Making a difference...together

REPORT TO REGIONAL WATER SUPPLY COMMISSION
MEETING OF WEDNESDAY, NOVEMBER 20, 2019

SUBJECT **Regional Water Supply System Dam Safety Program Update**

ISSUE SUMMARY

To provide the Regional Water Supply Commission (RWSC) with an update regarding the Dam Safety Program and related dam initiatives for the Regional Water Supply System dams.

BACKGROUND

The Integrated Water Services Department (IWS) of the Capital Regional District (CRD) manages 22 dams, 15 of which are directly related to the Regional Water Supply System and are noted below. Refer to Appendix A for a map of CRD managed dams and Appendix B for Regional Water Supply dam details.

A list of the major dams are as follows:

- Sooke Lake Reservoir
  - Sooke Lake Reservoir Dam
  - Saddle Dam
- Deception Reservoir
  - Deception Gulch Reservoir Dam
- Goldstream Reservoirs:
  - Butchart Lake Reservoir Dams #1 – #5
  - Lubbe Lake Reservoir Dams #1 – #4
  - Goldstream Lake Reservoir Dam
  - Japan Gulch Reservoir Dam

Retired Dams

Over time, several dams have been retired from the active drinking water supply but still require some maintenance by the CRD. Those dams include Jack Lake Dam (intentionally breached), Cabin Pond Dams #1 and #2 (intact), Mavis Dam (breached 2007), Ayum Dam (intentionally breached) and Charters Creek Dam (intact - Charters Creek is a tributary to Sooke River).

Regulatory Requirements

Dams within the Province of British Columbia are regulated under the *Water Sustainability Act* (the Act) and its related Dam Safety Regulation (the Regulation). The Act and the Regulation are enforced by Provincial Dam Safety Officers (DSO) within the Ministry of Forests, Lands, Natural Resource Operations and Rural Development. The Act allows for the issuance of water licenses by the Province for the use, storage and diversion of surface water. The Regulation provides more specific obligations for dam owners including:

- determination of the Dam Failure Consequence Classification (refer to Appendix C);
- responsibilities for dam condition and safety;
- preparation and updating of an Operation, Maintenance and Surveillance manual;
- preparation and updating of Dam Emergency Plans;
- site surveillance and formal inspections;
- Dam Safety Reviews and reporting; and,
- maintenance of dam safety records (refer to Application of the Dam Safety Regulation, Province of BC - Appendix D). The CRD staff consider the DSO's to be important stakeholders in the management of the dams and the staff provide information to the DSO as required by the Regulation.

Regular activities undertaken by CRD staff to meet regulatory requirements for active and retired dams where necessary include:

- routine inspections of dams and spillways;
- surveillance and reporting;
- preventative maintenance;
- exercising of valves and appurtenances;
- seasonal adjustments to flow releases;
- corrective action and capital improvements as required; and,
- internal dam safety auditing.

The CRD IWS staff that conduct duties related to dam safety obtain formal dam inspection training whereby they are trained to make field observations related to potential dam failure modes such as leakage, soil deformations, root and burrowing animal damage. This training is supplemented with emergency management training and exercises. In accordance with the Regulation, the CRD maintains a series of Operation, Maintenance and Surveillance documents for each dam as well as Dam Emergency Plans which are resources to be used in the event of a dam emergency such as earthquake, flood or dam breach.

In accordance with the Regulation, the CRD conducts Dam Safety Reviews at a prescribed frequency, prepared by teams of qualified professional engineers (consultants) and referencing the guidance document of the Engineers and Geoscientists of British Columbia titled "Legislated Dam Safety Reviews in B.C., APEGBC Professional Practice Guidelines". In doing so, the dams are assessed against the dam safety best management practices and guidance from organizations such as the Canadian Dam Association (CDA) and International Commission on Large Dams (ICOLD). The audit frequency is based on the population (life) that may be at risk if there was a failure of the dam (or dams in the case of a cascading effect), and potential impact to the environmental and cultural values, infrastructure and economy. The Dam Safety Reviews typically result in conclusions and recommendations that inform the operating and capital budgets for asset improvements and further study of specific topics such as seismic hazards, surveillance improvements, dam breach analyses and inundation zone mapping.

The CRD IWS staff maintain a dam safety database that summarizes the pending tasks, priority, resources, background and budget. The database documents completed tasks for internal use, but also for use by the DSO's and auditors. The CRD staff sought independent expert advice in 2017 and 2018 in order to validate previous conclusions and recommendations and to assess the IWS Dam Safety Program at a high level to identify opportunities for continual improvement.

The approach to dam safety management is progressing from a deterministic approach to a probabilistic risk-informed approach. The approach is documented in the CDA Dam Safety Guidelines, and involves probabilistic dam safety analysis, considers structural mitigation (rehabilitation, rebuilding, etc.), non-structural mitigation (surveillance, monitoring, early warning systems, emergency procedures, etc.) and risk reduction on an "as low as reasonably practicable" basis. The approach has a general cycle of monitoring, assessing, acting and repeating.

A list of completed improvements and studies was prepared for the previous staff report on this topic of September 20, 2017. The following information provides a summary of work-in-progress or completed, of note, since then:

Related to All Regional Water Supply (RWS) Dams:

Dam Emergency Plan (DEP) and Operation, Maintenance and Surveillance Manual (OMS)

A comprehensive DEP based on industry accepted content was drafted in 2018 and 2019 and is planned to be finalized and issued in 2020 and staff training will occur thereafter. In addition to the DEP update, the OMS manual for Sooke Lake and Goldstream Watershed dams is being updated and is planned to be reissued in 2020.

Independent Expert Dam Safety Review (IEDSR)

The 2016 Dam Safety Review for Sooke Lake Dam recommended that the CRD seek the advice of an independent dam safety expert panel to review a list of technically challenging project outcomes, including the recently completed seismic assessment work. The first phase of the IEDSR was completed by a former BC Hydro dam safety expert. This was a general review of:

1. outcomes of the recently completed Dam Safety Reviews;
2. outcomes of the Sooke Lake Dam, Saddle & Deception Dams Seismic Assessment; and,
3. the current IWS dam safety management system and practices relative to the Canadian Dam Safety Guidelines "Guiding Principles" including dam safety management, operation maintenance and surveillance, emergency preparedness, dam safety reviews, analysis and assessment.

Phase 2 has been deferred until some of the current studies that are underway or pending are completed in order to inform the expert panel.

RWSC Asset Management Plan and Program

A related capital project to prepare Asset Management Plans (AMP) for the RWSC Assets has included a specific asset management plan for the RWSC dams. This AMP will identify the level-of-service expected for the RWS dams, and include performance, operation and maintenance criteria and provide a comprehensive summary of actions that are expected to have future budget implications.

Hydrology Computer Model

IWS, in the past, retained a consultant to develop a RWS unique hydrological computer model (WD4Cast) for the watershed. This model is outdated and not used to its full capacity. There is an opportunity to utilize new software to proactively model and forecast the watershed inflows

related to storm events, simulate the outflow from the reservoir outlets and adopt operating procedures to reduce dam safety risks related to these scenarios. Options for hydrological modelling improvements were researched and assessed further in 2019 and proposed for implementation in 2020.

Related to Sooke Watershed Dams:

Sooke Lake Dam, Saddle Dam and Deception Dam - Dam Breach Assessment and Inundation Zone Mapping

Regular review of downstream dam breach consequences is a requirement under the BC Dam Safety Regulation and the work was recommended in the 2016 Sooke Lake Reservoir Dam Safety Review. The dam failure consequence classification is defined by this process and the classification is used to determine the dam performance criteria (i.e., seismic performance). The dams are considered to be in good condition and provide valuable benefits of supplying high quality drinking water for the region and flood control for residents living and working downstream in the Sooke River valley.

The CRD retained the professional engineering services of Northwest Hydraulic Consultants Ltd. (NHC) to update the 2003 Sooke Lake Dam breach assessment and inundation zone mapping. The dam breach scenarios that were assessed are considered to be very low probability, but very high consequence in nature. The key objectives were as follows:

1. Perform dam breach analysis, conduct flood wave routing, and develop inundation zone maps for Sooke Lake Dam, Deception Dam, and Saddle Dam and Sooke River valley;
2. Evaluate incremental consequences downstream and determine the dam consequence classification for Sooke Lake Dam, Deception Dam, and Saddle Dam;
3. Identify and provide details of any options for structural and non-structural mitigation measures; and,
4. Conduct multi-criteria evaluation, prioritization, and cost estimates for the mitigation measures with consultation with the CRD.

NHC successfully completed the computer modelling of many dam breach scenarios and updated the inundation zone mapping of the Sooke River valley using methodology available from the CDA Dam Safety Guidelines and following the requirements of the current BC Dam Safety Regulation. The key results are as follows:

1. Eight dam breach scenarios were evaluated and the worst-case dam breach scenario is a simultaneous flood-induced dam breach of Sooke Lake Reservoir Dam and Deception Reservoir Dam.
2. Compared with the previous 2003 dam breach assessment study that utilized a less sophisticated modelling tool, the present dam breach assessment predicted higher peak flows that could result in property damage due to flooding and inundation, and identified the population at risk. NHC has prepared a preliminary evacuation route plan for the evacuation of all population (permanent and temporary) within the inundation zone for a simulated dam breach event.
3. The earliest arrival time of the flood wave reaching the ocean, approximately 16 km downstream of the dam, was approximately 70 minutes.

4. Potential loss of the primary drinking water supply to the Greater Victoria region is considered one of the most important factors when assessing the dam failure consequence classification for the dams.
5. Confirmed that the existing dam failure consequences classifications for Sooke Lake Dam, Deception Dam and Saddle Dam were appropriate and therefore unchanged from previous classifications (Extreme, Very High and Very High respectively).

The process of implementing risk mitigation measures at the dams is being planned for implementation by the CRD, including improved warning time and emergency notification process, with surveillance and instrumentation upgrades and emergency riprap stockpiling. Additionally, the risk reduction benefits of setting reduced reservoir operating levels during the winter months, when water demand is lower, is planned for review. NHC have prioritized the risk reduction options and recommended that the following risk reduction measures be considered the highest priority for further assessment:

1. Feasibility of Installing an automated Emergency Warning System
2. Updating Reservoir Water Level Operating Rules

The potential inundation zone includes areas within both the CRD's Juan de Fuca Electoral Area and the District of Sooke (DoS), CRD staff are working with the local emergency authority staff for both the CRD and DoS to coordinate emergency management efforts and preparedness. The roles and responsibilities for both will be further defined and there will be public engagement in early 2020.

Seismic Stability Assessment, Sooke, Saddle and Deception Dams

The CDA Dam Safety Guidelines state that engineering analyses are required to demonstrate that a dam will remain stable under all hazards and loading conditions based on the current consequence classification (result of the dam breach analysis). In 2016, the CRD retained the professional engineering services of Thurber Engineering Ltd. (Thurber) to lead a team of consultants and complete a seismic stability assessment of Sooke Lake Dam, Saddle Dam and Deception Dam. In addition to the CDA Dam Safety Guidelines, the project was completed to meet requirements of the BC Dam Safety Regulation and recommendations from previous Dam Safety Reviews.

The objectives of the project were to update the estimate of the dam seismic design load, referred to as Earthquake Design Ground Motions (EDGM), and evaluate the anticipated performance of the dams during the application of the updated EDGM. The EDGM are described in terms of amplitude levels, frequency content and duration of ground motion, including time histories of actual measured events that characterize the EDGM. The return period and corresponding magnitude of the EDGM vary with the dam's consequence classification rating. For example, dams with a higher consequence classification rating (e.g. Very High or Extreme) are required to endure larger magnitude hazard events, with lower probability of being exceeded. The CRD's seismic performance expectation for the dams is aligned with the CDA Dam Safety Guidelines, which states "the performance requirement is that the dam structures subjected to the EDGM should perform without 'catastrophic failure' such as uncontrolled release of a reservoir, although severe damage or economic loss may be tolerated".

The method to complete the seismic assessment objectives consisted of three sequential project phases:

1. Probabilistic Seismic Hazard Assessment (PSHA) - A single PSHA was completed by a sub-consultant, Amec Foster Wheeler, using a seismic source model developed for BC Hydro in 2012, but modified to account for local conditions. The analysis considered crustal, in-slab and subduction interface type earthquake sources. Response spectra were prepared for Peak Ground Acceleration (PGA) and nine additional spectral periods for a range of ground motion exceedance periods from 475 to 10,000 years. Ground acceleration values for various spectral periods and return periods were required to be calculated in order to assess structures with different movement periods and different consequence classification ratings.

2. Selection of Ground Motion Time Histories – The results of the PSHA were used by another sub-consultant, Onur Seeman Consulting Inc., to select a set of 15 earthquake time histories for each return period of interest, taken from various earthquake databases covering seismic events from around the world. The time histories were selected with earthquake durations between 30 to 100 seconds, due to the majority of hazards being governed by a longer duration Cascadia Subduction Zone earthquake event. The records were scaled and modified to match the target response spectra calculated during the PSHA work. The outcome is the appropriate EDGM for the site, which can then be used as input for the stability analyses.

3. Geotechnical Deformation Analysis and Structural Analysis - Given the "Extreme" and "Very High" consequence classification ratings, an advanced "finite element" method of geotechnical deformation analysis was used by Thurber to estimate each of the embankment's displacements during the EDGM. The method required preparation of a two-dimensional computerized geotechnical model of the dams. The model simulates the static and dynamic behaviour of the earthen embankments, and requires engineering judgement and experience to establish various representative modelling parameters, assumptions and limitations. All 15 scaled earthquake time histories were input into the model and dynamic displacements were analyzed for each time history case. Additionally, Sooke Lake Dam structures (e.g. intake tower, spillway, etc.) were assessed by a structural sub-consultant, Mott MacDonald.

The consulting team led by Thurber provided a list of recommended structural and seismic retrofits for the dam spillway and intake tower and non-structural operational improvements and further studies to consider, in order to improve seismic resiliency, these will be included in future capital plans.

CRD staff plan to complete similar seismic stability analyses of the remaining RWS dams (Goldstream Watershed dams), using the same methodology summarized above. The outcomes of all of those studies will then be assessed as part of a comprehensive dams risk assessment and CRD staff plan to consult a small panel of dam safety experts to validate results and prioritize the next steps. This process is recommended in order to have a complete understanding of dam portfolio risks so that a prioritized long-term capital improvement plan can be prepared. In addition, the CRD staff are currently implementing the following risk-reduction measures: designing new dam safety instrumentation improvements, assessing valves and controls and updating dam emergency plans. Additionally, the risk reduction benefits of setting reduced reservoir operating levels during the winter months, when drinking water demand is lower, is planned for review (Updating of Reservoir Water Level Operating Rules).

Valve Actuator Assessment

As a result of routine inspections and audits, issues such as the failure and unreliability of valve actuators were observed. This has resulted in the approval of a comprehensive actuator assessment study for all RWS Dams and potential future recommendations for capital improvements. Included is the replacement of the hydraulic system for the two Sooke Lake Dam spillway sluice gates which are planned to be completed in 2019 during the lower reservoir level period.

Sooke Lake Dam Instrumentation Plan and Conceptual Design of New Piezometers

Many of the existing piezometers in Sooke Lake dam used to monitor dam performance are at the end of their service life and are planned to be replaced. Additionally, as a result of other studies, there is a need for increased surveillance using new instruments: piezometers, weirs, seismometers, ground motion detectors, topographical survey and an automated data acquisition system for data management and communications. Phase 1 is underway and is focused on installation of new piezometers, which is currently planned for detailed design in 2020. In addition, it is proposed to have the dam performance monitoring instruments report in real-time to the operators, currently the existing instruments are manually monitored on routine schedules.

Deformation Survey Benchmarking Survey – Sooke Lake Dam

The Sooke Lake Dam has not been surveyed for deformation since its commissioning in 2003 and therefore an initial deformation survey was conducted to benchmark the dam's vertical and horizontal location. This information will be compared to future periodic surveys (proposed on an annual basis) and after any significant seismic events to determine any movement.

Sooke Dam Spillway Underdrain Assessment

The Dam Safety Review of 2016 recommended that the Sooke Lake Dam spillway underdrain system be assessed. Phase 1 of an assessment was conducted in the fall of 2018 and concluded that in general the drains are functioning as designed but the review recommended further investigations and routine maintenance and inspection. Follow-up maintenance and inspection was completed in 2019 and will occur on a routine basis in the future. Further assessment and monitoring of spillway performance is planned.

Related to Goldstream Watershed Dams:

Probable Maximum Precipitation and Probable Maximum Flood Analysis for Goldstream Watershed Dams

A study of the probable maximum precipitation and probable maximum flood to determine how the reservoirs, spillways and dams may perform hydraulically during these events was conducted on the Goldstream Reservoir system in 2017 (a similar study was conducted in the prior year for the Sooke watershed). The studies successfully determined the probable maximum precipitation and inflow design flood conditions, as per CDA Guidelines. Modelling of the flood conditions was completed for each dam and confirmed that the existing hydraulic structures, such as spillways, have sufficient capacity to safely pass the probable flood flows without overtopping the dams.

Remediation of Lubbe Dam #4

Years ago, the routine inspections determined that Lubbe Dam #4 was leaking. After monitoring and study by consultants, it was concluded that the dam was in need of replacement and the design was completed and construction initiated in 2018 and was completed in 2019. Although the construction is complete, refilling of the Lubbe Reservoir is being phased during its commissioning stage to mitigate the risk and consequence of dam failure.

Remediation of Butchart Dam #5

During a routine inspection of Butchart Dam #5, a sinkhole was observed on the downstream slope in 2014. An investigation and remedial options study was conducted and it was concluded that the issue is related to the dissolution of the limestone bedrock on which the dam was founded upon. Thurber identified four options for rehabilitation and it was proposed to replace a section of approximately 50 metres of the dam and grout the bedrock foundation. The work was designed and the project was deferred at the tendering phase primarily due to the delay in completing the Lubbe Dam #4 project and construction schedule for Butchart Dam #5 has been revised to 2020. To manage risk, the Butchart Reservoir is maintained at a lower level until the remediation is completed and the seepage is monitored.

Goldstream Watershed Dams (11 total) Dam Breach Assessment and Inundation Zone Mapping

The 2015 Dam Safety Review (Thurber) recommended that the 1993 dam breach analysis and inundation zone mapping be updated. An engineering consultant, Hatch Ltd., was hired in 2018 and will provide its final report in 2019. This is a similar assignment to the dam breach assessment recently completed for the Sooke Lake Dam, Deception Dam and Saddle Dam by the consultant NHC.

Goldstream Watershed Dams Instrumentation Data Review

The 2015 Dam Safety Review recommended a review of the collected dam performance data from existing piezometers and concluded that the dams conform to the anticipated piezometric response for central core dams; however, there are anomalies which need to be monitored and/or studied further. The study also made recommendations for the replacement or supplementation of instruments, as well as a communications system for an automatic data acquisition system and improvements to the data collection and surveillance process (real-time monitoring).

The 2019 RWSC Capital Plan (2019 and Forecast 2020 to 2023) included the following dam safety related capital projects for 2019:

- Integrate Dam Performance and HydroMet to SCADA;
- Charters Dam Decommissioning;
- Cabin Pond Dams Decommissioning;
- Saddle Dam Piezometer Feasibility Study;
- Goldstream Dams Instrumentation Improvements;
- HydroMet Stations Upgrade; and
- Deception Dam Safety/Risk Reduction Options Assessment.

In addition, the following capital expenditures are planned for subsequent years (2020 to 2023):

- Deception Dam – Dam Safety Review and Improvements;
- Saddle Dam – Dam Safety Review and Improvements; and
- Sooke Lake Dam Update Seismic Assessment.

Proposed CRD Dam Safety Program Webpage

In addition to the operating and capital improvements, the CRD is evolving its dam safety program and in doing so is creating a webpage for the public and customers to obtain dam safety related information. The online information would include:

- more specific background information related to each dam and details related to dam operation;
- operation, maintenance and surveillance information;
- dam emergency plans;
- seismic hazards;
- dam safety reports;
- frequently asked questions and answers;
- reservoir volume status;
- photos and maps; and,
- details regarding completed or work-in-progress capital and operating projects.

CONCLUSION

The Integrated Water Services Department of the Capital Regional District manages numerous dams with the primary purpose of providing a reliable supply of clean and safe drinking water to the residents of our region. A comprehensive dam safety program is in place to manage the dams within the legislated framework. It is proposed to continue to evolve the dam safety program with the advice of independent experts and build a robust dam safety management system that will utilize a probabilistic risk-informed approach to mitigating dam safety issues. Recent dam safety reviews have highlighted the importance of improving existing dam performance monitoring systems to current industry best practices.

In general, the dams have performed well, with the exception of Butchart #5 for which there are plans underway for remediation and regulatory obligations are being addressed.

RECOMMENDATION

That the Regional Water Supply Commission receive this report for information.

Submitted by:	Scott Mason, B.Sc., P.Eng., Manager, Water Supply Engineering and Planning
Concurrence:	Ian Jesney, P.Eng., Senior Manager, Infrastructure Engineering
Concurrence:	Ted Robbins, B.Sc., C.Tech., General Manager, Integrated Water Services
Concurrence:	Robert Lapham, M.C.I.P., R.P.P., Chief Administrative Officer

ATTACHMENTS:

Appendix A – CRD Managed Dams Map
Appendix B – Summary of Regional Water Supply Dams
Appendix C – Application of the Dam Safety Regulation
Appendix D – Dam Failure Consequence Rating