RESPONSE TO WORKING GROUP AND PUBLIC COMMENTS ON THE SITE C CLEAN ENERGY PROJECT ENVIRONMENTAL IMPACT STATEMENT

Technical Memo

DAM SAFETY

MAY 8, 2013

Subject: Dam Safety

1. Purpose

This technical memo addresses comments and information requests made with respect to dam safety by the public and working group members during the comment period on the EIS. The technical memo is divided into the following sections:

- Section 2 lists the Sections of the EIS that relate to the safety of the reservoir retaining structures of the proposed Project
- Section 3 summarizes how dam safety is regulated under the British Columbia *Water Act*
- Section 4 summarizes BC Hydro's dam safety program that would apply to the Project
- Section 5 summarizes the geology of the dam site for the Project
- Section 6 provides information on the two existing BC Hydro dams upstream of the Project, including the two sinkholes that occurred at W.A.C. Bennett Dam and their remediation
- Section 7 discusses requirements for the analysis of potential cascading dam failures
- Section 8 discusses the requirements and procedures for notification in the event of a dam safety incident.

2. Environmental Impact Statement

The Environmental Impact Statement (EIS) provides the information required by the EIS Guidelines. The following sections of the EIS relate to the safety of the proposed Site C dam:

- Section 3 (Project Overview)
  - For the design of large-scale hydroelectric projects such as the Project, it is typical industry practice to retain external advisory review boards to provide independent due diligence, opinions, and advice on the technical aspects of the project design. The Project has an established international Technical Advisory Board that has provided technical advice on the project engineering and design. The members of the Site C Technical Advisory Board are globally recognized for their technical knowledge and experience with the design of hydroelectric projects around the world (Section 3.1.2 page 3-2).
- Section 4 (Project Description):
  - The earthfill dam, RCC buttress, power intakes, spillway headworks and associated training walls, which would impound the reservoir, would be designed and constructed to international and Canadian standards[1] to withstand normal loads as well as loads resulting from extreme floods and earthquakes (Section 4.3.1 page 4-9).
  - BC Hydro has adopted the highest Canadian Dam Association (CDA) dam classification for the Project. As a result the highest inflow design flood and earthquake design ground motion recommended by the CDA have been used for the design of the dam (Section 4.3.1 page 4-9).

[1] There are no formal Canadian Standards for dam engineering, standards in this context means standard of care, guidelines and norms of good practice.

- An earthfill dam has been identified as the best dam type for the foundation conditions at Site C. The design of the earthfill dam is conventional and there are many precedents around the world (Section 4.3.1 pages 4-9 and 4-10).
- The RCC buttress would support the south wall of the valley and provide an abutment for the earthfill dam and the foundation for the generating station and spillways (Section 4.3.1 page 4-9)
- The free overflow auxiliary spillway would provide additional spill capacity in the unlikely event that some of the spillway gates become inoperable during an emergency (Section 4.3.1 page 4-18)
- The Project would be operated, managed, and maintained in accordance with Canadian and international dam safety practices (Section 4.5.1 page 4-63)
- Operation, Maintenance, and Surveillance Manuals would be prepared for the cofferdams and the permanent reservoir retaining structures and associated equipment. Operation, Maintenance, and Surveillance Manuals would follow the CDA Dam Safety Guidelines and comply with the British Columbia Dam Safety Regulation[2] (Section 4.5.1 page 4-64)
- Emergency Preparedness Plans would be prepared for the cofferdams and the permanent reservoir retaining structures. Emergency Preparedness Plans would follow the CDA Dam Safety Guidelines and comply with the B.C. Dam Safety Regulations (Section 4.5.1 page 4-65)
- British Columbia is one of four provinces in Canada with a formal dam safety program. There are approximately 1,900 dams in the province, including some of the largest structures in Canada. These dams are regulated under the British Columbia Dam Safety Regulation, with oversight by the Dam Safety Program, B.C. Ministry of Forests, Lands and Natural Resource Operations. The Dam Safety Section, under the Comptroller of Water Rights, is responsible for administration of the provincial dam safety program and regulation of major dams (9 m or higher) throughout the province. BC Hydro's Dam Safety Program complies with the British Columbia Dam Safety Regulation. Dam safety management of the Project would be undertaken as part of BC Hydro's Dam Safety Program and would comply with the British Columbia Dam Safety Regulation (Section 4.5.1 page 4-64).

- Section 11.2 (Geology, Terrain and Soils) describes:
  - Regional seismicity (Section 11.2.5.1 pages 11-42 to 11-43)
  - Site specific seismic hazard assessments (Section 11.2.5.2 pages 11-44 to 11-48)
  - Potential for seismicity induced by reservoir filling (Section 11.2.5.3 pages 11-48 to 11-49)
  - Potential for seismic seiches and tsunamis (Section 11.2.5.4 pages 11-49 to 11-51)
  - Understanding of how petroleum industry-related activities may affect seismicity (Section 11.2.5.5 pages 11-51 to 11-52)
- Section 37.1 (Effects of the Environment on the Project) describes the ability of the dam, generating station and spillways to withstand extreme weather, earthquakes and floods:
  - The freeboard provided on the earthfill dam is greater than recommended by the CDA Dam Safety Guidelines for wind effects as it is governed by other factors (Section 37.1.3 pages 37-4 to 37-6).

[2] B.C. Reg. 44/2000, O.C. 131/2000.

- Permanent drainage and erosion control measures would be designed for the 200 year return period rainfall (Section 37.1.3 pages 37-6 to 37-7)
- The thickness of the material covering the impervious core of the earthfill dam is sufficient to prevent freezing of the core in winter (Section 37.1.3 pages 37-7 to 37-8)
- The downstream face of the spillway gates would be provided with an insulated enclosure, heaters would be provided to prevent ice buildup and all other flow control equipment would be housed in heated enclosures or provided with heaters to maintain required operability during the winter (Section 37.1.3 pages 37-7 to 37-8)
- Lessons learned from some major earthquakes are described. The lessons learned from the performance of dams during major earthquakes have been incorporated into the practices of modern dam engineering. The design of the dam, generating station, and spillways for the Project has been done in accordance with this practice (Section 37.1.6.1.1 pages 37-10 to 37-12)
- The seismic performance requirements for the dam, generating station and spillway are described for a range of ground motions up to the 1/10,000[3] earthquake design ground motion (Section 37.1.8.1.1 page 37-13)
- The performance of the earthfill dam is described for a range of earthquake ground motions up to the 1/10,000 earthquake design ground motion and the expected movements much smaller than the earthfill dam would be able to accommodate (Section 37.1.8.1.2 pages 37-14 to 37-16)
- If a seiche was caused by the earthquake design ground motions, the combined seiche and crest settlement would be 0.5 m compared to the earthfill dam freeboard of 7.6 m therefore the dam could not be overtopped (Section 37.1.8.1.2 page 37-16)
- The performance of the RCC buttress is described for a range of earthquake ground motions up to the 1/10,000 earthquake design ground motion. Movements and cracking during the earthquake design ground motion would not impair the ability of the RCC buttress to retain the reservoir (Section 37.1.8.1.4 pages 37-17 to 37-19)
- While the reservoir retaining structures would safely retain the reservoir after the maximum design earthquake, it is possible that some or all of the generating units and spillway gates would not be operational for a period. With none of the generating units and spillway gates operational, the Project could pass a total flow of 4,000 m^3/s through the auxiliary spillway and by overtopping of the spillway gates with the reservoir at the maximum flood level. This total flow is equivalent to the Peace Canyon dam with all four units operating at full capacity plus the 20 return period flood from the Site C local catchment (Section 37.1.8.1.5 page 37-20)
- The requirements for post-earthquake monitoring are described (Section 37.1.8.1.6 page 37-20)
- The capability of the diversion works to pass floods is described (Section 37.1.10 pages 37-21 to 37-24)
- The derivation of the extreme inflow design flood used for the design of the spillways is described (Section 37.1.11 pages 37-25 to 37-41)
- The Stage 2 upstream cofferdam and the earthfill dam would have sufficient freeboard to prevent overtopping by a landslide generated wave (Section 37.1.12.3 pages 37-44 to 37-45)

[3] An event with an annual exceedance frequency of 1/10,000 has an average return period of 10,000 years and has a 1% probability of occurring in a 100-year period.

- Measures that could be undertaken to enable the Project to pass floods greater than the inflow design flood should floods increase due to climate change are identified (Section 37.1.13.2 pages 37-46 to 37-47).

3. *WATER ACT*

In British Columbia, the operation of dams and the liability of dam owners for damage caused by the construction, operation or failure of their dam is governed under the *Water Act*[4]. The British Columbia Dam Safety Regulation applies to all owners of licensed dams[5].

Under the *Water Act*, dam owners are responsible for:

- obtaining a water licence and complying with its terms and conditions
- maintaining historical records of all observations, inspections, maintenance items, instrumentation readings, etc.

The objective of the Dam Safety Regulation is to mitigate loss of life and damage to property and the environment from a dam breach by requiring dam owners to inspect their dams, undertake proper maintenance, report incidents and take remedial action and ensure that the dams meet current engineering standards. The Comptroller of Water Rights instituted the Provincial Dam Safety Program in 1967. The program's goal is to set design, construction, maintenance, and surveillance standards, and assist dam owners in meeting these standards[6].

The regulation of licensed dams is carried out by staff of the Ministry of Forests, Lands and Natural Resource Operations.

BC Hydro will have to obtain a water licence for the Project. It is anticipated that the conditions of the water licence will include submission to the Engineer as designated under the *Water Act* of the following[7]:

- plans that show the general arrangement of the works
- criteria for the design of the works
- criteria for the operation of the works
- a schedule for the construction of the works
- an environmental management plan (EMP) for the management and mitigation of construction impacts

BC Hydro will not be able to proceed with the construction of any phase of the works covered by the Water Licence until after the Engineer designated under the *Water Act* has granted leave to commence construction for that phase of the works.

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4 R.S.B.C. 1996, c. 483.

5 http://www.env.gov.bc.ca/wsd/public_safety/dam_safety/ 21 March 2013.

6 Information Sheet - Application of the Dam Safety Regulation. http://www.env.gov.bc.ca/wsd/public_safety/dam_safety/cabinet/2011-info_sheet_ds_reg-4-23-2012.pdf accessed 21 March 2013.

7 Appendix G, Guide for Waterpower Projects, Scope of Information and Reports by the Independent Engineer http://www.env.gov.bc.ca/wsd/water_rights/waterpower/cabinet/appendix_g.pdf accessed 21 March 2013.

BC Hydro will not be able to commence commercial operation of the Project until after the Engineer under the *Water Act* has granted leave to commence operation.

4. BC Hydro Dam Safety Program

4.1 Overview

BC Hydro is committed to integrating safety in all it does. BC Hydro conducts its operations to minimize the chance of injury to employees, contractors and the public.

The objective of the dam safety program at BC Hydro is to manage the safety of all physical natural features and structures necessary to retain the reservoirs and control the passage of all flows through, around and beyond its dams, to ensure the integrity of the dam and to avoid any uncontrolled release of water.

The dam safety department at BC Hydro, which currently has 34 professional and technical staff is responsible for:

- Surveillance
- Regulatory Requirements
- Investigations
- Risk Analysis & Prioritization
- Project Initiation & Technical Oversight
- Liaison with other dam owners

Dam safety encompasses all aspects of the safe retention and passage of water including:

- All water retention structures, which for the Project are the Stage 2 upstream cofferdam during construction; and the earthfill dam, RCC buttress, power intakes, spillway headworks and associated training walls during operation
- All water conveyance structures, which for the Project are diversion tunnels during construction; and the approach channel, penstocks and spillways during operations
- All points of flow control up to the turbine, which for the Project are the intake gates

BC Hydro reports annually to the Comptroller of Water Rights on the safety of its dams

Dam safety management of the Project would be undertaken as part of BC Hydro's Dam Safety Program and would comply with the British Columbia Dam Safety Regulation

4.2 BC Hydro's Approach to Dam Safety Risk Management

Though ageing and normal wear and tear present challenges, and unanticipated challenges can emerge, BC Hydro's aim is to manage its whole fleet of dams, so that there is no significant deterioration in the risk position. To exclude risk altogether is impossible, for this or for any other significant hazard.

BC Hydro's method is to keep the condition of the dams and the risks they present under constant review within the requirements of the British Columbia Dam Safety Regulation, and to identify and measure, so far as possible, any unanticipated challenges, and to make any necessary improvements and repairs as soon as it is practicable.

Whenever it is possible to make improvements or necessary to take remedial measures, BC Hydro first refers to international and Canadian best practices, seeking to achieve as large an incremental increase in safety as possible, and at the very minimum, not to accept any reduction in the level of safety.

This approach involves constant monitoring and estimation of risks and threats, taking advantage of lessons learned worldwide. It requires an ongoing program of review, with improvements, and remedial actions where necessary prioritized according to:

a) the size and significance of the added safety that can be achieved, in relation to the cost
b) the degree of urgency

while recognizing the need to ensure the application of the best possible expertise.

4.3 BC Hydro Dam Safety Governance

The day-to-day dam safety activities and the management of annual or multi-year dam safety programs and projects that are the responsibility of the BC Hydro's Director of Dam Safety who:

- Reports to the Executive Vice-President of Generation at BC Hydro
- Communicates directly with:
  - the BC Hydro Board of Directors through a Board representative for dam safety
  - the Comptroller of Water Rights
  - National and international technical committees
  - Expert technical panels and advisory boards

4.4 British Columbia Dam Safety Regulation

The British Columbia Dam Safety Regulation applies to all BC Hydro dams. BC Hydro meets the requirements of that regulation as described below.

4.4.1 Operation, Maintenance and Surveillance

A consequence category is determined for all dams by the Provincial Dam Safety Officer assigned by the BC Comptroller of Water Rights (CWR). Each dam is operated in accordance with the Operation, Maintenance and Surveillance Manual for Dam Safety (OMS Manual), which incorporates all requirements (related only to dam safety) of the Dam Safety Regulation, Water License, emergency plan and any other applicable license, approval or order made under the Water Act. If necessary to meet a new order or approval related to dam safety, a revision or appendix to the OMS Manual is issued.

For each dam the OMS Manual is submitted for acceptance by the Provincial Dam Safety Officer. The OMS Manual is reviewed during Dam Safety Reviews and annually by the Dam Safety Engineer. The status of OMS Manuals is reported in the annual compliance report for the dam; nonconformances are tracked in the Dam Safety Database.

Generation Emergency Plans (GEPs) are prepared which outline internal emergency response procedures. Emergency Planning Guides (EPGs) are issued to external response agencies where communities would be affected by dam failure.

Security from unauthorized operation is the responsibility of the Generation plants and is addressed by operating orders.

4.4.2 Inspections and Tests

"Site surveillance" is conducted which consists of documented visual inspections and gate testing. Instrumentation monitoring and equipment testing are also detailed in the OMS Manuals.

Site surveillance includes:

- Routine visual inspections for: general conditions, depressions, cracking, seepage, and anything unusual or changed from the previous inspection
- Special inspections after: landslides, earthquake, high winds, spillway discharges, floods or other as specified in the OMS Manual
- Automatic and manual monitoring of instrumentation measuring: water levels and pressures, flows, turbidity, temperature, settlement and movements

Beyond the requirements of the British Columbia Dam Safety Regulation, BC Hydro surveillance is carried out with due consideration of consequences of failure, potential failure modes, and key performance indicators. Surveillance includes:

- Analysis of changes in performance, deviation of expected performance, and conditions that might threaten dam safety
- Tracking compliance of reservoir operations and adequacy of maintenance with dam safety requirements
- Adequate quality assurance to maintain the integrity of data, inspection information, dam safety recommendations, training, and response to unusual conditions
- Comparison of actual performance with design expectations

Any "safety hazards" revealed by inspection are reported to the Director, Dam Safety, and entered in a database for follow-up and action. These are termed "actual deficiencies" or "potential deficiencies" in BC Hydro's dam safety management system.

4.4.3 Reporting

All dam safety and surveillance records are kept permanently in the BC Hydro records system and are available on request by the Provincial Dam Safety Officer. An annual compliance report is submitted to the CWR summarizing inspections and performance of the dam during the year. Any significant performance issues that arise during the year are promptly reported to the CWR.

All new design and construction documents, dam safety and surveillance records are kept permanently as BC Hydro records, along with available historic design and construction records.

4.4.4 Dam Safety Review and Report

Dam Safety Reviews are carried out for all BC Hydro dams within the intervals required by legislation, or more frequently. The Dam Safety Review Schedule is reviewed and updated annually by the Director, Dam Safety, as part of the annual management plan. The Dam Safety Review report, prepared by a qualified and experienced professional engineer, is submitted by the Director, Dam Safety, to the CWR as requested.

The schedule for Dam Safety reviews for the upstream dams are 7-10 years for Peace Canyon dam (Very High Classification) and 5-7 years for WAC Bennett dam (Extreme classification). Peace Canyon Dam was last reviewed in 2008 and is next scheduled to be reviewed in 2016. WAC Bennett Dam was last reviewed in 2012 and is next scheduled to be reviewed in 2017.

Dam Safety Reviews are carried out by independent external engineers with a minimum of 25 years experience in the design, construction, performance evaluation and operation of dams.

BC Hydro has adopted the extreme level of classification for the proposed Site C dam and the schedule for dam safety reviews would be 5-7 years.

4.4.5 Hazardous Conditions at a Dam

Potentially hazardous conditions are tracked as potential or actual deficiencies in the Dam Safety Database on BC Hydro's intranet.

The Emergency Plans (GEPs and EPGs) are intended to prepare BC Hydro adequately to respond to hazardous conditions as required in the British Columbia Dam Safety Regulation. The Notification Charts include the designated contacts at the CWR and Provincial Emergency Program offices. In order to promptly warn persons in immediate danger, the Emergency Plans rely on a fan-out approach by contacting responsible downstream response agencies. See Section 8 of this Technical Memo.

4.4.6 Information and Evaluation

All dam safety and surveillance records are kept permanently in the BC Hydro records system. Records include: files of Director, Dam Safety; Generation records management system for drawings, reports, correspondence, and controlled documents; Dam Smart database for surveillance instrumentation data.

Copies of annual surveillance reports, and performance investigation reports are available to the Dam Safety Officer.

4.4.7 Instrumentation

The instrumentation plan is outlined in the OMS Manual for a dam. The OMS Manual is a controlled document in the records management system; a set of all instrumentation tables from the OMS Manuals is included in the annual Instrumentation Plan provided to the CWR's office.

Dam safety instrumentation of 79 dams in the BC Hydro system currently includes more than

- 3000 piezometers measuring water levels in slopes, dams and foundations
- 1950 flow measurement devices
- 4800 movement measurement devices including survey points
- 130 reservoir elevation measurement devices
- 190 weather measurement devices (rainfall, air temperature, snow depth, wind speed, etc.)
- 2700 miscellaneous devices, primarily consisting of groundwater temperatures; load cells, turbidity, and seismographs

The design of the Project will include a comprehensive instrumentation system to measure the performance of the reservoir retaining structures.

4.4.8 Expert opinion

Experts are retained to provide advice for significant dam safety issues. The Director of Dam Safety, coordinates selection and communication with the experts, and the reporting to the CWR. Levels of review include the following:

- Advisory Council provides highest level of review, at the level of corporate policy.

- Advisory Boards provide overall confirmation of project objectives and approach.
- Technical Advisory Boards provide independent technical reviews and opinions.
- Expert Engineering Panels provide technical working-level engineering studies and review.

Specialist consultants provide specific technical working-level expertise. The history of dam safety incidents and external technical review boards at WAC Bennett dam is discussed in Section 6 of this Technical Memo.

5. Dam Site Geology

5.1 EIS Requirements

Section 11.2 of the EIS describes the geology, terrain stability, and geotechnical soil conditions within the Project activity zone. Both current conditions and potential changes as a result of the proposed project activities are described.

Details of the geology, terrain stability, and geotechnical analyses are presented in supplementary technical data reports that are contained in Volume 2 Appendix B Geology, Terrain Stability and Soil Reports. Volume 2 Appendix B, Part 1 Terrain Stability Mapping describes the results of terrain stability mapping within the Project activity zone, and the potential changes to terrain stability resulting from activities such as removal of vegetation and access road construction. Volume 2 Appendix B, Part 2 Preliminary Reservoir Impact Lines describes the bedrock and surficial geology within the proposed reservoir shoreline technical study area in greater detail. Predicted changes to erosion and slope stability as a result of the creation and operation of the proposed reservoir are described. Reservoir impact lines delineating zones of potential flood, erosion, landslide, and landslide generated wave hazards are provided.

Section 11.2 describes the following which are pertinent to the dam site geology:

- Physiography and topography (Section 11.2.1)
- Regional bedrock geology (Section 11.2.2.1)
- Regional glacial history (Section 11.2.2.2)
- Regional surficial geology and terrain stability (Section 11.2.2.3)
- Dam site geology (Section 11.2.2.4).

As described in Section 11.2.2.4 of the EIS, bedrock reaches elevation 470 m on the north bank and elevation 455 on the south bank at the dam site. As described in Section 4.3 of the EIS, the dam, generating station and spillways would be founded on bedrock.

5.2 Additional Information Provided in Response to Comments

Although the following information was not required by the EIS Guidelines to be incorporated into the EIS, it is provided in response to comments on the EIS related to dam safety.

Extensive site investigations have been undertaken over several periods commencing in 1975. The investigations undertaken to date within the dam site area (EIS Figure 4.36) and immediately to the south of that area to determine the dam site geology include:

- 211 diamond drill holes with a total length of over 13,600 m

- 30 large diameter (0.9 m) drill holes (LDH) with a total length of 1810 m
- 202 percussion drill holes with a total length of over 3440 m
- 271 rotary holes with a total length of over 18,180 m
- 10 sonic drill holes with a total length of over 610 m
- 5 exploratory adits (tunnels) with a combined length of 950 m
- 268 test pits with a total depth of 1230 m
- 12 exploratory trenches with a total length of 1220 m
- 29 seismic lines with a total length of over 13,000 m

Geological mapping of bedrock was performed on natural bedrock exposures and on bedrock exposed in the exploratory trenches, 0.9 m diameter LDH and the adits. The LDH were large enough for personnel to be lowered down the hole for bedrock mapping and extract 150 mm diameter core samples. The adits were large enough for personnel to enter for in-situ rock mechanics testing as well as geologic mapping and bedrock sampling.

As described in Section 11.2.2.4 of the EIS, rock exposed at the site is part of the Shaftesbury Formation and consists of weak to medium strong, flaky to fissile, silty shale interbedded with siltstone, sandstone, and shale. Based on the laboratory and in-situ testing the following parameters are being used for the design:

- Compressive strength of the rock varying from 6 MPa (upper shale units) to 12 MPa (lower shale units)
- Shear strength of intact shale 250 kPa cohesion and friction angle 45° cross bedding and 250 kPa cohesion and friction angle 35° parallel to bedding
- The permeability of the rock mass at Site C is low, in the range of 10^{-8} to 10^{-9} m/sec, except for near-surface relaxed or decompressed zones where the permeability is greater, from 10^{-6} to 10^{-7} m/sec

Localized joints and other defects in the rock may have greater permeability than the rock mass. Exposed joints in the foundations and in the vicinity of the structure will be treated by a variety of methods including grouting.

A number of methods have been used to assess the rock modulus values at the dam site including plate load, Menard pressuremeter, Goodman Jack, USBM biaxial overcoring, seismic tests and from test chamber back analyses. The following deformation moduli are being used primarily based on the USBM biaxial overcoring results:

- 6.6 GPa parallel to bedding
- 4.4 GPa perpendicular to the bedding

Section 11.2.2.4 of the EIS describes the three sets of fractures found in the bedrock at the dam site

- Fractures or softened zones parallel to bedding (bedding planes, abbreviated as BP)
- Low angle shear zones of limited displacement
- Steep relaxation fractures parallel to valley slopes (relaxation joints)

Horizontal core samples containing bedding planes were obtained from LDHs and adits. Laboratory shear box testing was carried out to determine the strengths of the various bedding planes. In-situ

shear box testing was carried out on BP25 in one of the adits. Based on the stress strain characteristics from the shear box testing of bedding planes it was decided to use the residual strengths which are the lowest values and assume that large strains occurred during valley down cutting. Residual strengths were assigned to each bedding plane based on the results of the strength testing and the continuity based on geological mapping. The design strengths of the bedding planes range from as low as 8.5° (BP8 on the left bank) to as high as 16.5° (BP18 on the left bank).

The strengths of the shear zones were evaluated in terms of the persistence of the shear zones across the site, i.e. the proportion of large diameter holes in which each particular shear was identified and the results of laboratory shear testing. Residual shear strength values were established for each identified shear. The design strengths of the shears range from 10.4° to 21.4°.

As described in Section 11.2.2.4 of the EIS

- Steep relaxation fractures in the bedrock striking approximately parallel to the valley have been observed in exploratory trenches and in the exploratory adits on the north and south bank
- A zone of open relaxation fractures is also found within the top 8 m of rock in the riverbed

These features will be treated as follows:

- The core trench of the earthfill dam will be excavated through the open relaxation joints in the north bank and the river bed and any remaining joints will be grouted
- The foundation of the RCC buttress will be excavated to remove open and clay-filled joints to provide suitable foundation stiffness and remaining joints will be grouted
- Providing drainage tunnels in each abutment to safely convey seepage from the rock

6. Upstream Dams

The following information was not required by the EIS Guidelines to be incorporated into the EIS and is provided in response to comments on the EIS related to the safety of the existing dams upstream of the Project.

6.1 Existing Facilities

As described in EIS Section 11.1.1, BC Hydro owns and operates two hydroelectric generation facilities on the Peace River. The facilities play an important role in the BC Hydro system and together account for greater than 30% of the capacity BC Hydro's generation facilities. The existing facilities are operated as part of an integrated system to allow BC Hydro to respond to seasonal and hourly changes in electricity demand.

W.A.C. Bennett Dam, which is located on the Peace River upstream of the Project, was completed in 1968. It is a 183 m high zoned earthfill dam with a crest length of 2 km and a volume of 44 million m^3. The dam impounds Williston reservoir. The GM Shrum powerhouse at W.A.C. Bennett Dam has a total capacity of 2,730 MW.

The Peace Canyon Dam was constructed in 1976 approximately 23 km downstream of the W.A.C. Bennett Dam near the town of Hudson's Hope. The 61 m high concrete dam impounds the Dinosaur Reservoir. The Peace Canyon Generating Station, which is integrated into the dam, has four generating units with a total installed capacity of 694 MW. Operations of the generating station are generally matched to be in balance with upstream operations such that the flow through both generating stations is approximately equal at any given time.

6.2 Seismic Hazard

The design for new dams considers the Canadian Dam Association (CDA) guidelines, and the Project has been designed to withstand a ground motion with a mean annual exceedance probability of 1 in 10,000. Seismic withstand is given in terms of expected ground motions rather than Magnitude of the seismic event, since the actual ground motion depends not only on the Magnitude of the event, but also the distance from the event.

The W.A.C. Bennett Dam and the Peace Canyon Dam were designed based on the knowledge of seismic hazards at the time of their construction. As part of BC Hydro's ongoing Dam Safety work, a major project to update the seismic hazards for all of BC (including W.A.C. Bennett and Peace Canyon Dams) was completed in late 2012 (the 2012 seismic hazard assessment described in EIS Section 11.2.5.2.2). Using these updated seismic hazards, a review of the performance of both dams will be carried out on a BC Hydro system-wide priority-basis. The seismic performance assessment of W.A.C. Bennett Dam was started in 2012, and is currently ongoing. Preliminary results indicate that the dam will withstand a 1 in 10,000 ground motion event. The seismic performance assessment of Peace Canyon Dam is planned to start in 2013. Any deficiencies and upgrade options will be identified, and capital upgrades will be initiated, if required, on a priority-basis.

The Project would be located at straight line distances of 71 km and 85 km from Peace Canyon Dam and WAC Bennett dams, respectively. The probability of a major earthquake that could produce design-level ground motions simultaneously at the Project and one or both of the upstream dams has not been evaluated, but given the distance between these dams, the probability would be significantly lower than 1/10,000.

The updating of the seismic hazard for BC Hydro's dams followed by assessment of seismic performance and implementation of any required upgrades is an example of BC Hydro's ongoing commitment to ensure the safety of its dams in light of current criteria and improved understanding of hazards.

The reader may also wish to review the Technical memo on Seismic Considerations.

6.3 1996 Dam Safety Incident at W.A.C. Bennett Dam

The cross section of the W.A.C. Bennett Dam is similar to the earthfill dam of the Project: a central core of impervious material with supporting shells of granular material separated from the core by a downstream transition zone, fine filter and drain. The core material for W.A.C. Bennett Dam was made by mixing various natural silts, sands and gravels whereas the core material for the earthfill dam of the Project is a naturally occurring glacial till as described in Section 4.3.1 of the EIS.

In 1996 there was a dam safety incident at W.A.C. Bennett Dam when two sinkholes appeared in the crest of the dam. In one of the sinkholes, a loose zone was found down to a depth of 110 m. The investigations found that the sinkholes had occurred at two unique locations where survey benchmark tubes were set vertically from the foundation of the dam to the crest. The two sinkholes were successfully backfilled and compacted with a soil mixture similar to the original core.

Subsequent to the 1996 incident, a number of special external reviews of W.A.C. Bennett Dam have been undertaken:

- 1996 to 2000: Annual Advisory Board Meetings were held
- 2001 to 2006: annual reviews were undertaken by the Norwegian Geotechnical Institute which concluded
    - monitoring and reporting continuing in a professional way

  - no significant changes in the behavior of the dam had been observed
  - an annual external review was no longer required unless there was a significant change in the monitoring equipment and surveillance program; the frequency of external reviews was subsequently reduced to three years
- 2009: a review by the recently retired chief dam designer for Hatch Ltd. concluded that:
  - the system of instruments, monitoring, data assessment, and annual reporting is first class and highly reliable
  - the program is well planned and executed
  - the instrumentation system, process of data review is comprehensive
  - the instrumentation system is eminently capable of detecting anomalous behavior

In 2012, BC Hydro took an additional step of commissioning a complete detailed review of the dam performance by a panel of three international engineering experts. This review took one year and included three site visits and a review of the construction and condition from the original records.

This expert engineering panel commented that:

- the dam was well designed for the time it was constructed
- the dam was well constructed on the basis of extensive construction testing
- seepage flow rates are stable, and have been for a number of years
- the pore pressures in the core are in a steady state condition, but some erosion of the core may have initiated in cracks formed by hydraulic fracture during first filling
- the dam has a good filter system that may allow a small amount of erosion at the core / transition interface, but will prevent on-going erosion
- the dam has a large capacity to discharge leaks and to prevent instability of the dam

The expert engineering panel concluded that it is not warranted to attempt to densify the core and that it is sufficient to continue to monitor.

BC Hydro is addressing specific recommendations made by the panel:

- further investigations and assessments
- further characterization and modeling
- state of the art baseline deformation surveys over and under water
- investigate measures to seal up leaky casings

7. Analysis Of Cascading Dam Failures

7.1 EIS Requirements

Section 23.2 of the EIS Guidelines describes the potential accidents and malfunctions that have to be addressed in the EIS. Section 23.2 of the EIS Guidelines does not require an assessment of the effects of a failure of W.A.C. Bennett Dam or Peace Canyon Dam on the Project.

Section 37 of the EIS provides the information required by Section 23.2 of the EIS Guidelines.

7.2 CDA Guidelines

The Canadian Dam Association (CDA) Dam Safety Guidelines[8] consist of:

- Principles that are applicable to all dams
- Guidelines that outline processes and criteria for management of dam safety in accordance with the principles

An understanding of the consequences of dam failure underlies several principles of the dam safety guidelines. Dams are classified by the consequences of a dam failure. As stated in EIS Section 4.3.1, BC Hydro has adopted the highest dam classification for the Project. As a result the highest inflow design flood and earthquake design ground motion recommended by the CDA have been used for the design of the dam.

Dam breach analysis is used to determine the ultimate discharge from a hypothetical breach of a dam. The outcome is a flood peak or wave immediately downstream of the dam, which is then routed to determine the flood arrival time, flood peak arrival time, and the depth of flow at downstream locations. Mapping of inundation areas (i.e. areas flooded by the flood wave) is used for:

- estimating the potential consequences of a dam breach
- for emergency planning purposes

The CDA Guidelines state:

> *"If there are other dams or water retaining structures downstream, the study must consider whether the flood wave would also cause breaching of those structures. If it turns out that downstream breaching is likely to occur, the consequence assessment for the failure of* [the] *upstream* [dam] *must include the damage caused by the downstream failures."* [bracketed words added for clarity]

The applicable CDA Technical Bulletin states[9]:

> *"In the case of cascade projects, the safety of a particular dam is affected by any dams located upstream, so dam safety must be analyzed globally. The evaluation of failure consequences of a dam in a cascade must include the failure consequences of dams located downstream if such failure would be caused by the dam under study and if that failure would not otherwise have occurred in the scenario under study."*

The W.A.C. Bennett Dam and the Peace Canyon dam are both located upstream of the Project and therefore a cascading dam failure is not required to establish the consequences of a failure of the Project's dam.

If the Project is authorized and proceeds to construction, the dam breach analyses for the W.A.C. Bennett Dam and the Peace Canyon Dam will be updated to take the Project into account. These updated analyses will be used to update:

- the classification of the Peace Canyon Dam if the consequences of a failure change (W.A.C. Bennett Dam is already the highest classification)

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8 Canadian Dam Association, Dam Safety Guidelines, 2007.

9 Canadian Dam Association, Technical Bulletin: Inundation, Consequences, and Classifications for Dam Safety, 2007.

- the emergency preparedness plans for W.A.C. Bennett Dam and Peace Canyon Dam to incorporate any changes to dam break inundation mapping that result from the Project reservoir

Updated information would be provided to the applicable emergency responders.

8. Emergency Planning

8.1 Emergency Planning Legislation

Emergency response planning in British Columbia for hydro-electric dams is governed by provincial legislation including:

a) Emergency Program Act, Local Authority Emergency Management Regulation

b) Water Act, British Columbia Dam Safety Regulation

This legislation outlines the respective roles for dam owners, Water Management Branch, Emergency Management BC and Local Authorities.

Local Authorities, as defined in the Emergency Program Act, have a legislated duty to respond first to emergency situations within their jurisdictions and to have an emergency plan in place to keep citizens, infrastructure and the community as safe as possible.

BC Hydro would follow this legislation for the Project.

8.2 Emergency Response Planning

BC Hydro follows existing provincial legislation with respect to emergency response planning. In accordance with the British Columbia Dam Safety Regulation, BC Hydro produces an Emergency Planning Guide for the W.A.C. Bennett and Peace Canyon Dams that is provided to downstream response agencies responsible for public emergencies and safety. Downstream response agencies include Local Authorities and downstream communities in BC and the Government of Alberta.
BC Hydro reviews the Emergency Planning Guide with downstream response agencies to ensure an effective response in the case of an emergency. BC Hydro, for all aspects of its operations (Generation, Transmission and Distribution), works at a provincial and regional level with Emergency Management British Columbia (EMBC) who is the coordinating agency for the provincial government's emergency management activities.

The Dam Alert/Breach Notification Chart in the Generation Emergency Plan for W.A.C. Bennett Dam and Peace Canyon Dam includes:

- the Government of Alberta Coordination and Information Centre
- the Alberta River Forecast Centre

BC Hydro provides the government of Alberta the information needed for emergency planning.

BC Hydro would follow these practices for the Project.

8.3 Emergency Preparedness Planning

As outlined in 4.5.1.1 of the EIS, In accordance with the CDA Guidelines, Emergency Preparedness Plans describe the notifications to be issued and, in general terms, the actions expected from downstream responders in the event of a dam failure or passage of a major flood. Emergency Preparedness Plans are not response documents but contain essential information such as inundation maps and flood arrival details, so that authorities can develop their own response plans. In the event of

an emergency at the dam, the local authorities and other downstream stakeholders would be contacted. The CDA recommends that distribution of Emergency Preparedness Plans should generally be limited to those who have a legal and defined emergency response role. BC Hydro emergency plans are controlled documents with limited distribution for security reasons.

Emergency Preparedness Plans would be prepared for the cofferdams and the permanent reservoir retaining structures of the Project. Emergency Preparedness Plans would follow the CDA Guidelines and comply with British Columbia Dam Safety Regulation. The Emergency Preparedness Plans would be submitted to be BC Comptroller of Water Rights, with the Emergency Preparedness Plans for the cofferdams submitted prior to diversion of the river through the diversion tunnels and the Emergency Preparedness Plans for the dam submitted prior to reservoir filling. In both cases, the Emergency Preparedness Plans would be submitted in sufficient time to make any changes that the Comptroller of Water Rights may require prior to construction.

BC Hydro will consult on the contents of the Emergency Preparedness Plan with the Local Authorities defined in Section 8.1 and appropriate downstream response agencies prior to submitting to the BC Comptroller of Water Rights.

Related Comments / Information Requests:

This technical memo provides information related to the following Information Requests:

form_0004-020	gov_0003-016	gov_0005-037	gov_0007-001	gov_0010-083
gov_0011-030	gov_0012-045	gov_0012-047	gov_0012-048	gov_0012-049
gov_0012-050	gov_0012-051	gov_0012-053	gov_0012-054	gov_0013-002
gov_0013-018	pub_0088-002	pub_0088-003	pub_0226-001	pub_0229-001
pub_0242-001	pub_0243-008	pub_0252-001	pub_0257-001	pub_0294-001
pub_0438-021	pub_0540-005	pub_0544-002	pub_0544-003	pub_0601-001
pub_0601-014	pub_0601-015	pub_0601-017	pub_0601-033	pub_0633-005
pub_0852-001	pub_0859-001	pub_0981-001	ab_0001-029	ab_0001-156
ab_0003-041	ab_0004-104	ab_0008-004		