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ENERGY SHAPING BENEFITS OF 5L83

BC Hydro

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A. SUMMARY

The annual energy shaping benefits of the proposed 500 kilovolt transmission line from Nicola Substation near Merritt to Meridian Substation in Port Coquitlam (**5L83**) are expected to be between $0.11M and $1.67M based on simulation studies that model the hydraulic and electricity market conditions in the Pacific Northwest. This is due to the 560 megawatt (**MW**) to 750 MW (depending on season) increase in the Interior to Lower Mainland transfer capability (**ILMTC**) that 5L83 provides.

The energy shaping value of 5L83 was determined from hydrological studies that optimize trade activities based on reservoir inflow data for a typical 10-year period (1964-1974) to obtain an expected annual value. The average annual energy surplus for export was 6,900 gigawatt hours (**GWh**) and the March 2006 "BC border" electricity price forecast was used by the model. Energy shaping benefits are sensitive to the Heavy Load Hour (**HLH**) and Light Load Hour (**LLH**) and seasonal price spreads. The average daily spread between the Mid-C HLH to LLH electricity prices used in these studies was $14.05/MWh in F2016 (uninflated CDN2006$) that is consistent with BC Hydro's electricity price forecast.

The energy shaping benefits would increase to a range of between $0.84M and $3.07M if the North to South BC-US scheduling limits were raised to 3100 MW year-round under normal system conditions. This is the present official Western Electricity Coordinating Council (**WECC**) path rating (less the 50 MW transmission reliability margin (**TRM**)), but presently this is only achievable under more favourable system conditions in British Columbia (**B.C.**) and the Puget Sound area.

B. SCOPE

The focus of this analysis was to derive the energy shaping benefits ($M/yr) of adding 5L83. The 560 MW to 750 MW ILMTC increase due to 5L83 will allow more electricity to be exported when prices are high. The 5L83 energy shaping benefit is estimated as the difference between total annual system energy cost with the existing 5800 MW ILMTC and the total annual system energy cost with the ILMTC increased to between 6360 MW and 6550 MW by the addition of 5L83.

C. SYSTEM MODELING STUDIES

The detailed analysis follows BC Hydro's normal modeling procedures and is based on the sequential use of the hydrological simulation model (**HYSIM**) and Generalized Optimization Model (**GOM**). The simulations are first done in HYSIM to set target reservoir elevations which are inputs to GOM. This allows GOM to adequately capture the year to year storage effects of the large reservoirs. The detailed

bi-hourly analysis with GOM captures the types of operating effects that are necessary to quantify the operating benefits of 5L83.

GOM is a medium-term system optimization model and is the model that was used to assess Water Use Plan (**WUP**) operating regimes for the Peace and Columbia River systems and to conduct the 2006 studies in support of Revelstoke Unit 5. GOM takes as inputs the available resources and their operating characteristics (e.g. operating constraints, unit efficiency curves, forebay and tailrace elevations, etc.) and the domestic load for a given year. The forecasted market price of electricity is used to determine whether it is more economical to store or to draft specific reservoirs to meet load requirements and trade in the spot market. GOM seeks to maximize the value of BC Hydro resources, subject to operating constraints (i.e. restrictions on plant and reservoir operation, inter-tie limits on export and import capabilities to/from the U.S. and the Alberta markets, limits on ILMTC, etc.). Its simulation module includes detailed modeling of the hydraulic system of BC Hydro.

Relevant factors and data for the model included:

- GOM uses stream flow for the 10-year period from October 1, 1964 to September 30, 1974 which is representative of the full 60 years of water record because it contains a range of water conditions, including wet, average, and dry water years.
- A two-hour time step was used.
- GOM optimizes the operation of the five major hydroelectric plants in the BC Hydro system (GM Shrum, Peace Canyon, Mica, Revelstoke and Arrow Lakes Hydro) and spot market energy imports to meet the residual load served by these projects plus the energy export market. The residual load is the load forecast net of the contribution of Demand-Side Management programs, contracted independent power producers (**IPPs**) and other BC Hydro generation facilities.
- Within each month, daily inflows are assumed to be constant for the Peace River system, whereas daily inflows in the Columbia River system are based on historical data.
- Williston Reservoir operates within the variable minimum elevation constraint of the current WUP.
- The Peace River ice-bridge formation requirements are modeled as an annual pre-set (December 25 through January 31) controlled-flow period during which the Peace Canyon plant is permitted to peak for only 4 hours each day.
- The Revelstoke plant (2500 MW in F2016) is subject to the 5,000 cubic feet per second minimum flow restriction of the current Columbia River WUP (approximately 160 MW).
- The studies are based on the F2016 stage of BC Hydro's Base Resource Plan[1] (**BRP**) that has BC Hydro no longer relying on Burrard Thermal Generating Station for planning purposes after F2014.
- Generation from IPPs is based on (a) the historic energy profile of the existing IPPs, (b) the expected energy generation from the projects selected in the 2006 Call for Tender (based on

[1] The 22 August 2007 version of the BRP has been modified from the version provided in the 2006 Integrated Electricity Plan/Long-Term Acquisition Plan hearing to reflect the government's 2007 Energy Plan and Special Direction 10.

average generation provided by IPP developers) and (c) the characteristics of future generating resources in the BRP.

- Market Prices: The forecasted monthly HLH and LLH prices at Mid-C developed from the March 2006 HENWOOD model studies using U.S. Department of Energy's EIA forecast gas prices, with the same corresponding starting years are the source of market prices. The market electricity prices are adjusted by water year to reflect the impact of stream flow conditions in the Pacific Northwest. That data is used to develop bi-hourly export and import prices at the BC-US border. The hourly export price at the BC-US border is the price at Mid-C less wheeling and losses charges. The hourly import price at the border is the price at Mid-C plus wheeling and losses charges.
- System resources include a fifth unit at each of the Mica and Revelstoke plants as well as the upgraded turbines and up-rated generators of GMS units 6 to 10.
- Load forecasts:
  - Annual peak load (11,136 MW for F2016) after accounting for the effects of the Energy Efficiency-2 and Load Displacement-2 (EE2/LD2) and Energy Efficiency-3, 4 and 5 (EE3/4/5) programs based on BC Hydro's December 2006 reference monthly peak forecast for the total integrated system demand including obligations to (a) FortisBC under the Power Purchase Agreement (PPA) and (b) Seattle City Light (SCL) under the Skagit River Treaty and excluding all Powerex sales and related losses.
  - The annual energy forecast with EE2/LD2 and EE3/4/5 (62,790 GWh in F2016, or 62,976 GWh from October 2015 to September 2016) based on BC Hydro's December 2006 reference energy forecast for the total integrated system including the PPA and SCL obligations and excluding all Powerex sales and related losses.
- ILMTC is based on the information released by BCTC on September 18, 2007 (5L83 – Incremental Available Power Delivery to Ingledow Substation[2] - Table 1- Lines 1 and 5).
- Inter-tie transmission limits:
  - 2004 historic North to South and South to North western BC-US inter-tie limits are used during the periods of November 15– February 15 and July 1–September 30. For the rest of the year a western export/import limit of 2000/1950 MW is used.
  - 350 MW export limit on the eastern BC-US tie at Nelway. The import limit on this tie is set at zero to approximate the US-BC total path limit of 2000 MW
  - 400 MW limit in each direction for the B.C.-Alberta path.

[2] BCTC's "*5L83 – Incremental Available Power Delivery to Ingledow Substation*" report is available at: http://www.bctc.com/NR/rdonlyres/4A77CD0F-DF1F-47B4-91A5-1D19A1C4276D/0/BriefingPostingonDeliverytoINGRev1_Sept18.pdf

D. RESULTS

Table 1 summarizes the estimated annual benefit of 5L83:

Table 1: Estimated Annual Benefits of 5L83

	15 Percentile	Average	85 Percentile
Annual Benefit ($M)	0.11	0.86	1.67

Using the same hydrological data, the addition of 5L83 enables more effective generation scheduling at BC Hydro's major plants permitting incremental HLH sales that would otherwise occur in LLHs. The model results also indicate that, with 5L83, there will be an additional 60 GWh/yr of ILM energy transfer mostly due to increased LLH Alberta imports. With 5L83, the system is able to transfer more Southern Interior and Northern Interior energy through the ILM to U.S. markets during HLHs with increased Alberta imports during LLHs. Figure 1 is an extract from the GOM simulation showing the total (U.S.+Alberta) export/import over a 7-day period in winter. The graph shows that the addition of 5L83 allows for better energy shaping through higher LLH imports and higher HLH exports.

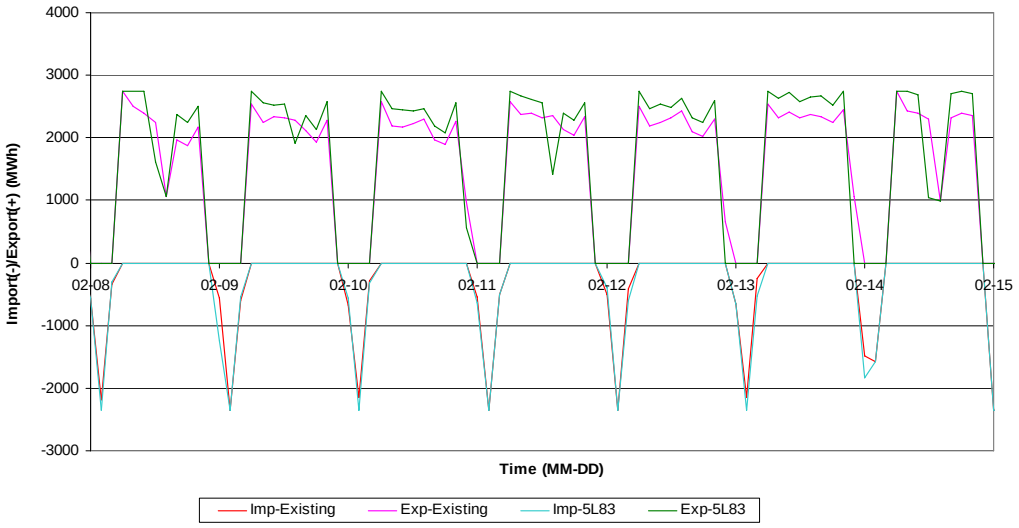

Figure 1: Import/Export Comparison with and without 5L83

Table 2 summarizes the changes in market transactions due to 5L83. With the addition of 5L83, there will be an increase in HLH sales and a corresponding decrease in LLH sales and increase in LLH imports.

Table 2: Impact of ILM Transmission Constraint on US and AB Electricity Trade

Case	Export		Import	
	HLH	LLH	HLH	LLH
Change due to 5L83 (GWh/yr)	52	-30	0	32

The studies indicated that, without 5L83, ILM transfer limits would restrict exports an average of approximately 542 hours per year with BC-US transfer limits restricting exports about 2580 h/yr. With 5L83, ILM restrictions decrease to an average of only 4 h/yr and BC-US restrictions increase to about 2750 h/yr.

Figure 2 shows the expected impact of 5L83 on average annual ILM transfer. Assuming all existing lines are in service for all hours of the year, the ILM transfers would be restricted about 6 percent of the time in the case without 5L83. Those restrictions would coincide with high electricity prices (HLH periods). There are virtually no ILM transfer restrictions after 5L83 is added.

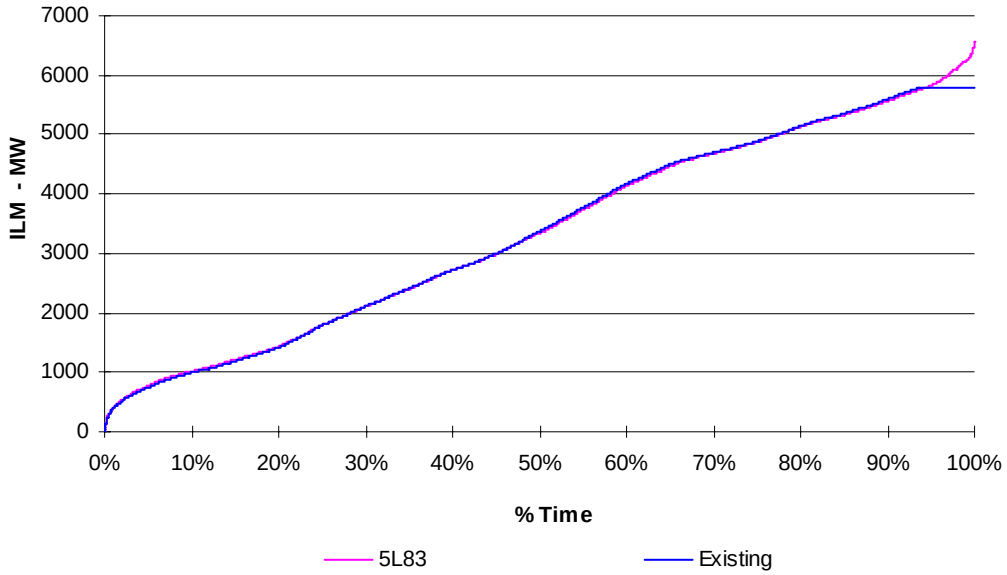

Figure 2: ILM Transfer Duration Curve with and without 5L83

E. OTHER CONSIDERATIONS

The energy shaping benefits described above are limited primarily by Westside-Northern Intertie constraints that reflect limits imposed on exports by outages in the Puget Sound area or within B.C. If it were possible through coordinated planning to operate the Northern Intertie at 3100 MW[3] in all hours of the year then energy shaping benefits could potentially increase by $1.02 Million on average as shown in Table 3.*]*

Table 3: Estimated Increase in Annual Benefits of 5L83 due to increasing in the Western Inter-Tie

	15 Percentile	Average	85 Percentile
Annual Benefit ($M)	0.74	1.02	1.40

[3] The official WECC North to South rating for Path 3 is 3150 MW of which 50 MW is set aside for the TRM.

Another variable that could significantly increase the energy shaping benefits is a wider spread between Mid-C LLH and HLH and seasonal energy prices. These price spreads are quite volatile and difficult to predict over the long term.

Another benefit of 5L83 is that it could support higher exports when other Interior to Lower Mainland lines are out of service.