

**BRITISH COLUMBIA HYDRO AND POWER AUTHORITY**

**PUBLIC SAFETY:  
HUGH L. KEENLEYSIDE DAM RISK ASSESSMENT**

**JANUARY 2016**



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# HUGH L. KEENLEYSIDE DAM RISK ASSESSMENT

## Background

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Prior to 2011 there was no national guidance or regulation regarding public safety around dams in Canada. On June 23, 2002 a 32 year old woman and her 7 year old son were killed downstream of an Ontario Power Generation Dam (Barrett Chute Dam). This event led to the creation of a working group of Canadian dam owners to develop national guidelines for public safety around dams. The initiative was led by Ontario Power Generation and was under the jurisdiction of the Canadian Dam Association. BC Hydro had two representatives on the working group; Clair Raska and Dave Cattanach. Both of these representatives are now retired from BC Hydro but Dave Cattanach is retained by the Canadian Dam Association as the lead trainer for their two-day training workshop on the Guidelines for Public Safety Around Dams.

The goal was to develop consistent guidelines for dam owners to recognize the hazards created by the presence and operation of their dams and to provide a consistent and rational approach to quantify and reduce the risks to the public from these hazards. The Guidelines are risk based using the conventional definition of risk which is the chance of injury or loss as defined as a measure of both the probability and severity of the event.

## About the Canadian Dam Association

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The Canadian Dam Association (<http://www.imis100ca1.ca/CDA>) is a group of Owners, Operators, Regulators, Consultants and Suppliers interested in dams and reservoirs. The Canadian Dam Association provides a forum for the exchange of ideas and experience in the field of dam safety, public safety and protection of the environment. Their mission is "to be the recognised leader in advancing knowledge and practices related to dams, consistent with social and environmental values."

## Overview of Canadian Dam Association's Guidelines

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*"In Canada, more people have died in accidents around dam sites that are not associated with structural failure of dams. This is a matter of considerable concern to dam owners, who are seeking guidance on how they can meet their responsibilities to protect public safety."<sup>1</sup>*

BC Hydro's safety vision is integrated into our business and operations decision-making and culture to ensure everyone goes home safely every night. We also have long-term plans in place to help reduce the potential risks to the public, property and infrastructure. This includes investing about \$1.9 billion in dam safety and seismic upgrades over the next decade.

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<sup>1</sup> Canadian Dam Association's "Guidelines for Public Safety Around Dams 2011"

BC Hydro, along with most other major dam owners in Canada, has adopted the Canadian Dam Association (CDA) Guidelines for Public Safety Around Dams (2011). These guidelines provide a consistent approach for assessing and reducing the public safety risks caused by the presence and operation of a dam, to the extent that is reasonable given the intended function of the dam.

The risk assessment analysis involves the determination of:

- Exposure to the hazards (number of people exposed to the hazardous event);
- Likelihood of adverse consequence occurring if a person is exposed to the hazards; and
- Consequence (outcome of an adverse event).

BC Hydro has consistently applied these analyses to all 42 hydroelectric dams. If the risk is assessed as high then new or enhanced control measures are implemented to reduce the risk.

## **Methodology**

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The following nine steps outline the methodology contained in the Canadian Dam Association's Guidelines:

1. Gather information (such as maps, local knowledge, previous assessments);
2. Establish boundaries (such as how far upstream or downstream, portions of the dam, such as the earthfill section or spillway);
3. Identify public activities (such as walking, driving, boating, hiking, biking, driving, swimming, fishing);
4. Identify the hazards to the public (such as steep banks, blind corners, limited sightlines, rapid changes in flows, overhead structures, open holes, exposed mechanical or electrical equipment);
5. Identify existing risk treatment and their effectiveness (such as signage, barriers, booms);
6. Assign the probability of an occurrence which is the entry of a member of the public into the hazardous area. This rating is defined as the Incidence Likelihood Rating (ILR) and ranges from 1 (no known occurrences in the last ten years) to 5 (more than ten occurrences in any one of the last three years or 25 or more occurrences in total in the last three years);
7. Assign the consequence of an incident which would result from a direct exposure to the hazard. This rating is defined as the Incident Consequence Rating (ICR) and ranges from 1 (No medical attention required) to 5 (fatality);
8. Determine the Risk Rating which is the produce of the ILR and ICR and ranges from 1 to 25; and

## 9. Evaluate risk and assign Risk Level.

### Risk Level

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Probability and severity can be expressed quantitatively or qualitatively. For a quantitative assessment the probability would be a number between 0 and 1 and the consequence expressed in real numbers (monetary value or number of fatalities). For a qualitative assessment both the probability and consequence are divided into a finite number of categories ranging from low to high. The Canadian Dam Association's guidelines use the qualitative assessment process and the both the probability and consequence are divided into 5 categories.

Risk is product of probability and consequence. Using a 5 by 5 matrix the risk will range from a low of 1 (1 times 1) to a high of 25 (5 times 5).

### About the Hugh L. Keenleyside Dam

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The Hugh L. Keenleyside Dam was completed in 1968 under the terms of the Columbia River Treaty. It is located at the south end of the Arrow Lakes Reservoir, approximately 8 kilometers from the City of Castlegar.

When the facility was built, the dam deck initially allowed for passage across the Columbia River. There was no passage across the river at this location prior to the construction of the facility. The dam deck is not part of the public road system. It has never been assumed by the Province of British Columbia as a public roadway and was not built to the standards required by the Ministry of Transportation.

### 2015 Risk Assessment of the Hugh L. Keenleyside Dam

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In May and June 2015 BC Hydro carried out a risk assessment of Hugh Keenleyside Dam using the Canadian Dam Association's methodology. The facility was divided into seven components that were individually assessed using the nine steps described above. The following table outlines the highest risks in each component and the additional steps BC Hydro is taking to reduce those risks.

Component	Highest risk	Risk Rating	Additional Controls
Upper Arrow Reservoir – Revelstoke Reach – Revelstoke to Shelter Bay	Power boats striking floating debris	3 – LOW	Maintenance of signage only.
Upper Arrow Reservoir – Shelter Bay to Fauquier	Power boats striking floating debris	3 – LOW	Maintenance of signage only.

Lower Arrow Reservoir – Fauquier to Hugh Keenleyside Dam	Power boats striking floating debris	6 - MEDIUM	Discussions with log transport companies to minimize accidental release of logs.
Earthfill Dam	Public access across dam to the parking lot adjacent to the lock	5 – MEDIUM	Ensure existing vehicle barrier is locked after hours.
Head pond (upstream of concrete dam and downstream of debris boom)	The existing debris boom is difficult to see and could be struck by a boat travelling at high speed.	16 - HIGH	The existing debris boom is at end-of-life and is being replaced. Public Safety is a project requirement and the replacement boom will be made more visible to boaters.
Lock and Concrete Dam	Public across the concrete dam	16 - HIGH	Recommendation is to permanently close this portion of the dam to public access. Vehicle and pedestrian access to the Navigational Lock will be maintained via the south side of the dam.
Tailrace – discharge area of High Keenleyside Dam	Boats entering the area immediately downstream of the dam and then being exposed to increased flows	20 – HIGH	Installation of a downstream public safety boom. Similar booms were installed downstream of Mica and Revelstoke Dams in 2014.

As shown on this table, allowing public traffic over the Hugh L. Keenleyside dam is a high risk activity with serious potential consequence due to the unusual configuration of the deck of the dam, poor or obstructed sight lines, driver inattention and failure to obey posted speed limits.

- The incident likelihood rating for the public access across the deck of HLK is 4, meaning there have been more than two occurrences in any one of the last three years.<sup>2</sup>

<sup>2</sup> Although the dam deck has been mostly closed to public access since 2011, the dam deck was opened to public access briefly in December of 2013 while construction activities were suspended. An occurrence refers to the entry of a member of the public into the hazardous area. This rating is defined as the Incidence Likelihood Rating (ILR) and ranges from 1 (no known occurrences in the last ten years) to 5 (more than ten occurrences in any one of the last three years or 25 or more occurrences in total in the last three years).

- The incident consequence rating is 4, meaning that the most likely potential consequence is permanent, partial or total disability.

The risk level is 16 (4 times 4). Corrective action is required to reduce any risk ranking of 8 points (“high risk”) or greater.

### **Safety Issues Related to Public Use of the Dam Deck**

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The risk assessment concludes that allowing traffic over the dam deck at the Hugh L. Keenleyside Dam is a hazardous activity with serious potential consequences. The safety issues related to the public use of the dam deck<sup>3</sup> include:

- Vehicles have crossed the dam at excessive speed forcing workers to jump clear.
- Some travel trailers have ignored the length restrictions and have attempted to traverse the switchback around the navigation tower, contacting the dam deck barriers in the process. This results in damage to the barriers, damage to the trailers and the release of raw sewage from the septic tanks to the environment.
- Vehicles have impacted barriers around the navigation tower and at the 90 degree corner located by the control building.
- Vehicles have run the red lights at either entrance resulting in the potential for head on collisions, especially when coupled with excessive speed and limited sight lines.
- Large trucks and tractor trailers have attempted to negotiate the tight corners over the dam deck, resulting in damage to barriers and curbs as well as blown tires.
- Maintenance work has been suspended as a result of vehicles refusing to heed directions, even those by flagging crews, as they drive through active work zones.

BC Hydro has taken a number of steps over the years to improve safety at the site, including implementing a speed limit of 20 kilometers per hour over the dam deck, installing traffic lights on both ends of the dam and installing safety barriers to protect workers. Unfortunately, these efforts have not been adequate to protect the employees working at the facility and the public who use the dam deck as an access route. There is ongoing maintenance at the site, and employees are frequently working on or around the dam deck.

Recent upgrades at the facility through the Spillway Gates Reliability Upgrade project have resulted in new challenges for public access across the facility. The hoist towers above the spillway gates were expanded to make it safer for our employees to access the equipment. Employees will be accessing tools and materials through a hatch located directly above the dam deck, which poses an additional hazard for traffic. In addition, the modifications to the tower supports have required installation of stairs from the downstream walkway into the tower legs.

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<sup>3</sup> See Appendix A for a diagram of the dam deck.

This severely impacts the space available for moving personnel and equipment on the walkway.<sup>4</sup>

### Dam Decks at other BC Hydro Facilities

Of BC Hydro's 42 dams, only eight<sup>5</sup> dams allow for public access over the dam crest. These dams are listed below and include the risk rating specifically associated with the public driving on the dam crest.

Dam	Risk ( 1 – 25)
1. Stave Falls Dam in Metro Vancouver (Dewdney Trunk Road)	3
2. Ruskin Dam in Metro Vancouver (currently closed for major redevelopment)	N/A <sup>6</sup>
3. John Hart Dam on Vancouver Island (currently closed for major development)	9 <sup>7</sup>
4. Terzaghi Dam near Lillooet	6
5. Strathcona Dam on Vancouver Island	3
6. Hugh L. Keenleyside Dam (closed for several years for upgrades)	16 <sup>8</sup>
7. Whatshan Dam near Needles	9 <sup>9</sup>
8. WAC Bennett Dam near Hudson's Hope	9 <sup>10</sup>

The risk at Hugh Keenleyside Dam remains the highest in BC Hydro's portfolio of dams. Although traffic volume is not as high as some of the dams in Metro Vancouver and Vancouver, the configuration of the dam makes it inherently unsafe for traffic. The dam deck is narrow with sharp bends with limited visibility. Unlike all of the other dams listed in the above table, BC Hydro office and crew work stations are located in the middle of the dam, exposing our workers to hazards not found at these other dams.

<sup>4</sup> See Appendix B for photos of the upgrades.

<sup>5</sup> There is one additional dam that vehicles can access (Bear Creek Dam on Vancouver Island) but there is no access across the dam.

<sup>6</sup> Ruskin Dam and John Hart Dam are both under major redevelopment and, although will continue to have public roads across them, considerable effort is being made to reduce public safety risk. New risk assessments and updated Public Safety Management Plans (PSMPs) will be prepared following completion of the redevelopment.

<sup>7</sup> See footnote #7.

<sup>8</sup> This rating reflects minimal traffic over the three year period as the dam deck was mostly closed to public access. If the dam deck had been open to access on an ongoing basis, the risk would increase to 20. (ILR = 5, ICR = 4, Risk = 20).

<sup>9</sup> Improvements will be made to the guardrails to reduce the risk to low.

<sup>10</sup> Improvements have been made to the lighting on the dam crest. As part of the current riprap replacement project, the road is being resurfaced and slightly widened with a proper foundation to allow for improved interlocking concrete barriers or guide rails. The dam deck road is also being returned to two lanes by erecting a bridge over the sinkhole. Once these measures have been implemented the risk rating will be low or medium.



## Corrective Action

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### ***Head pond***

The existing debris boom is at end-of-life and will be replaced. Public safety is a project requirement and the new replacement boom will be made more visible to boaters.

### ***Tailrace***

BC Hydro will install a public safety boom to prevent boats from entering the area immediately downstream of the dam and being exposed to increased flows. Similar booms were installed downstream of Mica and Revelstoke Dams in 2014.

### ***Public Access to the Dam Deck***

There are no reasonable safety measures that can be put into place to ensure worker and public safety while keeping the deck of the dam open for public access. Potential options that were considered include:

- The installation of additional fencing;
- Barricades and barriers;
- Additional signage;
- Additional traffic lights; and
- Speed bumps.

Unfortunately, these options would not provide enough protection to mitigate the risk, and in some cases, would actually increase the risk as they would make the dam deck even narrower than it already is. To address the safety risk of the public driving on the deck of the dam, it is recommended that BC Hydro permanently close the deck of the concrete dam to public access. The Risk Level will drop over time once the deck of the concrete dam is permanently closed to public access as the incidence likelihood rating will be reduced to a 1. It is important to note that the incident consequence rating will remain at a 4, and maintaining a decreased level of risk is dependant on the dam deck remaining closed.

BC Hydro will consult with local government, stakeholders and the community to discuss the results of the risk assessment, including the safety risks, and identify potential options to alleviate community concerns. The input that we receive from the community will assist us in finding a long-term solution.

Appendix A – Overview of Dam Deck

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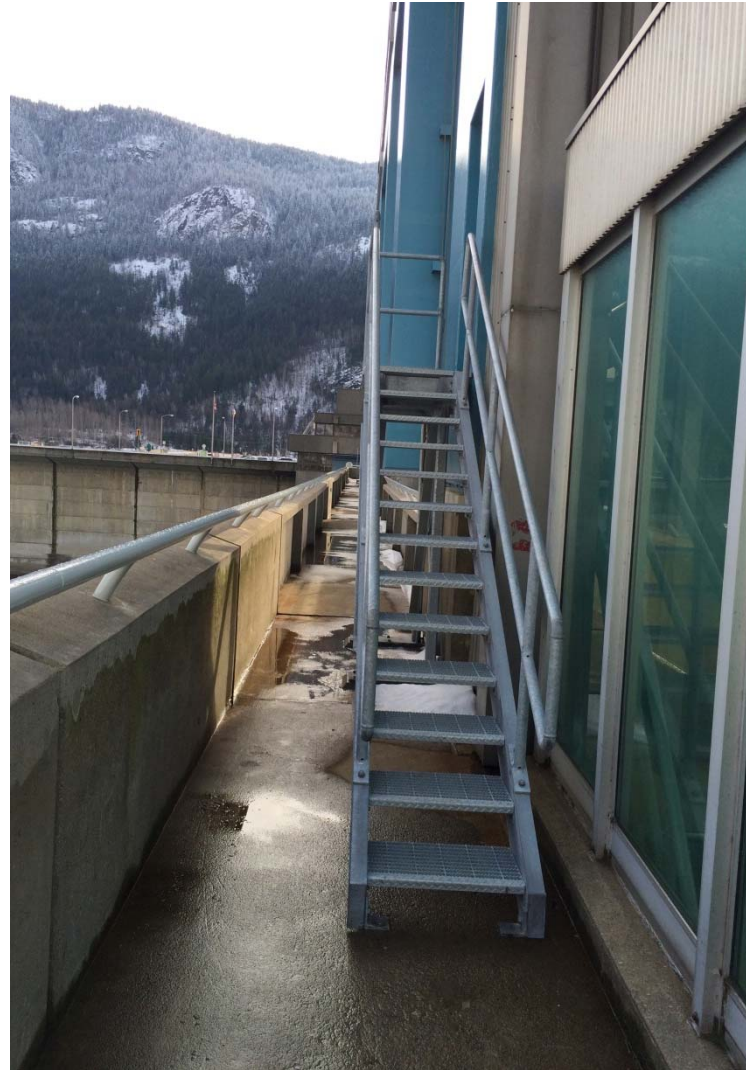


## Appendix B – Recent Upgrades

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*Hatch located directly above dam deck.*



*Stairs from the downstream walkway into the tower legs.*