BC Hydro
Power smart

Discussion/Information

Board briefing – DAM SAFETY QUARTERLY REPORT

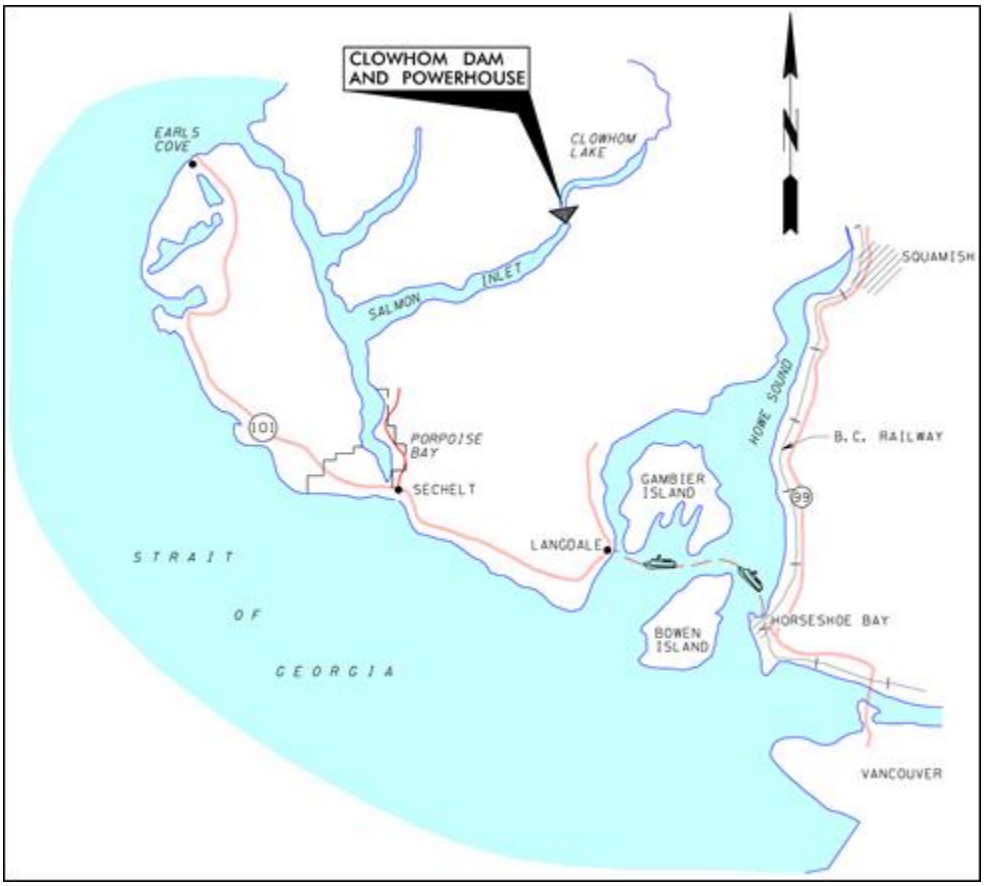
Executive Summary

The purpose of this report is to update the Capital Projects Committee of the Board of Directors on key dam risk management activities during the period from April 1, 2016 to June 30, 2016, and to provide reasonable assurance that the safety of dams operated by BC Hydro continues to be managed to the established guidelines and criteria of the Dam Safety program.

The Dam Safety Program has been carried out consistent with its stated objectives throughout the reporting period. The overall Dam Safety risk profile is shown in Figure 1. There has been an overall decrease in the risk profile this quarter due to the previously completed canal lining work at Kootenay Canal (having now proven to be effective), the downgrading of concern over the condition of the spillway at Buntzen and the refurbishment of the toe drain system at Duncan Dam.

Quarterly Featured Damsite – Clowhom Dam

Clowhom Dam is located approximately 32 kilometres northwest of Sechelt at the head of Salmon Inlet in southwestern British Columbia. It is accessible only by sea or air. Clowhom Dam was constructed from 1956 to 1957 with the generating unit commissioned in 1958.



Clowhom Dam Site Map

Prior to construction of the current project, a smaller plant with a concrete dam, penstock, and powerhouse had been built in 1952. The current dam is located immediately downstream of the old dam and the old penstock and generating equipment from the old powerhouse were removed.

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The 10 kilometre long Clowhom Lake Reservoir is retained by the Clowhom concrete gravity dam. The concrete dam is 22 metres high and 402 metres long. The central portion of the concrete gravity dam contains a two-gated spillway and a free overflow emergency spillway. The left portion of the concrete gravity dam contains the intake structure for the penstock with a single intake gate. A small earthfill saddle dam with concrete core wall is located on the left abutment infilling a narrow valley. Water is conveyed through the intake structure into the 4.27 metre diameter, 310 metre long steel penstock which leads to the powerhouse with a single 33 MW Francis generating unit. A steel surge tank is located upstream of the powerhouse.

The Clowhom Dam was originally considered as a Very High Consequence dam under the BC Regulations. As the dam falls well short of both seismic and flood design expectations for a Very High Consequence Dam, a project was completed in 2010 that removed all permanent population from within the inundation zone. This included relocating the BC Hydro caretakers' house, and purchasing a fishing lodge that was already on the real estate market. On this basis, the consequence category was downgraded to Significant. This allows for the BC Hydro decision to retain the flood and seismic risks rather than proceeding with costly upgrades. In addition, inspection requirements are monthly rather than weekly.

Clowhom Reservoir is susceptible to flash flooding, typically as a result of heavy rain on snow in the October to February period. All discharge facilities are required to pass the 1/1000 year annual exceedance frequency inflow design flood, the expectation for a Significant Consequence dam.

The estimated seismic withstand of Clowhom Dam is 0.15g, which relates to an event in the order of 1:500 annual exceedance probability. However existing stability analyses have followed only very simple, conservative methods, so that actual seismic withstand is likely equivalent to or exceeds the expectation of 1:1000 for a Significant Consequence dam. The seismic withstand of the intake and spillway gates, intake tower, penstock and surge tank is unknown.

Consequence Category

Since 2012, a floating forestry worker accommodation camp has been periodically moored at the log sorting yard in Salmon Inlet, across from the spillway. The floating camp houses up to 40 additional workers for varying periods of time. While the floating camp is in place, the consequence classification of the dam reverts to Very High. The risk to the floating camp is from large spills that may impact on the camp and from potential failure of the dam during an extreme flood or earthquake. With this classification, there is the expectation that the dam would be seismically upgraded, and there is a requirement for weekly inspections.

Rather than planning for seismic upgrades, this recurring, but temporary situation is being addressed by:

- Informing the logging company in writing of the voluntary risk that they are assuming when mooring the floating camp across from the spillway each time that the camp is put in place.
- improving emergency plans and communications with the logging company
- increasing the spillway gate testing frequency from quarterly to monthly, in line with other Very High consequence dams.

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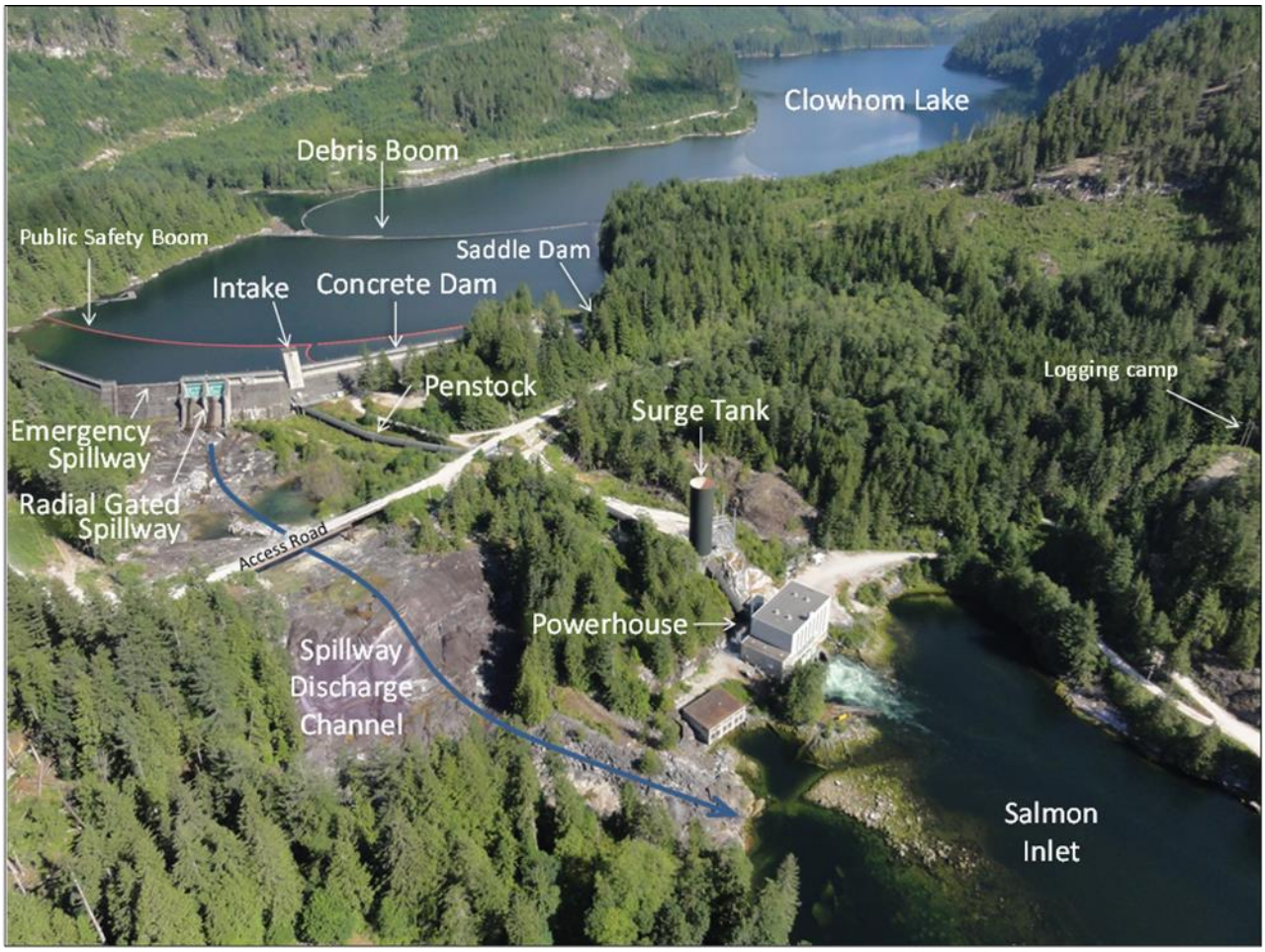

Clowhom Dam

It has been shown that, based on a review of the hazards and failure modes, an increase in inspection frequency from monthly to weekly will not reduce the risk when the floating camp is anchored in place. Retaining monthly inspections has been accepted by the Regulator.

Seismic Activity

An earthquake of magnitude 3.1 occurred with an epicenter less than 4 km west of the dam in early April 2016. The shaking was measured onsite at between 0.05g and 0.1g, the highest our seismic triggers have ever recorded at any site. This loading is about 33% of the conservative estimate of seismic withstand for the dam. No damage was reported.

If the reservoir were operated 1.2 metres lower than normal, the seismic withstand could be raised to about the 1:1000 level, in line with expectations for a Significant consequence dam. Operating at the current normal reservoir level is a risk that is currently being accepted based on the consequences of failure. The cost/benefit of pursuing a lower operating level is an issue that will be reviewed sometime in the next year or so.

Gate Reliability Project

The spillway gates are critical for passing flood events and maintaining the reservoir at a safe level for dam stability. With one gate out of service, the dam can only withstand a flood event with approximately 1/80 year annual exceedance frequency. Due to the remote location of Clowhom, the spillway gates are operated on an autospill system and there is limited time available to respond should the gates fail to open on demand. Reducing the response time or upgrading the gate controls and mechanisms are crucial to improving the reliability of the gates. A Gate Control Strategy has now been developed and is being used by the Gate Reliability Project to assess potential control system reliability improvements. This also includes reliability issues with the Power Line Carrier system that provides reservoir, gate and powerhouse telemetry. There have been a number of improvements already implemented, and more are planned.

Update on Other Major Dams

Mica Dam

A special investigations project for large embankment dams was initiated in F2014. The overall objective of this project is to develop tools and methodologies for performance monitoring of BC Hydro dams. At Mica, the objectives are to carry out a detailed performance assessment of the dam by developing, testing and verifying the following:

- A complete dam behaviour mathematical and numerical model
- A good understanding of the current condition of the dam as well as a set of monitoring and response systems that can be utilized for dam safety management decisions and activities.

As part of the performance assessment of Mica Dam in Q1, work continues on the development of a comprehensive three-dimensional computer model of the foundation of Mica Dam. The Expert Engineering Panel used in the evaluation of WAC Bennett Dam has now been retained to assist in the performance review. The first site visit with the panel will be carried out in Q2. This is the first step in a complete design review to be undertaken over the next few years.

Revelstoke Dam

New thresholds to assess the stability of the Marble Shear Block were established in Q1, based on the updated geological model and piezometer data.

The instrumentation installation project for the Left Bank slopes was completed in F2016. Project documentation is underway and is targeted for completion in Q2 of F2017.

WAC Bennett Dam

There are five ongoing dam safety projects:

Condition of the spillway (deterioration of the spillway chute concrete surface)

The Contractor mobilized to site in April 2016, and the second year of construction work is underway on the chute.

Spillway gate reliability

The project will upgrade selected electrical and mechanical components of the three spillway gates. The project is currently in Definition Phase, and engineering work is continuing.

Long-term performance of the dam core

Work in Q1 continued:

- Preparation of the WAC Bennett Dam performance assessment report which will incorporate the comments received from the Expert Engineering Panel (EEP) report, and on
- finalizing the methodology to perform testing of the Zone 2 Transition material to confirm whether or not a crack could hold open in a post-seismic scenario.

Casing Upgrades

This project was initiated to address the leaky open casings in the core, while retaining their usefulness where applicable. In F2016, all six observation wells and four casings were successfully grouted. In Q1 of F2017, the contractors started the work by developing the conceptual design options for unblocking the Cross-Arm device. Work will continue in Q2. A further 5 casings have been selected for grouting in a later stage of this project.

Condition of the riprap layer protecting the upstream face of the dam

The Early Contractor involvement phase of the work was awarded in Q4 of F2016. In Q1 of 2017, the British Columbia Utility Commission and full project funding approvals were received, and the start of borrow development is expected in mid F2017.

Ruskin Dam

Anchors were installed in the upper portion of the structure as an interim risk reduction measure in 2007. Some additional anchors will likely be required to stabilize the structure during an extreme seismic event. Any anchoring will be undertaken as a separate work activity nearing the end of, or following the current redevelopment project. Additional analyses are being undertaken to check the stability of the main body of the spillway against the updated seismic hazard results, as modified for actual hard rock site conditions. In Q1, the seismic parameters needed for dynamic analyses were further refined and this work will continue in Q2.

Campbell River System

Recent and ongoing work at the three sites is as follows:

Strathcona Dam

The overall strategy for long-term risk management was described in a previous Executive Summary (Dam Safety Risk Reduction Plans, Q3/F14). Construction of a low level outlet to allow for post-seismic drawdown of the reservoir will provide the best 'first-step' in risk reduction. This will then allow removal of the existing water passage underneath the dam (the major seismic risk) without interrupting river flows. Re-establishing a water passage in one of the abutments would require the relocation of the powerhouse, and may or may not be integrated with the Low Level Outlet. Other later steps in risk reduction include spillway upgrades and the eventual rebuilding of the dam.

The project to construct a new Low Level Outlet (LLO) is in a preliminary 'needs' phase to identify project requirements. Work in Q1 continued and included:

- selection of the target LLO drawdown discharge and drawdown time,
- completion of a memo summarizing the high level considerations of combining the LLO tunnel with the power conduit for the new powerhouse, and
- start of the layout work for the new LLO tunnel and new powerhouse.

Ladore Dam

The summary report on investigations to assess the seismic performance of the dam has been finalized. Results show that some upgrades are required for the spillway. The project to design and construct these upgrades is underway and a draft conceptual design report has been prepared.

John Hart Dam

This project was initiated in F2011 to address the seismic deficiencies associated with the dams.

Work by BC Hydro and our partners continued on the development of options for the Middle Earthfill Dam and the conceptual options for the spillway gate systems. Work in Q1 involved the following activities:

- Further refinement of the upgrade options for the Middle and North Earthfill Dams,
- Advancement of feasibility design of upgrades to the concrete dam, and
- Development and evaluation of upgrade options for the spillway gates system.

Advisory Board Meeting #2 is planned for Q2 of F2017, once these options are further developed.

GATE MAINTENANCE AND TESTING

During the period of April to end of June 2016, 61 scheduled gate tests at 23 sites were carried out. Three gate systems failed to operate on demand during testing. In four cases, gates operated on demand however certain equipment malfunctioned or was found to be in unacceptable condition.

As of the end of June 2016, operational restrictions were in place on five out of 111 flood discharge gates due to known deficiencies (no change from the previous quarter). No flood discharge gates were locked out for construction and operational reasons (same as the last quarter). Ruskin continues to operate with two new gates and one original gate.

A total of 22 corrective maintenance issues were identified through ongoing testing and maintenance between April to end of June 2016. A total of 12 new and previous issues were addressed in the same period, for a reduction of seven issues overall in this reporting period. There are now 64 corrective maintenance issues outstanding at the end of May 2016, compared to 71 as of one year ago.

CIVIL MAINTENANCE

There are 30 civil maintenance projects planned for F2017. To date, nine projects are substantially complete with a current spend for the program of $1,535,000. The nine substantially completed projects are: Bridge River 1 red penstock support repairs; La Joie Dam upstream dam face shotcreting

and intake inspections; Seton forebay joint repairs; Stave Falls tunnels 1 and 2 inspection; Hugh Keenleyside North Outlet Works underwater survey; Revelstoke draft tube and exit slab underwater survey; Revelstoke dam crest asphalt sealing; Wilsey head pond dredging; and Whatshan tunnel and penstock inspection.

Six projects have been deferred in order to reduce this years' operational budget by about $435,000 to a new total of $3,565,000. The six deferred projects include five bridge repair projects and the Seven Mile Dam drain cleaning work.

EMERGENCY PREPAREDNESS AND PUBLIC SAFETY

Emergency Preparedness[1]

Emergency preparedness work follows a pattern of 1) developing or updating internal dam/facility Emergency Action Plans, 2) training or exercising staff on the Emergency Action Plans, and 3) issuing updated Emergency Planning Guides and inundation maps to external emergency responding agencies. All the plans are required to be updated annually for all Significant, High, Very High and Extreme consequence dams.

In Q1, the Campbell River System emergency action plan was updated. Internal training on the Site C Emergency Action Plan was completed. The Peace Region Emergency Planning Guide and inundation maps were revised and issued externally. Both the Peace Region and Columbia Basin Emergency Planning Guides and inundations maps were reviewed in-person with those guide holders with emergency responsibilities in their respective regions.

A full-scale functional emergency response exercise was held on June 7th to practice the company's initial response to a simulated earthquake and tsunami off the west coast of Vancouver Island. Key objectives were to test emergency protocols, and challenge coordination and reporting between response groups that had impacted telecommunications. Multiple emergency plans were exercised and corrective action plans have been identified to be closed F2017-2019. Key areas to improve are tools, technology and communications systems, logistics, employee readiness and new/sustained work to update emergency protocols and procedures.

A project timeline with deliverables was identified for the joint initiative on community evacuation mapping with the District of Squamish, Squamish Lillooet Regional District, and Squamish First Nation. Project completion is scheduled for Q2.

Finalization of emergency plans for WAC Bennett, and the Small Generation Sites will be in Q2. The Provincial Dam Safety Officer has been apprised of these delays and no concern has been expressed.

[1] Emergency Preparedness is managed by the Strategic Emergency Management team. Dam Safety audits the updating of emergency plans for compliance with the BC Dam Safety Regulation.

Public Safety[2]

All Public Safety Management Plans are being reviewed on a three year cycle. The schedule for site visits and risk assessments related to these plans has been set with 13 plans across the fleet being targeted for completion in F2017. As this work progresses, high risk items identified for remediation will be forwarded to Generation Asset Management for prioritization and scheduling. The three year schedule will be adjusted to accommodate any unplanned exceptions requiring immediate attention.

Public Safety is also involved on a multi-year initiative to replace the ageing debris booms on several reservoirs. While some booms will be replaced on a like for like basis for expediency, where possible, design improvements to address both debris interception effectiveness and public safety function will be considered. Two new boom projects (Seven Mile and Mica) will be started this year, and two ongoing boom projects (Hugh Keenleyside and Revelstoke) will be in final design and construction.

COMPLIANCE WITH PROCESSES AND REGULATION

Annual Compliance Reports for all dams were submitted in May, 2016. Approval was requested and granted for the core raising of Duncan Dam, to carry out minor investigations at the toe of Mica Dam and to vary the consequence-based inspection frequency at Clowhom Dam in Q1. Approval was also requested for upcoming instrumentation work at Walter Hardman Dam and WAC Bennett Dam. The Elsie Dam Safety Review and the Mica and La Joie Operation, Maintenance and Surveillance Manuals were submitted for acceptance in Q1. The Expert Engineering Panel final report on WAC Bennett Dam was also submitted in Q1 to meet our water licence obligation for a three-yearly external review on the performance of the dam.

The revised BC Dam Safety Regulation was passed on February 29, 2016. How BC Hydro intends to meet the new regulation will be incorporated into the Dam Safety Governance Manual.

Inspections

Overall regulatory expectations were met in Q1 for weekly and monthly dam safety inspections except at Sugar Lake and Wilsey Dams due to the retirement of the inspector. However, no consecutive inspections have been missed, and plans are being put in place to temporarily cover this work until the retired inspector is replaced. Six of the 396 scheduled inspections for Q1 were not completed for the reason stated above, in addition to one missed inspection at Clayton Falls due to manpower constraints.

Dam Safety Reviews

Dam Safety Reviews are a regulatory requirement carried out at minimum intervals of every five to 10 years at high, very high and extreme consequence dams. Four Dam Safety Reviews are scheduled for F2017: Cheakamus, Comox, John Hart and Stave Falls. A request for quotations will be released in Q2 for this work

All five of the external Dam Safety Reviews for F2016 have been completed and final reports received. All findings for the F2016 Dam Safety Reviews will be entered into the dam safety issues database.

[2] Public Safety is managed by the Public Safety team in Safety Engineering. Dam Safety audits Public Safety activities related to dams.

Any required changes in Vulnerability Index will be noted in these Quarterly reports as these issues are re-rated over time.

VULNERABILITY INDEX: UPDATE

Changes in Vulnerability Index for actual and potential deficiencies, as outlined in Figure 1, are tracked on a quarterly basis and shown on Figures 2 and 3. This is an indication of the changes in the understanding of the dam safety risk profile. In Figure 3, the total index is shown (sum of actual and potential deficiencies), as well as separate plots for decreases and increases in the total index. Decreases are due to remediation projects as per the Capital Plan and resolution of issues via Performance Investigations. Increases in the index are due to the recognition of new issues. Existing issues are re-examined on a regular basis, and re-rated as required.

The baseline for the separate plots of decreases and increases to the VI has been set at the time of the development of the first 10 year capital plan.

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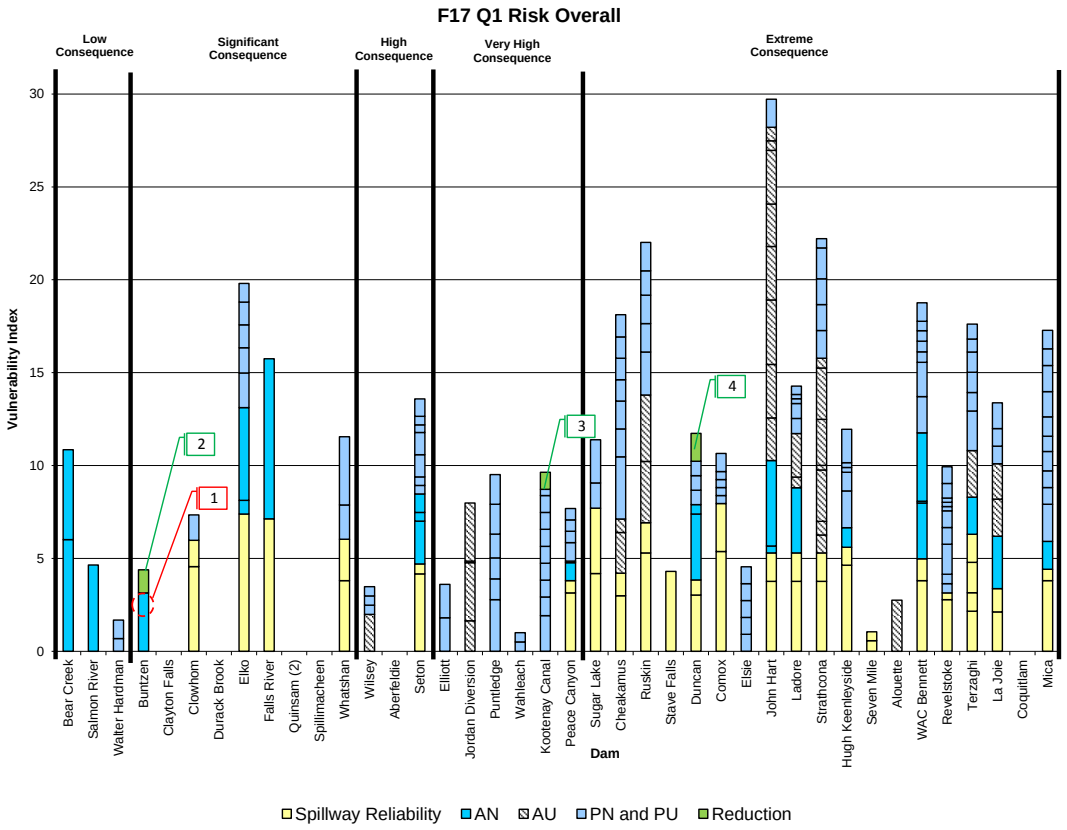
Figure 1 - Dam Safety: Overall Risk Profile



Legend and Summary of Changes

Increase in Risk

1. ***Buntzen Dam –*** *The likelihood of the dam being overtopped has been reassessed and is higher than previously thought.*

Reduction Risk

2. ***Buntzen Dam –*** *The condition of the spillway has been reassessed to be a maintenance issue rather than a deficiency.*
3. ***Kootenay Canal*** *– The addition of the carpi liner in the forebay has removed concern over the seismic performance of the forebay embankments.*
4. ***Duncan Dam –*** *The instrumentation project completed last year has refurbished the toe drain system and addressed this deficiency.*

A – Actual deficiencies have been shown to exist.
P – Potential deficiencies require further investigation.
N – Normal Load conditions; associated with daily or short-term operations.
U – Unusual Load conditions: associated with flood and earthquakes

Consequence classifications reflect current BC Dam Safety Regulations.
Dam order reflects generally increasing downstream consequences

NOTES:

- Vulnerability Index (Rating) is a qualitative assessment of future dam performance from all causes – the higher the rating the higher the likelihood of poor performance.
- 34 dam sites as identified have reportable risk at present
- This Risk Profile represents only currently known and rated issues. Changes do not necessarily indicate a physical change to BC Hydro assets that increase or decrease risk; rather they often represent a change in knowledge and understanding of the risk. Additionally, many known deficiencies (those without a direct impact on potential dam failure) have yet to be rated.

Figure 2 – Change in Actual and Potential Vulnerability Indices

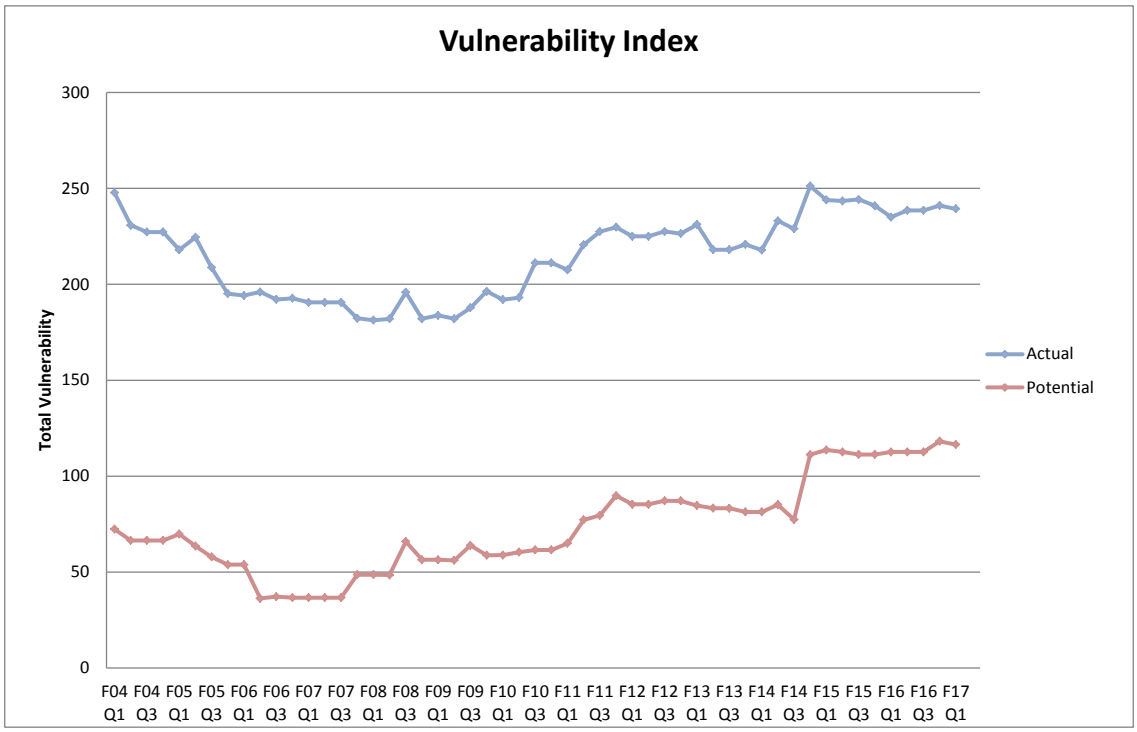


Figure 3 – Change in Total Vulnerability Index Components