9.0: Quarterly Dam Safety Report

Executive summary

The purpose of this report is to update the Operations, Planning, Information & Technology Committee of the Board of Directors on key dam risk management activities during the period from January 1 to March 31, 2023 (F2023 Q4) 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, 2023, but before the completion of this report have also been included.

The key highlights from F2023 Q4 and the beginning of F2024 Q1 documented in this report are:

- The system's aggregated Vulnerability Index decreased by 1.9 through F2023 Q4, with a low level outlet gate returned to service at Hugh Keenleyside Dam and an outlet works operating gate removed from service at Sugar Lake Dam. See page 3.
- The British Columbia Utilities Commission has approved BC Hydro's application for the John Hart Dam Seismic Upgrade Project. The Commission has found that the project is in the public interest and has fully accepted the project's expenditure schedule under section 44.2 of the Utilities Commission Act. See pages 6 and 14.
- All five Operation, Maintenance and Surveillance Manual updates and all five Dam Safety Reviews scheduled for F2023 have been completed and issued. See page 6.
- The completion rate of dam inspections was exemplary. As is typical, all 71 formal, annual and semi-annual inspections and reports were completed. Additionally, 1643 of 1644 routine weekly, monthly and quarterly inspections were completed as scheduled, with the single missed inspection being due to impassable road conditions immediately following a heavy snowfall in December. See page 7.
- Maintenance on the dams was well-delivered in F2023. The civil maintenance program completed all of its planned corrective and condition-based to within $1,000 of its budget and civil preventative maintenance completion continued to improve to 91 percent as the program matures. Spillway gate maintenance significantly reduced the number of outstanding maintenance tasks from 160 at the start of F2023 to 104 at the conclusion; a 35 percent reduction. See pages 9-12.
- Inundation modelling and mapping of the Alberta reaches of the Peace River for dam breach scenarios of the three Peace River dams, including the Site C Dam, was completed and shared with Alberta government offices, local authorities, and other Emergency Planning Guide holders. See pages 12 and 16.
- Piezometers and inclinometers were put into service on the St. Cyr landslide, adding to our ability to monitor this recently discovered feature on the Revelstoke Reservoir. See page 15.
- After six years of work, the Columbia River Stochastic Flood Modelling project has been completed. Modeling a system as large and complex as the Canadian portion of the Columbia River watershed in this manner was unprecedented. See pages 17 and 18.

Presenter: Bob Schubak (Director, Dam Safety)

9.0: Quarterly Dam Safety Report

Dam Safety Program Dashboard

The following dashboard provides an overview of the status of the Dam Safety Program. “Traffic lights” provide a qualitative indication of the status of each of five elements of the Program and trend arrows identify whether the status is improving, deteriorating or unchanged. As referenced, these indicators are supported by more detailed metrics and narratives in the report.

Risk Profile and Issues Management	G →	• **Vulnerability Index (pp. 3-4):** The aggregated Vulnerability Index was slightly reduced by 1.9 through Q4. • **Program Non-Conformances (p. 5):** The total number of non-conformances was reduced by 14 (approximately four percent) through Q4. • **New and Current Issues (p. 5):** No new issues arose in Q4 and existing issues pertaining to white sturgeon entering the low level outlets at Hugh Keenleyside Dam and the rockfall at Revelstoke Dam are under active management.
Regulatory Compliance	G ↑	• **Operation, Maintenance and Surveillance Manual Updates (p. 6):** The Ruskin Manual update was completed in Q4. The Cheakamus Dam Manual was completed in April. All Manual updates scheduled for F2023 have now been completed. • **Dam Safety Reviews (p. 6):** All Dam Safety Reviews that were scheduled for completion in F2023 were completed and issued.
Surveillance	G →	• **Dam Inspections (p. 7):** All 411 scheduled routine dam inspections were completed in Q4, and only one inspection was missed through all of F2023. The F2023 program of formal dam inspections was completed in full. • **Reservoir Slopes (p. 8):** The F2023 program of reservoir slopes inspections was completed in full.
Maintenance and Testing	G ↑	• **Civil Maintenance (p. 9):** Preventative civil maintenance was well executed in F2023, and the corrective and condition-based program was completed precisely to plan. • **Spillway Gates (pp. 10-12):** 244 of 245 scheduled gate tests were completed. No gates failed to operate on demand, although maintenance revealed damage to one gate which has since been repaired and returned to service. The number of outstanding maintenance tasks decreased by 22 over Q4 and by 56 (35 percent) through F2023.
Projects and Investigations	G ↑	• **Capital Projects (pp. 13-15):** The British Columbia Utilities Commission approved BC Hydro’s application for the John Hart Dam Seismic Upgrade Project. Instrumentation to monitor deformation and groundwater pressures in the St. Cyr landslide was put into service. Improved access and water collection for the Peace Canyon Dam drainage galleries was completed. • **Dam Safety Investigations (pp. 15-18):** The Columbia River Stochastic Flood Modelling project was completed.

Legend:	
G	All areas within the Program element are being implemented to a satisfactory level. Minor, isolated issues may exist but are not deemed to be indicative of deteriorating performance.
Y	One or more areas within the Program element exhibit or are at risk of underperformance and are being monitored.
R	One or more areas within the Program element exhibit unsatisfactory performance and require correction.
↑	Status of the Program element has improved over the quarter.
→	Status of the Program element was unchanged over the quarter.
↓	Status of the Program element deteriorated over the quarter.

9.0: Quarterly Dam Safety 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. The higher the value of the Vulnerability Index (scale of 0-10), the higher the likelihood of that deficiency leading to poor performance. The Vulnerability Index for each identified issue at each dam site is shown in Figure 1. Vulnerability Indices for the individual deficiencies are aggregated into stacked bars for each dam, and dams are sequenced from left to right in order of increasing downstream consequences per the BC Dam Safety Regulation. Changes in Vulnerability Index for actual and potential deficiencies (including those related to spillway reliability), aggregated across the entire fleet of dams, are tracked on a quarterly basis and shown in Figure 2. Notable changes in Vulnerability Index in F2023 Q4 are identified in Figure 1 and described below.

1. An ***addition*** of 2.47 (Spillway Reliability deficiency) at ***Sugar Lake Dam***.
   During routine monthly maintenance and testing of the Sugar Lake Dam's gates, the crew performing the work noted that the lower portion screw stem that raises and lowers Outlet Works Operating Gate 2 was bent. The ability of the gate to operate in that condition is suspect as the bent portion of the stem must travel through a guide, and compressive forces arising from driving the gate closed could lead to further damage. The gate was removed from service, but repairs were completed in early April and the gate returned to service. This issue is expected to be closed in F2024 Q1.

2. A ***reduction*** of 4.4 (Spillway Reliability deficiency) at ***Hugh Keenleyside Dam***.
   The F2022 Q4 report described that a hoist rope for Low Level Outlet Gate 7 was kinked, and that the gate was placed in restricted service. The hoist rope was replaced under a capital project in November 2022 and the gate was returned to full service. Since replacing the rope, the regular monthly tests have been successfully conducted and the issue was closed in Q4.

Over the last several years, new issues have added to the aggregated Vulnerability Index at a rate of approximately 12 per annum. To prevent deterioration of the overall risk position, reductions in Vulnerability Index through resolved issues should occur at the same pace or faster. Table 1 below confirms that Vulnerability Index reductions have far exceeded additions over the past four quarters and that Vulnerability Index reductions through F2023 exceeded the target.

Table 1 Trends and forecasts for Vulnerability Index changes in F2023.

		Actual / Forecast	Target	
Dam Safety Vulnerability Index	Reductions - Last 4 quarters	21.1	12	✓
	Reductions – Fiscal Year	21.1	12	✓
	Additions - Last 4 quarters	3.2		

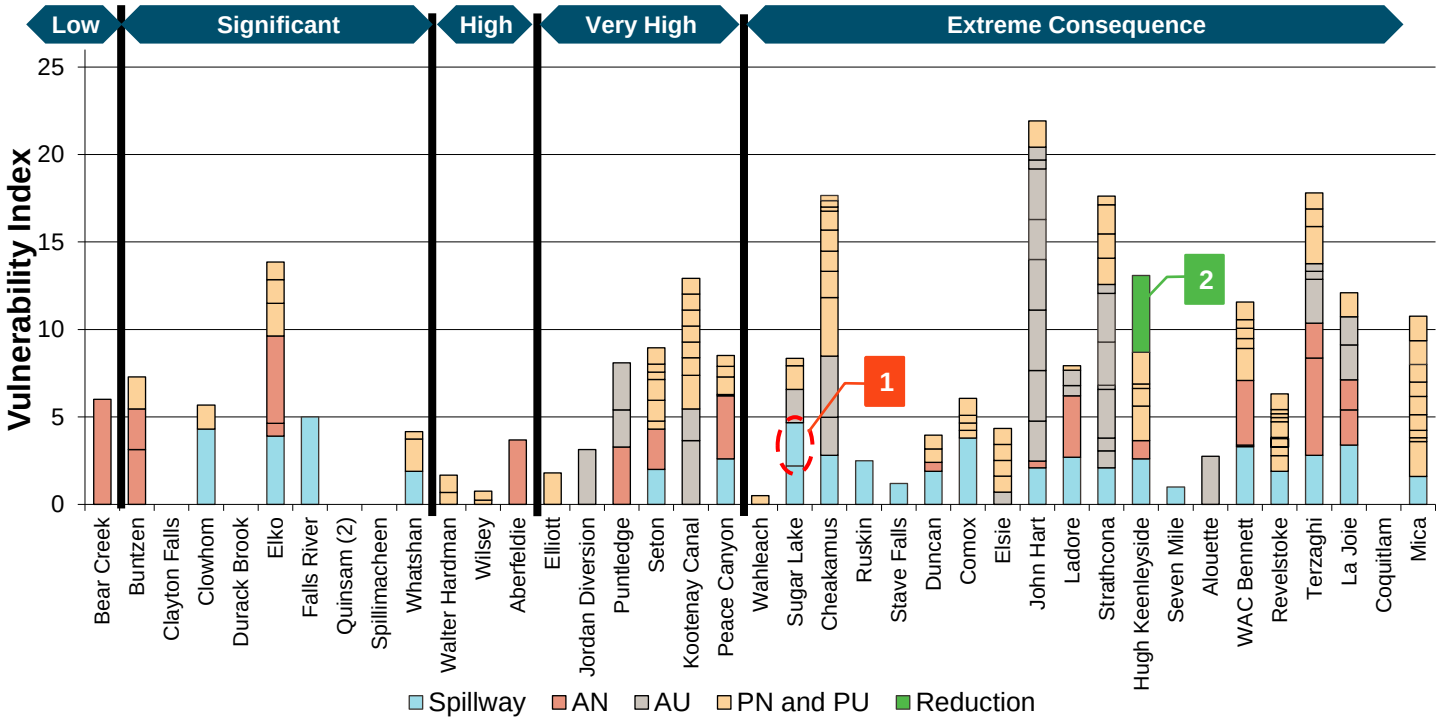

Figure 1 Dam Safety overall risk profile at the end of F2023 Q4, as represented by the Vulnerability Index. Changes this quarter are indicated by the numbered boxes.

AN	***Actual*** deficiency (demonstrated to exist) under ***normal*** load conditions
AU	***Actual*** deficiency (demonstrated to exist) under ***unusual*** load conditions
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 operational reliability of the dam's spillway and/or other flood discharge systems

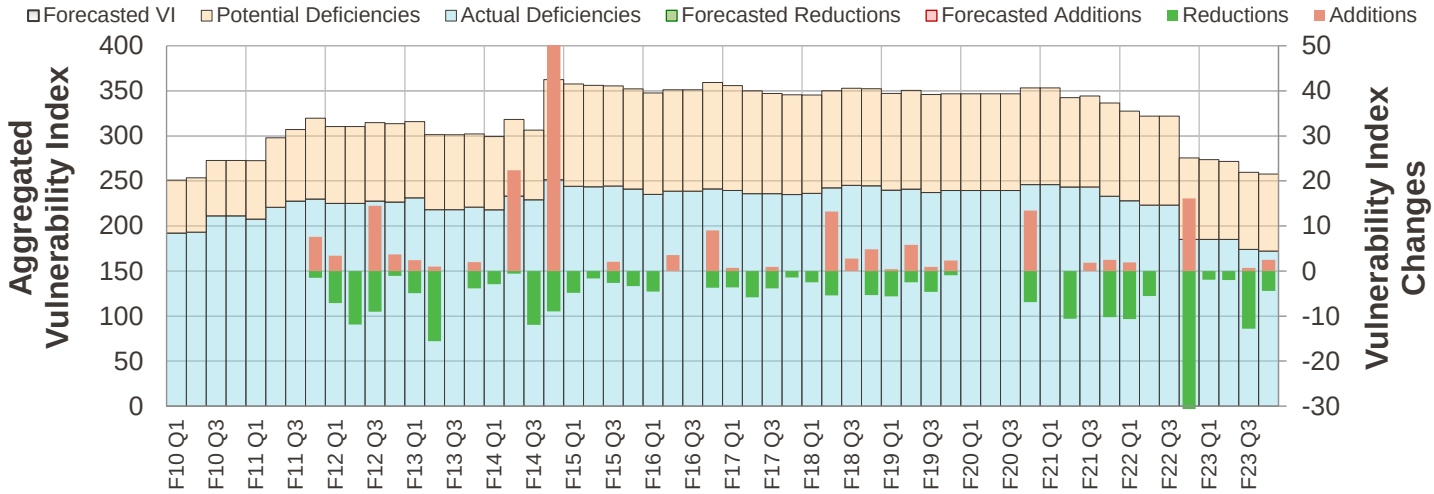

Figure 2 Historical and forecast changes and trends in the Vulnerability Index aggregated across the BC Hydro system.

Non-Conformances in the Dam Safety Program

Activities to identity, review, resolve and close Non-Conformance issues continued through F2023 Q4. As a result, 25 Non-Conformance issues were completed and eleven new issues were identified.

There are currently 350 outstanding Non–Conformance issues in the database, which is 35 less than at the start of F2023. Since the start of F2019, when resolution of such issues was made a priority within the Dam Safety Program, the number of Non-Conformance issues has been reduced by approximately 36 percent. Figure 3 below shows the continuing progress in reducing the number of Non-Conformance issues.

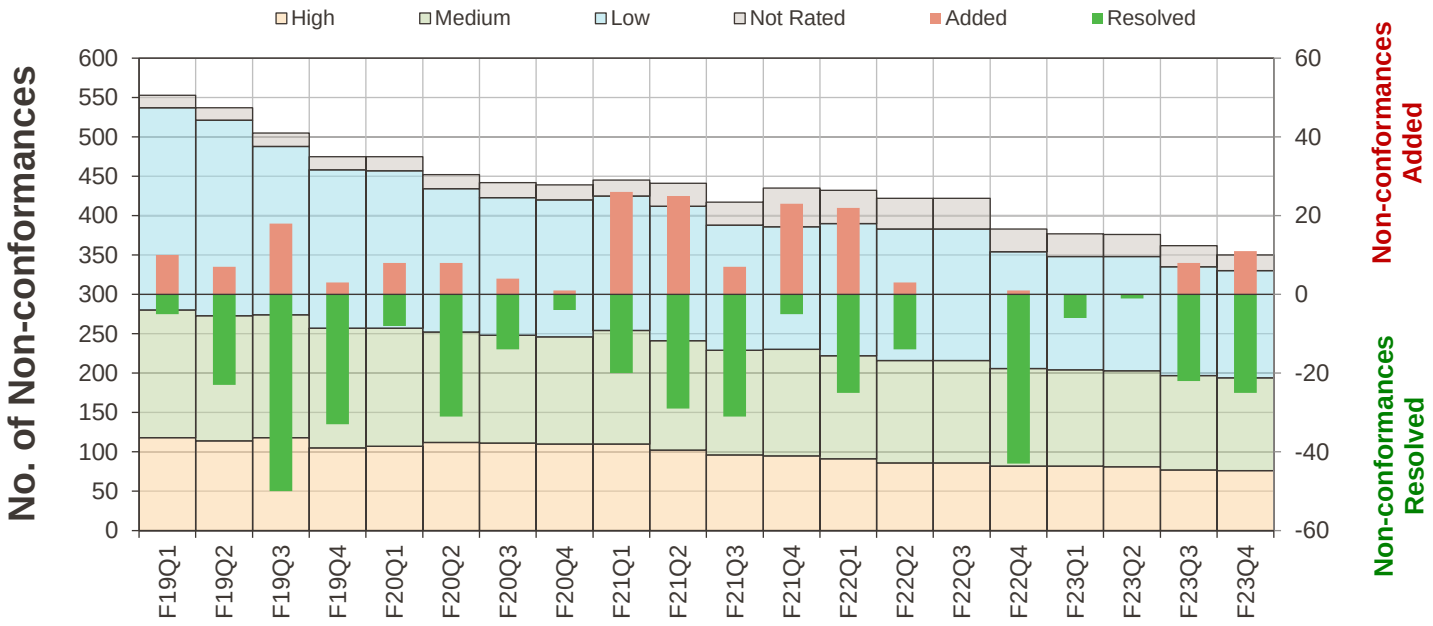

Figure 3 Changes and trends in the total number of Non-Conformance issues (characterized by level of importance) within the Dam Safety Program.

New Issues

No new issues arose in F2023 Q4.

Update on Existing Issues

Hugh Keenleyside Dam – White Sturgeon in Low Level Outlets

As reported in past quarters, white sturgeon have been observed entering the dam's low level outlet ports and swimming up the operating gate slots to access the tops of the gates during the summer months. To avoid injury or mortality to these fish, which is an Endangered Species under the Federal Species at Risk Act, BC Hydro is continuing to monitor for the presence of white sturgeon before any operation or testing of the gates. While there have been no fish present in the outlets since December 2022, this issue is expected to reoccur during the summer months when the sturgeon return to the dam's tailrace area. Engineering solutions to prevent sturgeon from entering the gate slots are now being developed as part of a project within the small capital portfolio.

9.0: Quarterly Dam Safety Report

Compliance with Processes and Regulations

Regulatory Communications – British Columbia Utilities Commission

Proceedings for the application to the British Columbia Utilities Commission for the John Hart Dam Seismic Upgrade Project concluded in Q4. As described in last quarter's report, Interveners generally indicated their support for the project need, alternative selected, project scope and cost estimate, and recommended that the Commission determine that the project is in the public interest and approve the project expenditure schedule. On May 5, 2023, the Commission issued its Decision and Order G-107-23, accepting that the project and associated expenditure schedule are in the public interest. For details, see Capital Projects, page 14.

Regulatory Communications – Comptroller of Water Rights

Two submissions were made to the Provincial Dam Safety Office in Q4 of F2023: (1) a request for authorization to alter a berm on the north side of the tailrace at Hugh Keenleyside Dam to prevent fish stranding; and (2) a request for approval to install instrumentation in the Revelstoke concrete dam. Both requests were approved.

Initial meetings were held with the Independent Engineer and Provincial Dam Safety Office for the John Hart Seismic Upgrade Project's Leave to Commence Construction process. A site visit was carried out at John Hart Dam in mid-March.

The 2023 annual meeting between Dam Safety and the office of the Comptroller of Water Rights was held on January 23 and 25 with one day dedicated to updates on the capital projects and the second day focused on the Dam Safety Program.

Operation, Maintenance and Surveillance Manuals

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

The Manual for Ruskin Dam was completed and issued in F2023 Q4, following receipt of drawings and other information pertaining to the upgrade project. The Manual for Cheakamus Dam was not completed prior to the conclusion of F23 due to an unexpectedly high level of effort associated with its completion. The Cheakamus Dam Manual has since been completed, however, and all five Manuals scheduled for updates in F2023 have now been completed.

Work is also underway on the Revelstoke Dam and Spillimacheen Dam Manual updates that are scheduled for completion in F2024.

Dam Safety Reviews

Dam Safety Reviews are independent, systematic reviews and evaluations of all aspects of a dam's physical condition, design, construction, operation, maintenance, processes, and other systems affecting the safety of the dam. Performed by external consultants, they 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.

In Q4, the three F2022 Dam Safety Reviews on the Bridge River System – Terzaghi Dam, La Joie Dam, and Seton Dam – were completed and issued, and the Dam Safety Review of Elsie Dam was completed and issued on schedule in Q4. Work on the Ruskin Dam Safety Review continued on plan.

9.0: Quarterly Dam Safety Report

Surveillance

Key activities comprising dam safety surveillance include inspections, monitoring of instrumentation and quality control of data, and characterization of dam performance. Table 2 below provides key metrics regarding these activities, which are described in the following sub-sections of the report.

Table 2 Dam safety inspections and surveillance activities.

		Quarter Q4		Fiscal Year	
		Actual	Target	Actual	Target
Routine dam inspections	Completed	411/411 = 100%	100%	1643/1644 = 99.9%	99.5% ✓
	Missed	**0**		**1**	
Formal (annual and semi-annual) dam inspections	Field work completed	0	0	71	71 ✓
	Reports issued	49	40	71	71 ✓
Instrumentation data checks		199/195 = 102%	95%	792/780 = 102%	95% ✓
Reservoir slopes inspections	Field work completed	0	0	20	20 ✓
	Reports issued	12	8	20	20 ✓

Routine Dam Inspections

Routine weekly and 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.

Through the course of F2023, only one of 1644 scheduled site inspections was missed. As described in last quarter's report, that single missed inspection was the result of heavy snowfall in December that made the access road to Alouette Dam temporarily impassable over that week's inspection window. This is a remarkable level of completion by the assigned Dam Safety and Stations Field Operations staff, and clearly demonstrates the commitment of these personnel to this very important activity.

Formal Dam Inspections

Formal inspections of the dams are regulatory inspections completed by Dam Safety Engineers on a semi-annual or annual frequency, as dictated by each dam's Consequence Classification. These inspections include a comprehensive visual inspection, a review of the monitoring data and an assessment of the condition of the water containment and conveyance structures. The Dam Safety Engineers are required to complete 71 of these inspections and reports annually. As of the end of the fiscal year, all 71 inspection reports had been completed and issued.

9.0: Quarterly Dam Safety Report

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. 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 Automated Data Acquisition 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. 792 of these checks were completed in F2023, which is slightly above the target of 780.

Reservoir Slopes

Reservoir Slopes inspections are completed on a frequency ranging from semi-annually to once every 10 years depending on the assessed hazard of the slope. They are typically carried out by the Reservoir Slopes Geologist and the Specialist Dam Safety Engineer for the Upper Columbia Region. Each inspection generally consists of a review of all monitoring data, a visual inspection completed from helicopter with boots-on-ground assessment of identified areas of concern, and documentation by a sealed engineering report. As of the end of the fiscal year, the reports for all twenty slopes inspections had been completed and issued, and no new issues or concerns had been identified through these inspections.

Unusual Events or Observations

The Dam Safety On Call Person responded to 87 calls in Q4, which typically includes instrumentation alarms, operational inquiries, operations notifications during high inflows and earthquake notifications. This number of calls and responses is about typical.

Civil Maintenance

Civil Maintenance on Dam Safety and Generation assets was well executed through F2023. Notably, the corrective and condition-based civil maintenance program completed all 33 projects in the plan and precisely on budget.

Table 3 Dam Safety and Generation civil maintenance for F2023.

		Quarter Q4		Fiscal Year F2023	
		Actual	Target	Actual	Target
Corrective and Condition-Based Maintenance	Spend ($k)	518	404	3,321	3,320
	Work Orders Completed	8	7	33	33
Preventative Maintenance	Tasks Completed	188	161	832/910 = 91%	

Preventative Maintenance

In F2023, Stations Field Operations and Engineering Services completed 832 civil preventative maintenance tasks against a plan of 910, continuing the trend of gradual improvement for what is still a relatively new program.

Corrective and Condition-Based Maintenance

One of the projects completed in Q4 was a detailed inspection and assessment of the low level outlet at the Elsie Saddle Dam, part of the Ash River facility. The low level outlet is the primary means of releasing water from Elsie Lake into the Ash River and cannot be taken out of service for inspection unless Elsie Lake is high enough to pass water over the spillway. Due to this and other constraints, this system had not had a detailed inspection since it was refurbished in 2004.

The low level outlet consists of a 2.2 metre diameter steel pipe running under the dam, with a hollow cone valve at its downstream end to regulate flow, a midstream butterfly valve to isolate the hollow cone valve, and a maintenance gate at the upstream end to allow inspection of the pipe and valves.

Preparatory work to refurbish the maintenance gate hoist and recertify the gate for single device isolation was completed in advance of the inspection's original fall schedule when Elsie Lake is normally high. Unseasonably low inflows left the lake lower than usual, and the project team had to coordinate with Generation System Operations to reschedule the work to Q4

A team of civil and mechanical engineers entered the space and completed a detailed assessment. The components were found to be in generally good condition, providing assurance that this system can continue to be relied upon.

Other work completed in Q4 included concrete repairs at Sugar Lake Dam and specialized, rope-access vegetation removal at Seven Mile Dam.

Figure 5 Ash River low level outlet, looking downstream with the butterfly valve in the foreground and the hollow cone valve in the background.

Spillway Gate Testing and Maintenance

Spillway Gate Testing

During Q4 of F2023, 245 of 246 scheduled gate tests were completed, including annual gate tests at five dams. Table 4 below provides key metrics related to spillway gate testing.

The single missed test for the quarter and for the fiscal year occurred at Cheakamus Dam in March due to an error in interpreting the maintenance program. For this site, the monthly test procedures for the two spillway gates and the low level outlet are prescribed on a single maintenance instruction. In March, Stations Field Operations staff performed the annual full open tests of the spillway gates, but the maintenance instruction for these annual tests does not mention the required low level outlet testing which, as a result, was missed. To prevent this from reoccurring, the site's Field Maintenance Engineer is modifying the maintenance instruction for annual full-travel testing of the spillway gates to also identify the required low level outlet testing.

Table 4 Spillway gate testing results for F2023.

		Quarter Q4		Fiscal Year F2023	
		Actual	Target	Actual	Target
Monthly Tests	Completed	245/246 =99.6%	100% ✗	893/894 =99.9%	98% ✓
	Missed	1		1	
Gates Failing to Operate on Demand during Testing	No. of failures	0		3	
	Failure rate	0/245 = 0.0%		3/893 = 0.3%	

No gates failed to operate on demand in Q4, although maintenance revealed damage to one gate which was forced out of service. As described under the Vulnerability Index Update on page 3, the crew performing monthly maintenance and testing of the Sugar Lake Dam's gates observed that the lower portion screw stem that raises and lowers Outlet Works Operating Gate 2 was bent. The ability of the gate to operate in this condition is suspect as the bent portion of the stem must travel through a guide and compressive forces arising from driving the gate closed could lead to further damage. Consequently, the gate was removed from service. Repairs were given a high priority and completed, and the gate was returned to service in early April.

Exceptions to Gate Testing Program

Gate testing scopes were reduced to exclude gate movements at some dams, as described below:

- At La Joie Dam in February, due to a conflict with implementing a protection and control project.
- At Duncan Dam, due to implementation of capital work on the spillway gates.
- At Terzaghi Dam, due to unavailable position indication for one of the low level outlet gates.
- Through the winter, certain gates at Terzaghi, Mica, Elko, Duncan, WAC Bennett, and Peace Canyon dams due to the potential for gate damage due to freezing conditions.

Table 5 Spillway Gate Maintenance Results for F2023.

Corrective and Condition-Based Maintenance Tasks	Quarter Q4		Fiscal Year F2023
	Completed	Planned	
Planned Tasks	14	25	71/97 = 73%
Emergent Tasks	12		33

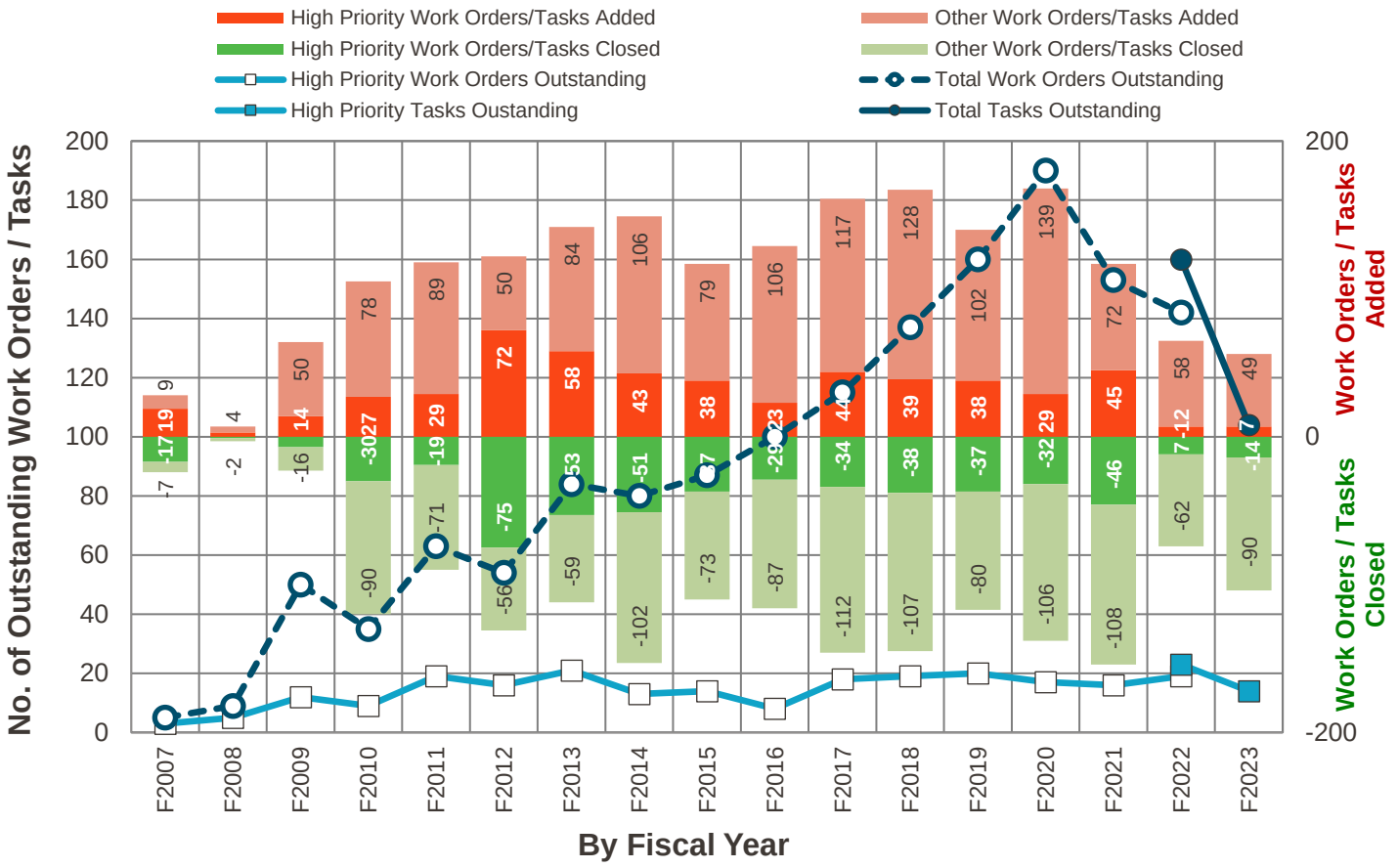

Figure 6 Number of outstanding corrective and condition-based spillway gate maintenance work orders and tasks, new work orders and tasks added, and work orders and tasks closed as at the end of each previous fiscal year.

Notes:

1. At the conclusion of F2022 moving forward into F2023, figures were restated as outstanding tasks instead of outstanding work orders to align with Operations reporting.
2. Work Orders / Tasks Added includes new work orders / tasks created in the year and identified with the gate reliability work group. It does not include work orders / tasks from previous years that were recategorized with the gate reliability work group.
3. Work Orders / Tasks Closed includes work completed through the annual maintenance program. It does not include cancelled work orders / tasks or work orders / tasks that were recategorized out of the gate reliability work group.
4. Due to notes 2 and 3, above, the net change in the number of Outstanding Work Orders / Tasks will not always equal Work Orders / Tasks Added less Work Orders / Tasks Closed

Gates Out of Service or Under Restricted Service

The availability of flood passage devices is a key measure of our ability to pass high inflows and manage reservoir levels. As at the time of writing this report, all spillway gates and flood passage devices are in service.

Spillway Gate Maintenance

Spillway gate maintenance results are shown in Table 5 on the preceding page. Work on planned tasks lagged behind the plan in Q4, which was compensated for by completion of emergent tasks. Twenty-six planned and emergent spillway gate maintenance tasks were completed in Q4, and ten new tasks were entered into the system.

The number of outstanding gate maintenance tasks is shown in the chart in Figure 6 on the preceding page. Through Q4, the total number of outstanding maintenance tasks was reduced from 126 to 104. Through F2023, there has been a 35 percent decrease in outstanding maintenance tasks from 160 to 104.

“High priority” maintenance tasks are those where the asset shows moderate to severe signs of deterioration and/or its ability to perform its intended function may be compromised and failure of the asset could lead to loss of reservoir control, albeit with a long intervention time available. Including the addition of seven new high priority tasks entered into the system, the net number of outstanding high priority maintenance tasks has been decreased from 23 to 14 though F2023

The reduction of outstanding spillway gate maintenance since F2020, reversing a longstanding trend of growing backlog, is strikingly evident in Figure 6 and has been particularly so in F2023. This is due to the well-considered planning and significant efforts of personnel in Programs and Contracts Management and Station Field Operations, supported by staff in Generating Stations Maintenance Planning and Dam Safety.

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 Dam Safety Regulation as part of annual 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 Quarterly Safety & Emergency Management Report, submitted to the Operations, Planning, and Information & Technology Committee, for updates on emergency preparedness and public safety.

Site C Clean Energy Project

Dam Safety, Generation System Operations and the Site C Clean Energy Project team are engaged in ongoing collaborations to integrate the Project’s design and construction activities and the eventually constructed facilities into BC Hydro’s Dam Safety Program.

The Operation, Maintenance and Surveillance Manual for Site C Dam and Interim Dam Safety Risk Management Plan for water management at the upstream Peace River dams (WAC Bennett, Peace Canyon) that will take effect on closure and conversion of one of the diversion tunnels and will remain in effect through reservoir filling, commissioning and bringing the generating units on-line were finalized, sealed and issued to the Comptroller of Water Rights in Q4.

Inundation modelling and mapping of the Alberta reaches of the Peace River for dam breach scenarios of the three Peace River dams, including the Site C Dam, was completed and shared with Alberta government offices (Alberta Agriculture & Irrigation, Alberta Emergency Management Agency), local authorities, and other Emergency Planning Guide holders.

Capital Projects

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

Bridge River 1 – Penstock Concrete Foundation Refurbishment

There are four penstocks at Bridge River 1 that supply power to the four 50 megawatt generating units. Inspections have found that the penstocks' concrete foundations have visible cracks and spalls, and steel supports have physical defects such as corrosion and deformations due to rock impacts. Slope protection measures along the penstocks' alignment have been inadequate or have deteriorated, leading to over 40 per cent of the foundations and a substantial amount of the penstocks having been buried in loose rock and other debris. The foundations require refurbishment and, further, the penstocks are due to be recoated (in another project) in 2026, requiring removal of the debris. The purpose of this project is to remove the rock debris, refurbish the concrete foundations and steel penstock supports, and refurbish and upgrade the slope protection and stabilization works to ensure the continued serviceability of the four steel penstocks.

The debris removal along the penstocks was completed in Q4. The design-build contractor has updated their slope stabilization design following inspections of the rock as guided by the design basis. The degree of recommended slope remedial measures has increased as a result of the poor rock quality found following the debris removal. Dam Safety and Engineering are reviewing the proposed works to confirm what work is required for safe access to the slopes for the upcoming foundation refurbishment work and the penstock recoating.

Bridge River 1 – Slope Drainage Improvements

The steep mountain slope above the Bridge River 1 Generating Station has experienced numerous debris flows due to poor drainage. These flows have occurred along existing creek channels, notably Town Creek and School Creek that flow into the Bridge River 1 Generating Station, switchyard, townsite and adjacent Tsal'alh First Nation land. There is a further risk of a debris flow associated with a spoil pile from the original power tunnel excavation that was dumped along School Creek, which poses a hazard to a former school property that is currently owned by the Tsal'alh First Nation Band but is not currently used. The objective of this project is to reduce the risk of future debris flows to BC Hydro workers and facilities and to remove related hazards from past BC Hydro operations (i.e., the spoil pile) to neighbouring properties.

The project secured endorsement to continue into the Feasibility Design Stage at the Major Project Gate Meeting in Q4. The Leading Alternative that will be advanced in Feasibility Design includes removal of the spoil pile and all other BC Hydro related hazards to the Tsal'alh First Nation School Creek property, construction of a variety of new drainage catchments and debris flow protections on School and Town Creeks and at the Bridge River townsite, and trenchless crossing under the CN Rail line to complete the drainage into Seton Lake.

Hugh Keenleyside – Tailrace Gantry Crane Upgrades

Two gantry cranes of identical design are located on the Hugh Keenleyside tailrace deck and are used to install and remove the dam's low level outlet maintenance gates. The cranes were manufactured in 1967 and have had no significant upgrades since that time. A 2016 crane assessment identified a number of regulatory non-compliances and safety deficiencies. A second assessment in 2019 found the cranes to be in unsatisfactory condition and recommended that both cranes be upgraded to improve their safety to meet modern standards. This project to implement those upgrades was released in Q4.

Cheakamus – Recoat Unit 1 and Unit 2 Penstocks (interior and exterior)

The overall scope of this project is to strip the old, failed coatings on the exterior and interior surfaces of the two penstocks and steel lined tunnel at Cheakamus Generating Station and recoat them to prevent further corrosion and extend their service lives. Supporting scope includes the installation of hatches and fall arrest systems on the penstocks and construction of a new road and vegetation removal for improved access to the penstocks.

In F2023 Q4, the project completed debris removal, rock scaling and hazard mitigation along the penstock corridor. Scaffolding and containment was erected around the lower third of the penstocks in preparation for exterior recoating to commence in April. During a scheduled outage, repairs to coating deficiencies were completed inside the tunnel and the Unit 1 penstock. Interior recoating of the Unit 2 penstock resumed and will be complete in May 2023.

Figure 7 Scaling and meshing in progress at the trestle section of the Cheakamus penstocks.

John Hart – Seismic Upgrades

On May 5, 2023, the British Columbia Utilities Commission issued its Decision and Order G-107-23, accepting that the John Hart Dam Seismic Upgrade Project and associated expenditure schedule are in the public interest.

Notably, in coming to its decision, the Commission found that renewal of the Campbell River System through this project (and other projects planned on the system at Ladore and Strathcona) is economically sound. The Commission further determined that: the preferred alternative provides a cost-effective solution to address the noted dam safety deficiencies; the project estimate, schedule and procurement approaches are reasonable; and project implementation risk has been appropriately considered and identified risks adequately treated.

With this decision, the project intends to commence construction under the main civil works contract, i.e., the upgrades to the earthfill dams and conversion of several concrete gravity dam blocks to a free overflow spillway, in Q2 of F2024.

Revelstoke – St. Cyr Landslide Instrumentation

Assessment of satellite remote sensing around Revelstoke Dam in 2021 identified a large active landslide between St Cyr and Coursier Creeks. The proximity of St. Cyr landslide to Revelstoke Dam means its failure would pose risks to the safe operation of both Revelstoke and Mica Dams. There is limited information of the slide area, and this project is the first step in developing a greater understanding of the geology and potential instability of the massive St. Cyr landslide by installing instrumentation and conducting geotechnical investigations. The drilling and installation of instrumentation in two locations along the highway at the base of the identified landslide area took place over Q2 and Q3 of F2023. The installed instruments were placed into service in Q4.

Peace Canyon – Instrumentation and Drains Upgrade

The Peace Canyon spillway is founded on sedimentary rock. Due to the low strength of bedding planes within that rock, the dam's original construction featured additional drainage and a sump pump system improve the dam's sliding stability. A 1988 Deficiency Investigation reassessed the stability of the dam's spillway blocks and concluded that no remedial measures would be required provided that high drainage efficiency could be maintained.

This project was released in 2018 to refurbish existing drains under the spillway blocks, evaluate the need for additional drains, install new piezometers to monitor the uplift pressures of the spillway blocks, and to improve seismic monitoring. The project will also make improvements to the drainage gallery for safer access to inspect and maintain the drains.

In Q4, the project completed the gallery improvement work that included the installation of a water collection system in the lower and upper galleries, the installation of a gutter in the downstream gallery, and the replacement of a ladder to a landing in the drainage sump with stairs. See Figure 8, below. Installation of seismic monitoring instrumentation will commence in Q1 of F2024. The new piezometers are forecast to be in service in October 2024.

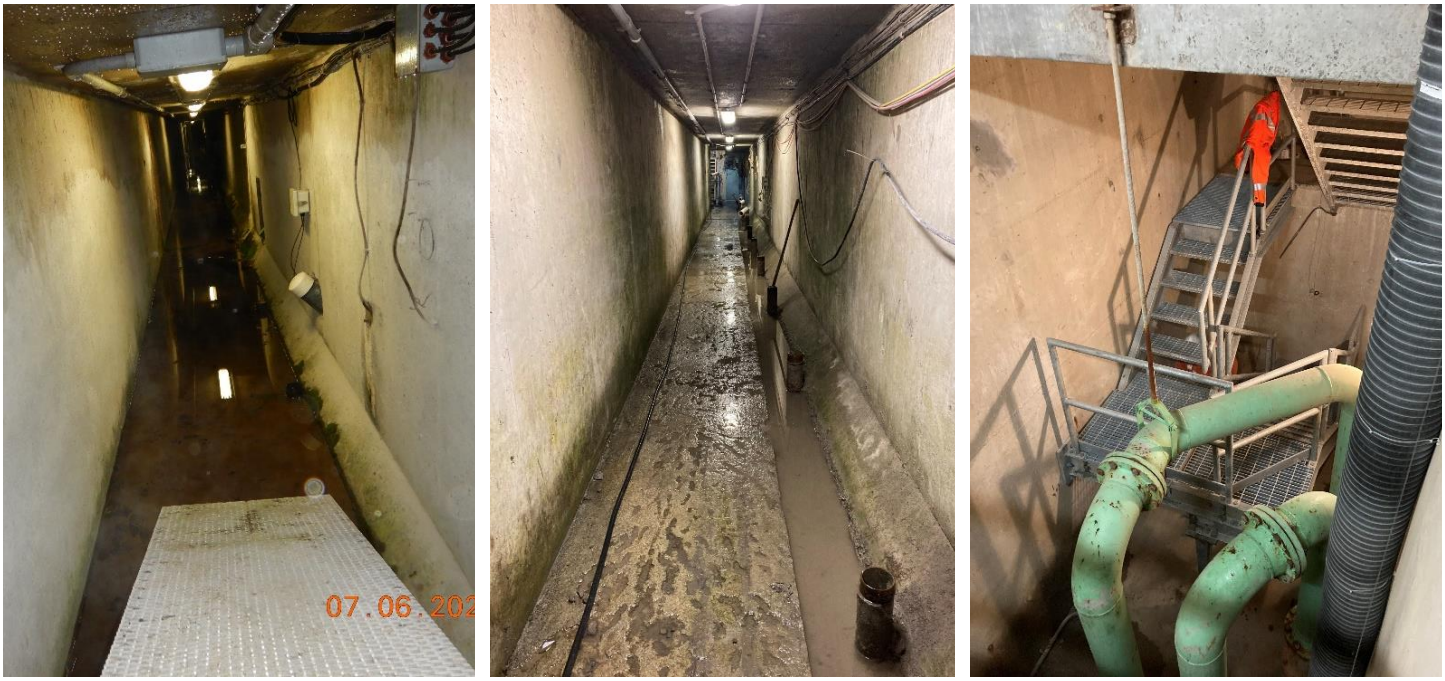

Figure 8 Peace Canyon drainage gallery improvements. Bucket block gallery before (left) and after (middle) improvements; access stairs that replaced a ladder into the drainage sump (right).

Dam Safety Investigations

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

Elsie Dam Performance Assessment

The Elsie Dam performance assessment was initiated in response to potential deficiencies that were identified during the 2015 Dam Safety Review, and will investigate, identify, confirm, and document the as-built characteristics and design parameters of the dam to:

- Assess the performance of the main dam and its components under normal and unusual loading conditions;
- Determine the seismic withstand of the main dam and its components; and
- Review the number, location, reading frequency and alarm thresholds of the existing instrumentation.

Following the performance assessments, the investigation will determine if any upgrades are required to ensure the satisfactory performance of the dam under normal and unusual loading conditions, and identify any recommended changes to monitoring and surveillance activities.

The first phase of the Elsie Dam Performance Assessment was completed in Q4 F2023. The first phase of the investigation included a review of available information to identify gaps in documentation. It also included a screening-level investigation of the main dam related to the compaction of its core, seismic withstand, reservoir seepage, and crest settlement. Findings were:

- Compaction of the core materials is adequate and sampled moisture contents are not indicative of excessively brittle behaviour of the core.
- A simplified seismic deformation analysis indicated that the main dam might experience deformation in excess of the design limit under seismic loading for the Safety Evaluation Earthquake. Further analysis will be required in the investigation's second phase to better define the seismic withstand of the main dam.
- Finally, a survey of dam crest elevations found that the main dam and saddle dams 1, 3 and 4 are lower than their design crest elevations. A small capital project will be initiated to raise these dams' crests to their design elevations.

Landslide Induced Wave Hazard

This new investigation was initiated in Q4 of F2023 to update, investigate and compare approaches to modeling the hazards from landslide-induced waves. This investigation will use a postulated, hypothetical landslide from Dutchman's Ridge into Kinbasket Lake, about 1.5 km upstream of Mica Dam, as an input to predicting the magnitude of the resulting landslide-induced wave. The investigation will use two different numerical modelling approaches, along with empirically-based assessments and previously completed physical hydraulic modelling to establish a standard methodology that can be applied to other landslide wave modelling projects. Following this study, a follow-up investigation to update the range of possible slide volumes and the resulting wave characteristics is envisioned.

FLOODSiMM Update Program

The flood simulation and mapping model ("FLOODSiMM") update program develops inundation models for all main dams for dam breach scenarios, maximum spillway flows, and lesser intermediate discharge flows. The results of this work inform the failure consequences of the dams and related structures at BC Hydro's facilities. They're also used in the emergency management plans for each facility. In F2023, updated flood simulations and inundation maps were completed for the Ash River system, the Shuswap system, and the Alberta reaches of the Peace River.

Safety Evaluation Flood Update Program

A key parameter in the design or safety evaluation of any dam is the magnitude of inflow flood that the dam can safely pass downstream, generally through a combination of temporary surcharging of the reservoir and discharges over spillways and other controlled means. By convention, these extreme inflows are widely referred to as "Inflow Design Floods." Identifying the need to distinguish between the inflows that a dam was *designed* to safely pass – properly referred to as design floods – and the inflows that by current accepted practice a dam *should be able* to safely pass and against which its safety should be evaluated, BC Hydro Dam Safety began referring to the latter as the "Safety Evaluation Flood."[1] In practical terms, the Safety Evaluation Flood is identically what the Inflow Design Flood would be were the dam being designed and constructed today.

Many of the Safety Evaluation Floods for BC Hydro's dams are due for updates, so this program was initiated in F2023. In F2023, the updated Safety Evaluation Flood for La Joie Dam was completed. The update of the Safety Evaluation Flood for the Coquitlam – Buntzen Lake system is substantially complete, and final reports are pending.

Columbia River Stochastic Flood Modelling

Widely accepted industry practice uses deterministic, standards-based approaches to calculate Inflow Design Floods or Safety Evaluation Floods. While BC Hydro continues to use conventional, deterministic approaches to calculate the Safety Evaluation Flood, we have also been amongst the world's leaders in the development and implementation of probabilistic – or stochastic – approaches to determining extreme inflows, using stochastic analysis techniques to derive the full probability distribution of floods with representation of these calculations' inherent uncertainties.

We use stochastic flood modelling results to better understand the flood hazard and, among other things, augment our judgment regarding the urgency of the issue should the Safety Evaluation Flood not be met by a dam. For example, if a dam cannot fully pass the Safety Evaluation Flood, we assess that to be a deficiency and then, where available, use stochastic flood results to establish the frequency at which the dam might be overtopped in calculating the Vulnerability Index and considering risk management options.

Stochastic event flood modelling is a data and computation-intensive activity, requiring significant time and resources to perform. Consequently, these models do not yet exist for much of BC Hydro's system.

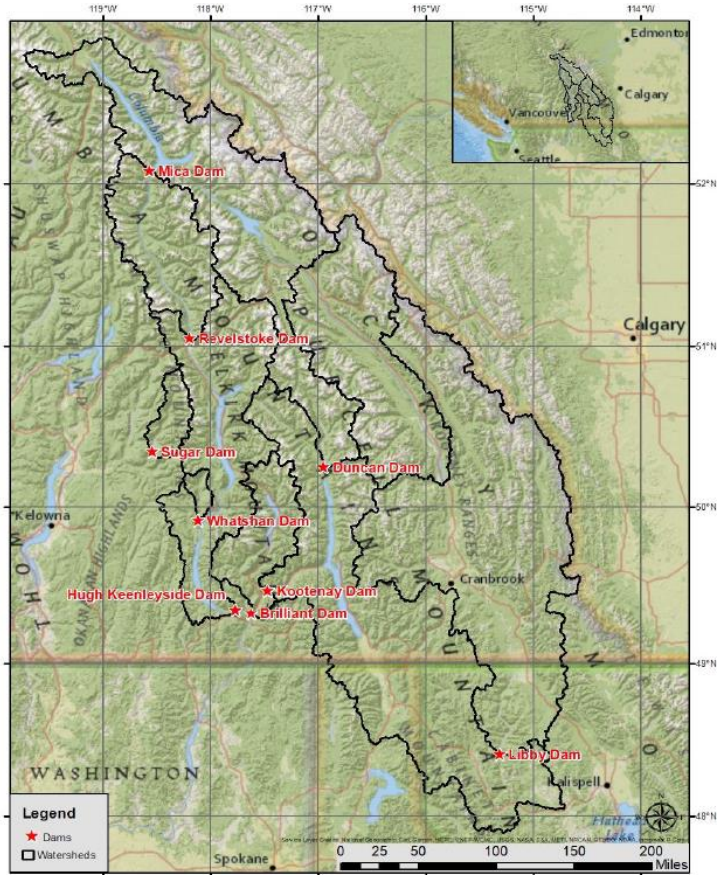

Figure 9 Geographic extents of the Columbia River stochastic flood model.

[1] This terminology has since been adopted by Engineers & Geoscientists of British Columbia in their Practice Advisory "Determining Dam Hydrologic Loading" (August 2022).

9.0: Quarterly Dam Safety Report

The Columbia River Stochastic Flood Modelling project was initiated in F2017 to develop a stochastic flood model for the Canadian portion of the Columbia River System that includes the following BC Hydro dams – Mica, Revelstoke, Keenleyside, Whatshan, Kootenay Canal, Duncan, and Sugar Lake. Libby Dam in Montana was also included in the model to account for its significant influence on the system. The model routes inflows through the system according to current reservoir operating orders and procedures in efforts to realistically simulate operations during flood conditions.

Modelling a system of this size, comprising nine different watersheds as shown in Figure 9, and in this manner was unprecedented. After approximately six years of work by experts from BC Hydro Engineering and external consultants, the model is complete, and the final report was issued in Q4 of F2023. Dam Safety is currently reviewing the report of the model study's findings, to be incorporated into planning for potential subsequent investigations.