determine whether they were completed using practices and procedures normally followed in the development of hydroelectric sites.

MHI's review involved an examination of the key documents to assess the methodology adopted and information used to develop the final project arrangement. Clarifications were obtained from Nalcor during meetings held to discuss key aspects of the development. The review was not intended to be exhaustive but to be sufficient to ensure that the decisions and recommendations reached for development of the project were well founded on factual and appropriate information.

The proposed layout and design of the project appear to be well defined and consistent with good utility practices. Available studies have identified technical risks and appropriate risk mitigation strategies.

Based on the information available, the overall construction duration is believed to be reasonable. The project schedule indicates that the Muskrat Falls development can be completed within a total of

about 62 months, assuming release for construction and commencement of contract awards in January of year one.¹³³

The cost estimate was prepared using an appropriate methodology that was applied in a comprehensive manner with relevant input data and assumptions. The scope of work identified for the estimate is in keeping with utility best practices. The resulting cost estimate appears to be consistent with the nature of the works proposed for construction, local conditions, and construction market conditions. The Base Cost Estimate for the works appears to be reasonable and should fairly represent the costs to be included in the Infeed Option. The approach adopted for project cost contingencies and escalation is also reasonable.

The following key findings are noted from the Muskrat Falls development review:

- The proposed layout and design of the Muskrat Falls Generating Station appears to be well defined and consistent with good utility practices.
- The general arrangement of the permanent works is a reasonable proposal for the optimum development in terms of cost and construction duration.
- Based on the information provided, the design and construction of Muskrat Falls Generating Station is consistent with good engineering and construction practices, and should not pose any unusual risks for construction or operation of the facilities.
- The available studies have identified technical risks and appropriate risk mitigation strategies.
- The cost estimate for the Muskrat Falls development has increased by 104% between 1998 and 2010 which can largely be explained by inflation and a change in scope. The change in scope is the addition of the 2 – 345 kV transmission lines from Muskrat Falls Generating Station to Churchill Falls Generating Station, associated switchyards, environmental costs, and other items such as insurance. Despite the additional costs, MHI considers the cost estimate at DG2 to be within the accuracy range of an AACE Class 4 estimate (+50%/-30%) which is representative of a feasibility level study.

¹³³ CE-15 Rev.1 (Public), SNC Lavalin, “Muskrat Falls Hydroelectric Project – MF1010 – Review of Variants”, March 2008