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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 January 1 to March 31, 2021 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. To keep the Committee as fully abreast of the Dam Safety Program as possible, some notable developments that took place after March 31 but before the completion of this report have also been included. The key highlights from F2021 Q4 documented in this report are:

- In F2021 Q4, there was a net decrease of 7.78 in the Vulnerability Index, with two newly identified Potential deficiencies at Duncan Dam and Mica Dam (+2.19), the resolution and closure of two Actual Normal deficiencies at Mica Dam and Spillimacheen Dam (-4.92), and the recharacterization and downgrading of two Actual Normal deficiencies at Wilsey Dam and Revelstoke Dam to Potential Unusual deficiencies (-5.05). See page 3 for details.
- The lifting mechanism for an intake gate at La Joie Dam failed during annual testing, dropping the gate five feet to the concrete sill in the water passage so that it blocks one of two intakes into the dam's low level outlet. Inspections and efforts to remove the gate from the passage are planned for May 2021. See page 5 for details.
- Operation, Maintenance and Surveillance (OMS) Manual updates and Dam Safety Reviews progressed as forecast last quarter. Nine of ten planned OMS Manual updates were completed in F2021 and all ten planned Dam Safety Reviews were completed, though one report could not be transmitted to the Dam Safety Officer and issued before the end of the fiscal year. See page 8 for details.
- Dam Safety has partnered with the Canadian Space Agency and two Vancouver-based consulting firms to advance the use of satellite-acquired remote sensing (InSAR) data for landslide detection and monitoring, with promising early results. See pages 9-10 for details.
- The Civil Maintenance Program completed its full program of planned projects and, in its first year of full implementation, Civil Preventative Maintenance completed 94% of planned work orders. Spillway gate maintenance also had strong performance in Q4 and F2021 overall, with the number of outstanding gate issues reduced from 190 at the end of F2020 to 153 at the end of F2021. See pages 11-12 for details.

Impacts of COVID-19 on Dam Safety:

- Critical dam safety activities, such as surveillance, inspection and spillway gate testing, continued with minimal interruption under safe work protocols.
- There were isolated impacts to the progress and/or expenditures on some projects and initiative roll-outs, identified at various points in the report.

This report has been slightly reformatted at the request of the Capital Projects Committee. The report now contains a Program Dashboard on page 2 that summarizes the overall performance of the Dam Safety Program and the issues and work items being tracked. It is expected that this dashboard will evolve through the coming reports in response to feedback from the Committee.

Board briefing – DAM SAFETY QUARTERLY REPORT

Dam Safety Program Dashboard - F2021

As at March 31, 2021 - End of Quarter 4

Surveillance

		Quarter		Year-To-Date	
		Actual	Target	Actual	Target
Routine dam inspections	Completed	411/411 = 100.0%	100% ✓	1643/1644 = 99.9%	99.5% ✓
	Missed	0		1	
Instrumentation data checks		203/195 = 104.1%	80% ✓	841/780 = 107.8%	80% ✓
Semi-annual inspection reports					
Reservoir Slopes inspections					
Dam Performance Reviews					
Dam Issues Database Reviews					

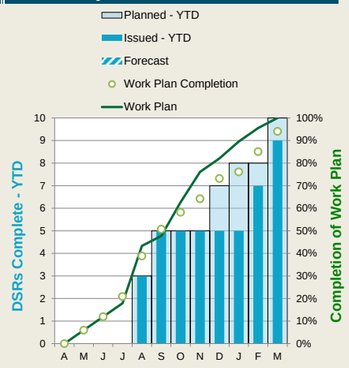
Metrics to be developed and reported in F22

These metrics and the activities or outcomes that they measure are described within the Surveillance section of this Quarterly Report.

Regulatory Submittals

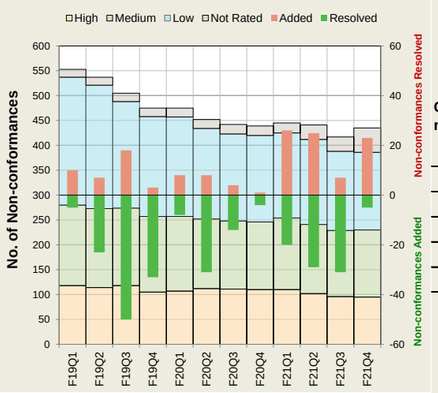
OMS Manuals

Dam Safety Reviews



These metrics and the activities and outcomes that they measure are decribed within the "Regulatory" section of this Quarterly Report.

Program Non-Conformances



Current Program non-conformance totals:

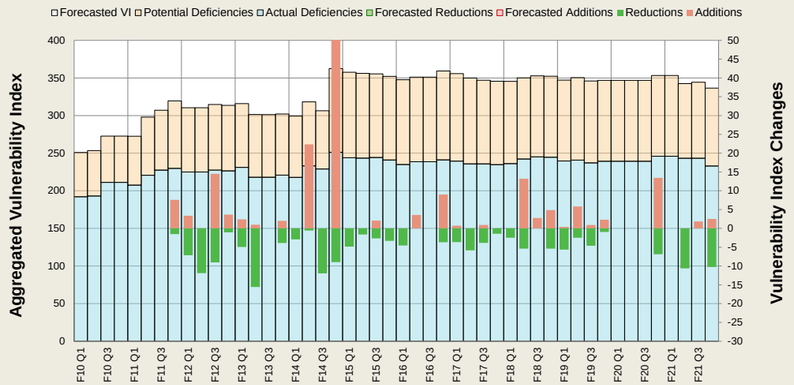
NCI (information)	224
NCM (maintenance)	63
NCO (operation)	11
NCP (procedure)	61
NCS (surveillance)	38
OMS (OMS Manual)	38

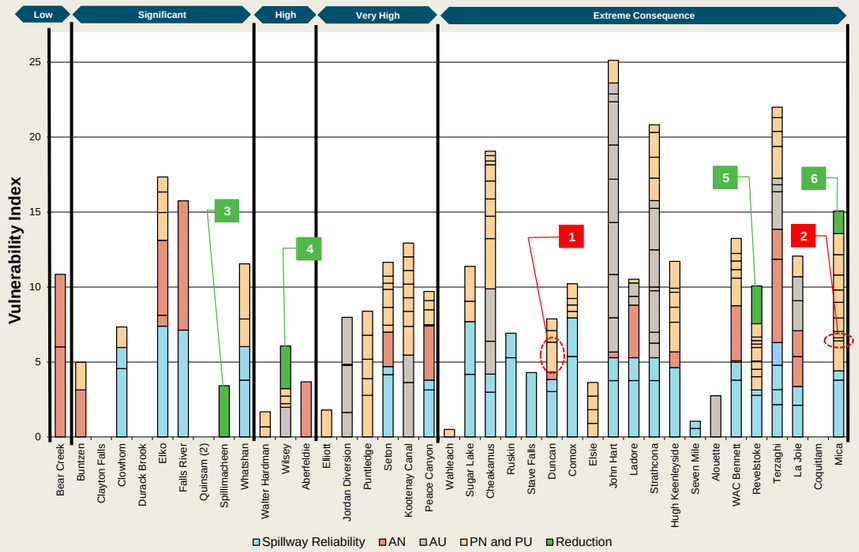
Details regarding progress in resolving and reducing the number of Program non-conformances are provided in "Non-Conformances in the Dam Safety Program" within the "Risk Profile of BC Hydro's Dams" section of the Quarterly Report.

Vulnerability Index

		Actual / Forecast	Target
Dam Safety Vulnerability Index	Reductions - Last 12 months	20.9	12 ✓
	Reductions - 12-mo forecast	11.68	12 ✗
	Additions - Last 12 months	4.33	

VI change in Quarter: ↓ -7.78





AN	***Actual*** deficiency (demonstrated to exist) under ***normal*** load conditions (associated with daily or short-term operations)
AU	***Actual*** deficiency (demonstrated to exist) under ***unusual*** load conditions (associated with flood and earthquake loading)
PN and PU	***Potential*** deficiency (requiring further investigation to demonstrate existence) under either normal or unusual conditions
Spillway Reliability	Actual or potential deficiency related to reliability of the dam's spillway and/or other flood discharge systems

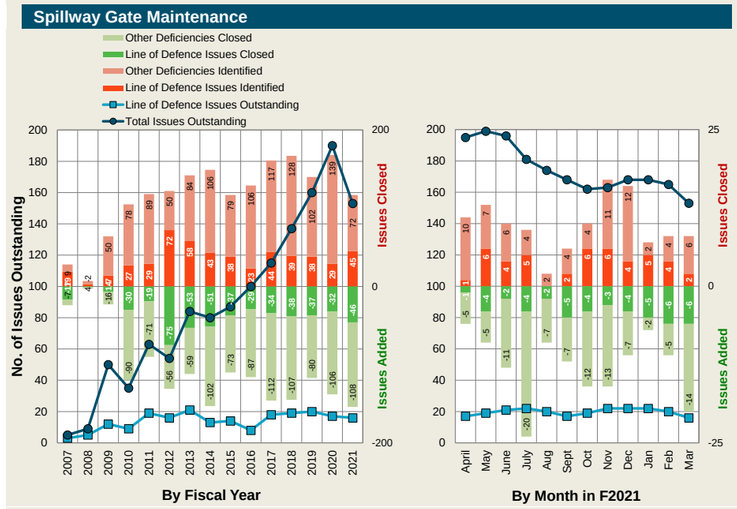
Details regarding any noted changes to the Vulnerability Index are provided in the "Vulnerability Index Update" within the "Risk Profile of BC Hydro's Dams" section of the Quarterly Report. Changes in the reported quarter are numbered in the chart above and in the report text for cross-referencing.

Maintenance and Testing

Civil Maintenance Program		Quarter		Year-To-Date	
		Actual	Target	Actual	Target
Condition-Based Maintenance	Work Orders Completed	8/4 = 200%	90% ✓	42/40 = 105%	90% ✓
	Work Plan Completion	208%	90% ✓	102%	90% ✓
Preventative Maintenance	Tasks Completed	118/57 = 207%	90% ✓	738/783 = 94%	90% ✓

These metrics and the activities or outcomes that they measure are described within the Civil Maintenance section of this Quarterly Report.

Spillway Gate Maintenance



Spillway Gate Testing		Quarter		Year-To-Date	
		Actual	Target	Actual	Target
Monthly Tests	Completed	57/58 = 98%	100% ✗	229/231 = 99.1%	99% ✓
	Missed	1		2	
Gate System Failures to Operate during Testing	Current Year Numbers	*Metrics to be developed and reported in F22*			

These metrics and the activities or outcomes that they measure are described within the Spillway Gate Maintenance and Testing sections of this Quarterly Report.

Projects and Investigations

	Quarter		Year-To-Date	
	Actual	Target	Actual	Target
Metrics to be developed and reported in F22				

These metrics and the activities or outcomes that they measure are described within the Capital Projects and Dam Safety Investigation sections of this Quarterly Report.

Board briefing – DAM SAFETY QUARTERLY REPORT

Risk Profile of BC Hydro's Dams

Dam Safety Contribution to Enterprise Risk

Dam Safety is assigned a high "risk priority" within BC Hydro's Enterprise Risk report. Please refer to that report for additional details.

Vulnerability Index Update

Identified physical deficiencies in BC Hydro's dams and the degree of concern that exists with respect to their impact on the integrity and performance of the dam are characterized by the Vulnerability Index (VI). The higher the value of the VI (scale of 0-10), the higher the likelihood of that deficiency leading to poor performance. Please refer to the centre panel of the dashboard, on which the VI for each currently identified issue at each dam site is shown, with dams sequenced from left to right in order of increasing downstream consequences per the BC Dam Safety Regulation. Also shown is the quarterly variation in VI for actual and potential deficiencies – including those related to spillway reliability – aggregated across the entire fleet of dams.

Notable changes in VI in F2021 Q4 are described below and identified on the dashboard.

1. A VI ***addition*** of 1.98 (Potential Normal deficiency) at **Duncan Dam**.
   An area of active seepage and roiling sand was observed at the western end of the seepage collection ditch at the toe of the dam. The roiling sand remained within the small, localized seepage area, there was no evidence such as turbidity in the water to indicate potential erosion of finer silt and clay materials, and hydraulic gradients measured in the foundation and near this location are below values that are generally considered necessary to drive internal erosion. Exit features can such as drainage ditches can cause localized higher exit gradients as flow lines converge around the ditch, and this is believed to be the cause of the observed behaviour. The seepage feature has been covered by a sand filter blanket which has been effective. A re-evaluation of this area will be completed after the reservoir reaches full pool sometime in the first half of F2022.

2. A VI ***addition*** of 0.21 (Potential Unusual deficiency) at **Mica Dam**.
   The seismic withstand capacity of the downstream slope of the embankment dam may be inadequate to prevent shallow (local) slope failures in the Maximum Design Earthquake. Analysis of the downstream slope stability under seismic loading is underway.

3. A VI ***reduction*** of 3.42 (Actual Normal deficiency) at **Spillimacheen Dam**.
   The installation of a concrete plug in the power tunnel at Spillimacheen Dam was reported in F2021 Q2, fully addressing the issue reported in F2020 Q4 report. That issue has now been completed and the VI has been removed.

4. A VI ***reduction*** of 2.59 at **Wilsey Dam** due to recharacterization of an Actual Normal deficiency (VI = 2.84) to a Potential Unusual deficiency (VI = 0.25). The main dam's stability was assessed (see "Dam Safety Investigations") and the arch dam's stability was found to be adequate under all applicable loads. The "plug dam" structure at the arch's toe, however, has a sliding factor that is less than the Canadian Dam Association recommended value for seismic loading if the sediment level is above El. 433.8 m.

5 A VI ***reduction*** of 2.46 at **Revelstoke Dam** due to recharacterization of an Actual Normal deficiency (VI = 2.51) to a Potential Unusual deficiency (VI = 0.05). Susceptibility of the Revelstoke spillway during spills due to cracking in the concrete above the Marble Shear Block have been investigated. Spillway operation does not appear to affect water levels in the Marble Shear Block and significant cracking of the spillway would only be considered possible under rare and extreme seismic loads exceeding the 1/10,000 Annual Exceedance Frequency event.

6 A VI ***reduction*** of 1.5 (Actual Normal deficiency) at **Mica Dam**.
As reported in the F2021 Q2 quarterly report, the grouting of the six vertical movement gauges in Mica Dam has eliminated this potential source of hydraulic fracturing or internal erosion the core of the dam.

Over the course of F2021, VI reductions of 20.9 were achieved against a target of 12. New issues with VI summing to 4.33 were entered into the Database in F2021, with a net reduction in the aggregated VI of 16.57. The target of VI reductions of 12 over the course of a year is derived from considering that, on average over the past decade, new issues have arisen with VI increases at that same rate. Meeting this target should therefore contribute to preventing a deterioration of the overall risk profile of the dams. Several existing issues are currently under review for closure (*e.g.*, spillway gate issues at Ruskin Dam) or downward re-rating, and it is anticipated that this will result in VI reductions of 11.68 in F2022.

In F2021 Q4, all Actual Normal (AN) deficiencies in the Dam Safety Issues Database were reviewed in a series of three meetings as part of the annual quality control process. These issues were reviewed to ensure they were clearly characterized and remained current, that their ratings were reasonable and consistent across the system, and that interim risk control measures have been implemented as practicable and advisable.

Non-Conformances in the Dam Safety Program

Activities to identity, review, resolve and close non-conformance issues continued in F2021 Q4. Reviews of the Dam Safety Issues Database were conducted for ten sites, resulting in the recharacterization of some deficiencies, described above, as well as the resolution of five non-conformance issues, bringing the total number of resolved non-conformances to 85 for the fiscal year. In addition, there were 23 new non-conformance issues added to the database this quarter, primarily with the finalization of five Dam Safety Reviews, resulting in 81 non-conformance issues being added through the fiscal year. A number of these new issues are expected to be resolved or recharacterized during F2022 as the Dam Safety Engineers evaluate the findings in the Dam Safety Review reports, identify and implement corrective actions to address the issues and prepare sealed memoranda documenting the resolution of each issue.

New Issues

La Joie Dam – Failure of Intake Gate Hoisting Mechanism

There are four intake operating gates at La Joie Dam. Two gates – INOG1 and INOG2 – are at the upstream end of the South Conduit that conveys water to the La Joie powerhouse. The other two gates – INOG3 and INOG4 – are at the upstream end of the low level outlet, referred to as the North Conduit, that leads to two hollow cone valves that release water directly into the Middle Bridge River during generator outages and periods of high inflows. The intake gates themselves are not used to control downstream flows and are typically held in the open position unless maintenance is required on downstream equipment.

During annual testing on March 23rd, 2021, a part of the lifting mechanism of INOG4 failed and dropped the gate approximately five feet onto the concrete sill of the gate opening. INOG4 is currently inoperable and in the closed position. Construction Services is expected to install stoplogs in front of INOG3 and INOG4 in early May to allow inspection of the gate, hoist, guides, and sill. Following inspection, if possible, the gate will be lifted out of the passage to allow full flows through the North Conduit, but INOG4 will remain out of service until the broken hoist component can be repaired or replaced.

The consequences of this failure will depend upon the findings of the inspections planned for May. If observed damage to the concrete sill is sufficiently minor to allow the passage of water and INOG4 can be lifted out of the way in May or early June, operational impacts are expected to be minor or none at all; if otherwise, stoplogs may need to be left in place in front of INOG4, reducing the discharge capacity of the North Conduit. Such an outcome would result in an increased probability of greater than planned surcharges of Downton Reservoir, discussed below under “Update on Existing Issues”.

Similar components for all four intake gates are reported to be in poor condition. Pending the outcome of the inspection and engineering assessment, Dam Safety is preparing for the potential release of an ex-plan capital project to replace the INOG4 components as soon as possible, and then to continue to replace those for INOGs 1 through 3 over F2022 and F2023.

Update on Existing Issues

Dam Safety Response to COVID-19

Dam Safety staff are generally continuing to work from home or dispatch from home to the dam sites and reservoir slopes. Although some projects and rollouts of new initiatives have experienced delays, as noted else where in this and previous reports, Dam Safety critical work has continued with very little impact.

Downton Reservoir (La Joie Dam) Surcharge

In the fall of 2020, to mitigate the impacts of an extended outage of the Seton Generating Station on increased flows in the Seton River that could affect salmon runs, a temporary surcharge of Downton Reservoir to a maximum elevation of 740.0 m was authorized and implemented. This allowed the reservoir to rise above the current Normal Maximum Reservoir Level of 734.0 m that has been in place since 2015 to manage the risk of failure of La Joie Dam following a major earthquake and the cascading failure of Terzaghi Dam downstream. See the F2021 Q3 report for a description.

To prevent or mitigate spilling down the Lower Bridge River in the sensitive fall period, Generation System Operations is currently forecasting the need for another surcharge this year. The current forecast places Downton Reservoir in surcharge from the beginning of August through late October and reaching an expected peak elevation of approximately 735 m. During surcharge, the reservoir will be managed under an Interim Dam Safety Risk Management Plan, similar to the one issued for last year's surcharge, and monitored by the Bridge River Dam Safety Engineer.

If INOG4 at La Joie Dam cannot be rendered to a state that allows full discharge through the hollow cone valves by the end of May or early June (see "New Issues", above), the required surcharge of Downton Reservoir may have to be longer and/or to a higher elevation.

Ruskin Dam – Left Abutment

As reported in the F2020 Q4 report, two sinkholes developed on the downstream slope of Ruskin Dam's left abutment. There is no indication of any connection between the reservoir and observed seepage, so this situation does not pose a risk to the integrity of the dam, but ongoing erosion would pose a threat to generating station infrastructure as well as the downstream filter blanket that was constructed to improve the earthquake resistance of the left abutment. Consequently, Dam Safety has initiated the Ruskin – Left Abutment Sinkhole Remediation Project to develop and implement a permanent fix. Further information on the scope and progress of that project can be found under "Capital Projects", later in this report.

Alouette Dam – Interim Dam Safety Risk Management during Smolt Outmigration

The Alouette Dam spillway is expected to be damaged by ground motions arising from a major earthquake – expected to occur on average once every 1000 to 2500 years – after which it would not be safe for use. Additionally, the tunnel that carries water from Alouette Lake to Stave Lake for generation at Stave Falls and Ruskin has structures that are not designed to resist earthquake loads. Until the tunnel is upgraded (see the Alouette – Headworks Tower and Surge Tower Seismic Upgrade Project under "Capital Projects" later in this report) the reservoir is being managed in a manner to extend the period of time before the spillway would pass flows following an earthquake.

Figure 1 Left: staging of crane and Superbags on the crest of Alouette Dam. Right: test placement of Superbag upstream of the sluice gate.

Each year from April 15 to June 15, however, the sluice gate on the spillway is opened to pass water over the spillway for outmigration of sockeye salmon smolts. Per the Water Use Plan, those spillway discharges are typically 3-7 m^3/s which are facilitated by a very small opening of the gate. Should a damaging earthquake occur, there is a risk that the sluice gate could be stuck open, but that opening

could be sealed by sandbags that have been stored at site in recent years. In this and a number of subsequent years, however, BC Hydro has agreed to support a study on the potential benefits of higher flows over the spillway to smolt outmigration. Outflows will average 10-11 m^3/s with gate openings of about 800 mm, exceeding the capacity of conventional sandbags to seal off should an earthquake occur. In response, Dam Safety initiated a Dam Safety Investigation (see the F2021 Q2 report) and worked with Engineering, Generation System Operations and Environment to develop means of stopping the spillway flows in the unlikely event of a damaging earthquake under an Interim Dam Safety Risk Management Plan. Under this plan, a crane and very large, one cubic metre sandbags, commonly referred to as "Superbags", have been staged on the dam crest (Figure 1) to provide a means of stopping the spillway flows if the gate cannot be closed. These measures will remain in place through the end of the smolt outmigration period on June 15, 2021.

Wahleach Tunnel Sudden Dewatering

As reported in last quarter's report, in the early hours of December 13, 2020, power to the intake gate on the upstream end of the Wahleach power tunnel was lost, causing the gate to close and the tunnel to be quickly dewatered. Fortunately, ensuing inspections by Dam Safety showed that the tunnel had suffered no significant damage and Wahleach Generating Station was returned to service on January 7, 2021.

In Q4, a root cause analysis was conducted by Field Maintenance Engineering in consultation with Stations Field Operations and Dam Safety. Corrective actions include:

- Initiation of a project to replace the diesel generator at Jones Lake, targeting completion in F2022 (in progress);
- Changing of several alarm priorities, with previous call-out of personnel to attend to site upgraded to prompt or immediate shut-down of the generating unit (in service);
- Addition of automatic trip to unit protection in the event of a lower tunnel pressure alarm (in service); and
- Addition of automatic shut-down for loss of communications from Jones lake to Wahleach Generating Station, to be delivered with completion of the Wahleach Over-Velocity Detection System Project; (in progress).

With these changes, Dam Safety is confident that a sudden dewatering of the tunnel due to loss of power or communications with Jones Lake will not be repeated and this incident is considered to have been resolved.

Compliance with Processes and Regulations

Regulatory Communications – British Columbia Utilities Commission

In Q4, Dam Safety coordinated the response to two series of Information Requests – one from the British Columbia Utilities Commission and the other from an intervenor – relating to BC Hydro's Fiscal 2022 Revenue Requirements Application and reported variances in capital expenditures and additions for fiscal 2020.

Regulatory Communications – Comptroller of Water Rights

The annual meeting between the Comptroller's Office and BC Hydro Dam Safety took place by way of online sessions on February 8, 10, and 11.

Regulatory Communications with the Provincial Dam Safety Office consisted of submission of the Engineering Design Conformance Records documenting the completion of the Bugaboo Dam Decommissioning and the Spillimacheen Tunnel Plug. In addition, Operation, Maintenance and Surveillance Manuals and Dam Safety Reviews were submitted as described below.

Operation, Maintenance and Surveillance Manuals

Each dam has an Operation, Maintenance and Surveillance Manual ("**OMS Manual**") for Dam Safety that identifies responsibilities and expectations within BC Hydro for maintaining the safety of the dam. OMS Manuals are a requirement under the Dam Safety Regulation and must be updated every seven to ten years, depending upon the dam's failure consequences classification.

The work and delivery plans for the OMS Manual updates are shown in the centre-left panel of the dashboard under "Regulatory Submittals". Overall, nine of ten planned OMS Manual updates were completed in F2021. Four OMS Manuals were scheduled for updating in Q4. Updates for Elko, Buntzen, and Coquitlam Dams were completed but, as discussed in the F2021 Q3 report, the update to the OMS Manual for Ruskin Dam has been delayed into F2022 until additional information is available from the project, at which point all of BC Hydro's OMS Manuals will have been updated in compliance with the Dam Safety Regulation.

Dam Safety Reviews

Dam Safety Reviews are carried out at minimum intervals of every five to ten years for dams that are classified in accordance with the Dam Safety Regulation as High, Very High and Extreme consequence dams.

The work and delivery plans for the Dam Safety Reviews are shown in the dashboard under "Regulatory Submissions". In all, ten Dam Safety Reviews were due in F2021; five of those in Q4. The Aberfeldie and Jordan Dam Safety Reviews were both completed and issued to the Dam Safety Officer in February and the Coquitlam and Strathcona Dam Safety Reviews were completed and issued to the Dam Safety Officer in March. The Sugar Lake Dam Safety Review was also completed and received by BC Hydro in late March but, owing to the size of the file, could not be transmitted to the Dam Safety Officer before the end of the month. Therefore, while completed in F2021, the Sugar Lake Dam Safety Review has not been recorded as "issued" in F2021 and, on that basis, nine of ten scheduled Dam Safety Reviews were completed and issued in F2021.

Surveillance

Inspections

Routine weekly / monthly inspections are a regulatory requirement. These visual inspections are carried out by trained inspectors within Dam Safety or Stations Field Operations using checklists prepared by the Dam Safety Engineer. The purpose of these inspections is to identify changing conditions at a dam, reservoir or appurtenant structure that could threaten the safety of the dam. As shown in the dashboard's upper-left panel under "Surveillance", all 411 scheduled site inspections were completed in Q4 and a total of 1643 inspections were completed during the fiscal year with only one missed inspection (at Coquitlam Dam during the second quarter of F2021) over the course of the entire year.

Dam Safety's new "Inspection App" that allows site inspections and manual instrument readings to be recorded on corporate iPhones was rolled out in Q2 and described in that quarter's report to the Capital Projects Committee. The rollout of the App was slowed through Q3 due to COVID-19 related difficulties in training operations staff in its use, but significant progress was made in in Q4. In Q4, the App was rolled out for weekly and monthly inspections at eight more dams and was used in the collection and data entry of 71% of the manual instrumentation readings (1133 out of 1594 readings). It is expected that full implementation of the App will be accomplished in F2022.

Instrumentation and Monitoring

Dam Safety Surveillance collects, checks and assesses about two million data points a month. A vast majority of the data is collected and checked against threshold values automatically by the Automated Data Acquisition System (ADAS). Even though most of the data is checked automatically it is essential that qualified staff review the data regularly to ensure the systems are functioning as expected. The Dam Safety Technologists in each region regularly check instrumentation data plots for all dams to ensure the ADAS system is functioning as expected, identify any unusual trends, and ensure continued accuracy of the data being for ongoing engineering assessment. They are tasked to perform three such checks per week. During Q4, 203 checks were completed, exceeding the target of 195. This is shown in the dashboard's upper-left panel under "Surveillance".

Reservoir Slopes

Dam Safety has partnered with the Canadian Space Agency (CSA) and two Vancouver-based consulting firms, TRE ALTAMIRA and BGC Engineering, to advance the use of satellite-acquired remote sensing (interferometric synthetic aperture radar, or "InSAR") data for landslide detection and monitoring. Previous trials with InSAR have been unsuccessful in penetrating the dense vegetation canopies and snow cover on our slopes. Recently, the Japanese space agency has launched a satellite with longer wavelength "L-band" radar that is able to penetrate the vegetation and snow cover. Through this partnership, we have acquired data from this satellite to perform detection on several of our reservoirs. CSA is cost-sharing with BC Hydro and acquiring access to the data, TRE ALTAMIRA is processing the data through customized algorithms, BGC Engineering assists in the data interpretation and follow up, while BC Hydro Dam Safety establishes the target areas and overall project objectives.

The primary project objective is to identify large, potentially damaging landslide activity around BC Hydro reservoirs that was previously undetectable by other available technologies and aerial surveys. The reservoirs selected for analysis include Revelstoke, Seton, Downton (La Joie Dam) and Site C.

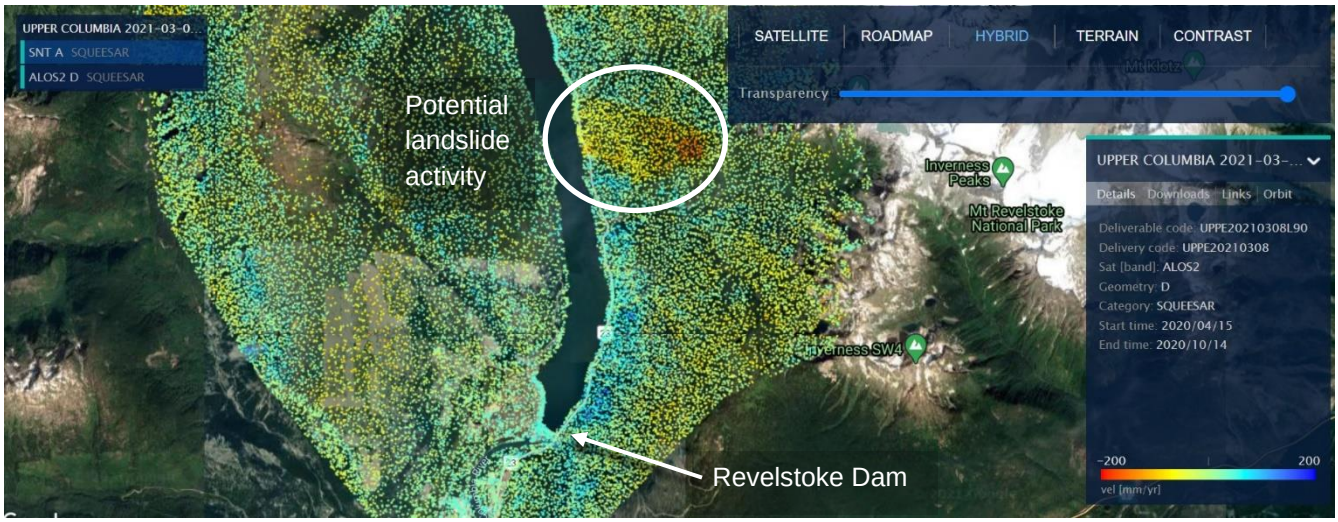


Figure 2 Imagery from the current InSAR landslide detection trial. The bright orange and yellow dots denote an area of measured slope displacement and potential landslide activity.

Preliminary results have been extremely promising. Figure 2, above, shows what may be an active landslide located approximately 10 km north of Revelstoke Dam. The general outline of the slide, the slide magnitude and landslide displacement rates can all be approximately quantified with this technology. This area has not previously been identified for landslide movements. Follow up work in early F2022 will include aerial inspection and ground based mapping of this site to confirm landslide activity.

The trial will continue over three years with continued satellite monitoring of this site and the slopes around the other reservoirs listed above.

Unusual Events or Observations

The Dam Safety On Call Person (DSOP) responded to 90 calls in Q4 of F2021, which included instrumentation alarms, operational inquiries, operations notifications during high inflows and earthquake notifications. This number of calls and responses is consistent with expectations and past experience. None were sufficiently noteworthy for inclusion in this report.

Maintenance

As described in the F2021 Q1 Report, Dam Safety has taken on elements of maintenance planning and, jointly with Generating Stations Maintenance Planning within Stations Asset Planning, will prepare and administer the annual maintenance plans for the dams and generating stations. In F2021 Q4, the two groups developed and finalized a set of governing principles to provide clear guidance on Rights and Obligations in F2022 for both parties. The governance lays out a collaborative approach that leverages the resourcing and expertise of each group. Successes and areas for improvement identified during F2022 will be used to further adjust and refine existing processes.

Civil Maintenance

The performance of the Civil Maintenance Program through F2021 is summarized in the right-hand panel of the dashboard. The Civil Maintenance program met its targets in F2021, completing 42 projects against a plan of 40 with a total spend of $2.96M against a plan of $2.89M. Projects completed in Q4 were: Revelstoke Visitor Centre slope drainage improvements; Seven Mile Dam draft tube foundation drain cleaning; Wahleach tunnel vertical shaft survey (see below); Peace Canyon Dam foundation drain cleaning; Lower Buntzen 1 penstock drainage depression repairs; Lower Buntzen 1 penstock expansion coupling repair; Revelstoke spillway bridge repairs; and Revelstoke Dam foundation drain cleaning.

Good performance was also achieved in Civil Preventative Maintenance. In Q4, Operations completed 70 Civil Preventative Maintenance work orders against a plan of 39, continuing the trend of good progress in the first full year of this program. The Civil Preventative Maintenance plan at the start of the year, prior to any reductions, called for completion of 866 work orders. To accommodate the impacts of COVID-19, the plan was adjusted downward early in the year to 783, of which 738 (94% of the adjusted target) were ultimately completed.

Wahleach tunnel vertical shaft repeatable survey

The Wahleach tunnel vertical shaft repeatable survey was completed in Q4. This was an ambitious project, planned over several years, that used leading edge underwater Remotely Operated Vehicle ("**ROV**") technology as no other methods for safely inspecting this shaft exist. ASI Marine was selected through a Request for Proposal to perform this work, which used an ROV equipped with 2D and 3D Multibeam Sonar, an Inertial Navigation System, and high definition cameras for photogrammetry.

The survey was conducted in August of 2020 with the tunnel fully watered. ASI provided a full report with supporting video, photographic and point cloud data for the full inspection, and cross section profiles at specified locations for further analysis. See Figure 3 for a sample rendering of the survey data.

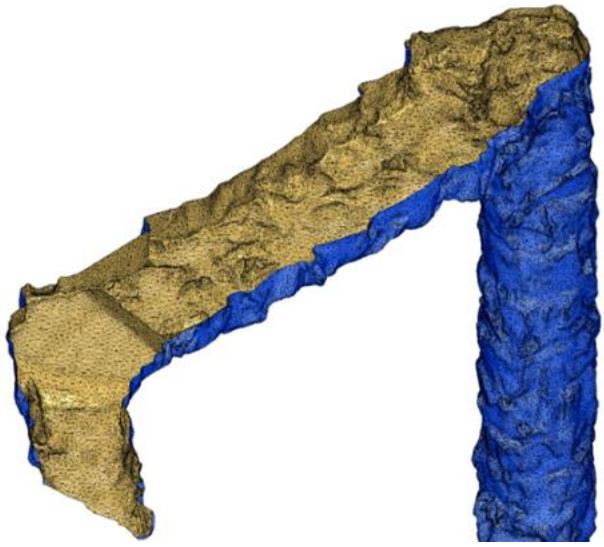


Figure 3 Mesh of sonar data from the Wahleach tunnel vertical shaft repeatable survey. The top of the shaft and the upstream connector segment of the tunnel are shown.

A key aspect of the deliverables was to ensure repeatability of the survey to a localized positional accuracy of 30 cm or better. ASI performed a repeatability check by taking 2 passes of section 0+050 to 0+057 of the shaft and comparing the data. All data points were within 10 cm of each other, and 98.88% of the points were within 3.7 cm; well within the specified tolerances, giving confidence that these results will be repeatable for future inspections.

The inspection was overseen and reviewed by BC Hydro Generation Stations Civil Engineering, who have concluded that the inspection provided reliable data and that there were no significant concerns identified.

Spillway Gate Testing and Maintenance

During Q4 of F2021, 61 of 62 scheduled gate tests at 23 sites were completed. The exception arises from an incomplete test record from one site that is missing important information. The Field Maintenance Engineer for this site has followed up with Stations Field Operations personnel to correct these omissions and prevent future occurrences.

Three gate systems failed to operate on demand or were out of service during operations and testing:

- At La Joie Dam, an intake gate hoist mechanism component failed blocking one inlet of the North Conduit water passage. See the description in “New Issues”.
- At Sugar Lake Dam, a “below-the-hook” lifting device, required for placement and removal of stoplogs on the overflow bays of the dam, was deemed out of compliance per Generation Maintenance Standard 07.60.BUL.02 due to lack of engineered drawings and a certified Working Load Limit.
- At Elko Dam, the low level outlet gate was frozen in place when operational flow release was required.

The Sugar Lake stoplogs and Elko gate have since returned to service. The La Joie intake gate hoist is being inspected in May and the water passage is targeted for return to service in June 2021.

In eleven cases, while gates did operate on demand, certain individual components of the gate system that are critical to one or more operational paths of a gate – “lines of defence” – malfunctioned. Seven of those were corrected within the quarter. A total of 23 condition-based or corrective maintenance issues were identified in Q4 of F2021 while a total of 38 new and previous issues were addressed. Seventeen of the issues addressed were “line of defence” issues, while the remainder were other deficiencies.

Progress in resolving outstanding gate reliability issues is shown in the chart on the right-hand panel of the dashboard. The total number of outstanding issues has decreased from 190 at the end of F2020 to 153 at the end of F2021. These remaining 153 issues comprise 135 corrective and condition-based maintenance issues recorded in Passport, 4 other issues being tracked by Dam Safety but not in Passport, and 14 issues that are to be resolved through small capital projects and are being tracked through the capital planning process. In F0221, the total number of issues resolved (154) exceeds the number of new issues identified (117).

This progress was the result of an ongoing collaborative and concerted effort by Dam Safety, Stations Asset Planning, Programs and Contract Management, and Stations Field Operations. In particular, Program and Contract Management maintained focus on completing outstanding gate reliability issues, proactively identified execution risks and communicated the status of the plan to Dam Safety.

During Q4, Dam Safety continued engagement with Stations Asset Planning and delivery partners in Program and Contract Management to maintain focus on the gate reliability issues and to explore opportunities for improvement in execution and reporting. Dam Safety has adapted existing practices for prioritization of maintenance work orders to better reflect the operational and safety-critical nature of spillway gate systems. Communication of the changes to impacted groups took place during Q4 and the changes have been incorporated into the F2022 Stations Business Rules.

Emergency Preparedness and Public Safety

Emergency Preparedness is managed by Security & Emergency Management. Dam Safety reports on the updating of emergency plans for compliance with the BC Dam Safety Regulation as part of annual compliance reporting to the Comptroller of Water Rights. Public safety near dams and reservoirs is managed by the Public Safety team in Safety Engineering & Work Methods. Dam Safety reports on Public Safety activities related to dams during the Dam Safety Reviews. Please refer to the Safety & Emergency Management Quarterly Report delivered to the Operations and Planning Committee for updates on emergency preparedness and public safety around dams.

Capital Projects

Summaries of Dam Safety Capital projects are available for reference in the Dam Safety “book” in Diligent. This section provides updates for the newly launched projects and for the projects where significant developments occurred or milestones were achieved.

Ruskin – Left Abutment Sinkhole Remediation

The Ruskin Dam and Powerhouse Upgrade Project included construction of a zoned filter blanket and drain on the left abutment powerhouse slope, which was substantially completed in 2017. In early January 2020, a sinkhole was discovered near the toe of the blanket, and between January and mid-March 2020, several rain events caused the sinkhole to enlarge and another sinkhole to form. See past quarterly reports from F2020 Q4 and later for additional information. The sinkholes do not pose an immediate safety risk to the dam, people or workers, but the accumulation of the eroding soils is impacting the new powerhouse drainage system and, if left unaddressed, continued erosion increases the risk of:

- Additional erosion and sinkhole development;
- Localized slope failure;
- Degradation of the powerhouse station drainage system;
- Undermining of the transformer vault, communications duct bank, and disconnect slabs; and
- Compromised post-earthquake performance of the slope and installed anchors under the north wing of the powerhouse.

The Ruskin – Left Abutment Sinkhole Remediation Project was released in F2021 Q4 to conduct investigations to determine the extent and cause of the sinkholes and to design and implement remedial works. The investigations are substantially complete and have confirmed ground improvement as the leading alternative to address the sinkhole issues. In-situ sampling and testing of soils was completed in Q4 to provide design input while design options were being developed and detailed.

Alouette – Headworks Tower and Surge Tower Seismic Upgrade

The tunnel that conveys water from Alouette Lake to Stave Lake for generation at Stave Falls and Ruskin Generating Stations was constructed in 1928, and segments of the tunnel and its ancillary structures and equipment (intake tower, surge tower, and headworks operating gates) are not expected to remain in service after a moderate earthquake. This project was initiated to ensure that the discharge facilities at the Alouette Project can be relied upon after the Maximum Design Earthquake to pass the reservoir inflows to Stave Lake and retain control over the Alouette Lake Reservoir.

Feasibility Design and constructability reviews have been completed, but the project has not been successful in advancing First Nations consultation and stakeholder engagement to a point where reservoir drawdowns required for construction can be selected and the associated variances can be sought from the Comptroller of Water Rights. The project team is working with Dam Safety, Indigenous Relations and Environment to develop an alternative staging of the work that would allow the project to advance implementation of selected risk reduction upgrades that do not rely on reservoir drawdowns, while engagement and consultation continues on facets of the project that impact reservoir elevations and First Nations and stakeholder interests.

Coquitlam LB1 – Tunnel Gates Refurbishment

The Coquitlam Buntzen Tunnel Inlet was built in 1903 and modified in 1911. The facility is constructed in natural rock with maintenance and operating gates installed in fixed locations 27 metres underground. The two operating gates are original from 1911 and have a history of mechanical problems resulting in reliability issues. The project was initiated to ensure the reliable conveyance of water via the tunnel for generation at Lake Buntzen 1 Generating Station and to manage reservoir elevations in Coquitlam Lake Reservoir.

In F2021 Q4, civil work for the new Intake Maintenance Gate was completed. The outage was extended into April to allow for additional work on the intake operating gate shaft and blasting for chamber enlargement.

Bridge River 1 – Penstock Foundation Refurbishment

Inspections have found that the concrete foundations for each of this generating station's four penstocks have visible cracking and defects. Without remediation, the penstock supports could be undermined and lead to a penstock failure which would impact the switchyard, powerhouse, staff on site, CP Rail, and the local community. Moreover, rockfall has partially buried a number of supports and significant lengths of the penstock inverts (bottoms), preventing full inspections and eventual planned recoating of the penstocks.

This project was initiated in F2021 Q4 to refurbish the concrete foundations and retaining walls to ensure the continued viability of the four steel penstocks, and to clear accumulated rockfall from the penstock alignments in advance of the BR1 Penstock Recoating project.

Ash River – Extend Life of Steel Penstock

This project was initiated to extend the service life of the steel penstock and portal tunnel steel liner by applying full interior re-coating and carrying out localized repairs of failed patches in the exterior

coating. The project also includes the installation of access hatches to facilitate the interior re-coating as well as future inspection and maintenance work.

During the completion of Feasibility Design in F2021 Q4, the Total Expected Capital Expenditure was increased from $12.8 million to $22.9 million based on recent actual costs from other similar projects. Despite the cost increase, the project was recommended to proceed without deferral to mitigate further degradation of the steel penstock and to avoid the need for a more costly replacement option. The Gate Board Meeting on March 19th, 2021 approved the project to proceed into Definition and Partial Implementation Phase.

Revelstoke – 731 Block Stability Improvement

The 731 Block is a 180 ft high prominent rock mass above Highway 23 on the left abutment of the Revelstoke Dam. Two rows of high capacity anchors were installed at the 731 Block to stabilize accelerating rock slope movement during construction. This project was initiated to address ongoing rockfall and rockslide risk posed by the 731 Block to the existing anchors, Penstocks 5 and 6, the powerhouse, personnel working on the slope and to the public that use Highway 23. After completion of Season 1 construction in Q3, the contractor de-mobilized from the site for winter. The contractor re-mobilized to start the Season 2 construction in Q4.

Various – Spillway Gate Standby Power Improvements

Past spillway gate reliability projects at various sites have installed two forms of standby power to operate the spillway gates if the normal AC power sources are lost. Since those projects were completed, however, deficiencies have been identified in both. The installed Uninterruptible Power Supplies are not able to function as intended when AC power is not available, and the existing backup diesel generators have failed on a number of occasions due to design deficiencies. This project was initiated in F2021 Q4 to improve standby power supplies by replacing or retrofitting existing Uninterruptible Power Supplies into battery inverter systems and by upgrading the existing Diesel Generators to eliminate the identified deficiencies.

Dam Safety Investigations

Dam Safety Investigation Projects ("**DI**"s) are generally performed to either refine knowledge regarding potential issues or non-conformances of information recorded in Dam Safety's Issue Database or to perform precursor work for planned capital upgrade projects. This section provides descriptions of newly launched DIs and updates for those DIs where significant developments have occurred or where milestones were achieved.

GMS – Spillway Seismic Assessment

This DI was initiated to assess the seismic performance and post-seismic operability of the spillway headworks, chute and flip bucket after a Maximum Design Earthquake and, where required, to provide an initial range of potential retrofit concepts for select components.

The DI is now substantially complete, and the draft reports have been received. The results of the assessment show that the spillway structures meet Canadian Dam Association's guidelines for acceptance criteria under usual and extreme load combinations, including earthquake and flood. On receipt of the final sealed reports, existing issues in the database regarding potential deficiencies of

the spillway following the Maximum Design Earthquake will be reviewed and updated or closed, as appropriate.

Sensitivity analyses were also performed and scenarios – with waterstops having failed and drains completely plugged – where the acceptance criteria would not be met were identified. These results underscore the importance of maintaining drains and waterstops in good working order.

Peace Canyon – Intake Gate System Emergency Close Assessment

Dam Safety assumed responsibility for asset management of generation water passages in F2021, and oversight of the performance of these assets is being integrated into the Dam Safety Program. One aspect of this is developing a program to test intake gates under full flow to ascertain their ability to function in the event of a water passage failure, as occurred in 2009 at Russia's Sayano Shushenskaya Dam.

This DI was initiated to assess the feasibility and perform full flow closure tests on the Peace Canyon Intake Gate System, and to serve as a pilot for future tests at other facilities. Engineering assessments confirmed the feasibility and safety of performing full flow closure tests on the Intake Gate System. In F2021, one of the four intake gates (INOG2) was successfully tested. A report was submitted to document the test and make recommendations for improvements to future tests. Tests of the remaining three gates were delayed by the COVID-19 pandemic but are scheduled for completion in F2022.

Wilsey Dam – Static and Seismic Performance Assessments

Dam Safety initiated an investigation in 2019 to assess the stability of the main dam, to obtain a clear and complete understanding of the dams' deficiencies, and to determine the scope and high-level costs for any required repairs and upgrades.

The report on the stability of the main dam was issued at the end of Q4. The analysis was performed using a three-dimensional dam and foundation finite element model that considered reservoir and sediment loads, uplift pressures, anchor post-tensioning effects, summer and winter thermal effects, and seismic loads under various industry standard combinations. From this assessment, the main dam's arch was found to be stable under all considered combinations. The so-called "plug dam" at the base of the dam was also found to be stable but not meeting Canadian Dam Safety Association Guidelines under earthquake loads if the sediment level at the face of the plug dam is above El. 433.8 m. Other report findings are currently being assessed.

System Wide – Flood Simulation and Mapping Model (FloodSiMM) Updates

The first Flood Simulation and Mapping Model (FloodSiMM) project was initiated in 2008. Data collection, hydraulic model development, scenario analysis and preparation of approximately 150 inundation maps covering 40 main dams on 26 river systems were completed in 2012. A total of 29 inundation modelling and mapping reports were completed in the original FloodSiMM project.

The original FloodSiMM models were prepared using MIKE 11 software and are regularly used for reservoir routing, dam breach analysis and downstream flood routing. The software developer has since switched to a new platform; "MIKE HYDRO River". In response, this project was launched in F2019 to migrate and update BC Hydro's FloodSiMM models to MIKE HYDRO River. These migrations and updates are now essentially complete.