Approaches to Managing the Safety of Aging Dams

panel presentation by

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This presentation is in four parts, the first discusses the implementation of emergency action plans, the second and third, the changes in spillway operations which can result from reduced operating staff, and the fourth, the different design criteria and concepts in design-build and unit price contracts.

1. Emergency action plans – perception and reality

Synopsis.

There is a vast difference between what is expected from an emergency action plan, and what is likely to take place during an actual incident. Very little has been documented about such occurrences, no doubt due to the very few dam break incidents (if any) that have happened where there has been an emergency action plan in place. However, a comparison with other accidents or tests of action plans reveals differences between what should happen and what actually takes place. A description of one such incident illustrates how this experience influenced the design of additional spill capacity at an existing hydro power development to meet new PMF criteria.

The Port Hawkesbury heavy water plant.

In the mid-sixties, a heavy water plant was built a couple of kilometers to the west of Port Hawkesbury, on the straight of Canso, in Nova Scotia. It has now been dismantled. The plant processed a large quantity of water to extract the few molecules of deuterium, with a process involving the use of hydrogen sulphide gas under high pressure. This gas is colorless, extremely toxic and is heavier than air, so that it settles to the ground. Due to the possibility of a gas leak, the plant had several operating safety requirements, as the author discovered on a visit to the plant to investigate a hydraulic problem.

As the plant ramped up to full capacity, the canal discharging ordinary water overflowed. The canal had several sharp bends, and at some, the water was slopping over the sides. When the author arrived at the plant, he was given a description of the operating safety precautions, which included:-

- A gas mask and 20 minute portable air supply cylinder.
- A mobile radio, with instructions to call the gate attendant every 5 minutes.
- A restriction on time and movement within the plant. All staff entering the plant had to file a “route and work plan” showing where the worker would be, and the path taken to and from the work area. An estimate of time within the plant was also needed.
- A “buddy” system, whereby every worker had a “buddy” who walked with a separation of about 7m. to be available to provide emergency notification and assistance during a gas leak.

The plant perimeter was defined with a 3m high fence, topped with barbed wire. Prior to entering the plant any new visitor had to undergo a 20-minute safety instruction on use of the equipment. The plant was equipped with gas snifters to detect a leak, and if one was detected, a siren would sound, and numerous propane gas burners installed at a height of 8m, would light to heat the air, causing it to rise and hopefully lift the heavy gas. Faced with all this, it was with some trepidation that the author entered the plant area.

The author walked with his “buddy” to the canal, where he found that the overflow could be easily controlled with some baffles. He than proceeded on down beside the canal to the fence, where he was confronted with schoolchildren walking past on the other side! The fence was not far from the plant process piping, hence well within the area which could be affected by a gas leak. Naturally, this elicited some questions, the first of which was whether the sirens had ever been tested.

With the plant being close to town, the residents had been given ample instructions on what to do in the event of a gas leak. Sirens had been installed on the roof of the fire station and on all schools. These would sound at the same time as the plant sirens. Town hall meetings had been held and instruction pamphlets distributed to all residents. The instructions were fairly simple and were as follows:-

- All persons outdoors to return indoors.
- Homeowners and building supervisors to close all windows and shut off forced air ventilation.
- All vehicle drivers and passengers to abandon vehicle and enter the nearest public building.
- All schoolchildren to return to classes.
- Wait for further instructions from the local radio station.

Students had even been recruited to visit all residences to go over instructions and answer questions. It was decided to conduct a test on an afternoon when the schools were out to recess. The test time was well publicized, and when undertaken, was an outstanding success. Everything worked out as expected.

However, the plant managers thought the test was too successful and wondered what would happen if no test time warning were given. So about a month later, the sirens were activated just before noon on a weekday. All hell broke loose. What happened?

- The older schoolchildren left classes and ran home, starting a panic, which resulted in all schoolchildren running home.
- Parents and wives of plant workers immediately called the plant to find out what had happened, jamming the plant switchboard.
- With no answers from the plant, most of the wives and parents jumped into vehicles and drove to the plant, causing a traffic jam and a few fender benders on the road to the plant.
- Other drivers immediately started to drive out of town away from the plant, some, who followed the instructions, found they were not welcome at closed buildings.
- The local radio station, unable to reach the plant by phone, sent a reporter, who called in from a telephone kiosk, reported the massive traffic jam on the plant road and asked for ambulances, which were duly dispatched.

Fortunately, there were no injuries. There were some other unexpected ramifications, suffice to say that the test revealed a vast difference between what happens during a training exercise and the real thing. Needless to say, the test was never repeated, and there was massive opposition to undertaking any further pre-warned tests.

Conclusions.

The lesson to be learned from this case is that people are going to react differently during a test and during a real emergency. In the real world, family will come first, and this will always have an effect on how officials and operators react. Confirmation of this can be obtained from experience with nuclear missile operators in deep silos in the USA. Despite detailed psychological testing and successful simulated test missile firings, a significant number of operators refused to turn the key and press the firing button in more realistic test simulations. Other small instances of operators not believing data or disregarding unusual warning lights adds to the skepticism associated with successful completion of emergency action plans.

2. Spillway operation during a PMF.

Synopsis.

During a major flood, the correct operation of a spillway is critical to the safety of both the power facility, and the downstream residents. Any simplification to the decision process during the series of events which precede spillway gate opening, are a factor which should be taken into account during design of the spill facility. At Bearspaw, this concept played a major part in the selection of the design concept for the spillway expansion.

The Bearspaw Spillway.

About 12 years ago, TransAlta started on a program to upgrade all spill facilities to meet the new Alberta Dam Safety guidelines. One of the powerplants where the spillway had to be about doubled in capacity was Bearspaw, located on the Bow River, about 30km upstream of Calgary. The expansion has been well documented in papers presented to this Association and at the CEA, hence details on the work can be found elsewhere. Suffice to say, that spill capacity was increased from about 4,000 m^3/s to about 8,000m^3/s. What has not been discussed are the options which were available to increase spill capacity, and the influence operating decisions had on the layout selection.

Two alternative spillway layouts were found to be the most attractive from both an economic and design viewpoint. There could be described as Option A and Option B.

Option A required the construction of a standard reinforced concrete spillway with 2 large vertical lift wheeled gates, built adjacent to the left bank and just downstream of the existing dam, which would act as a cofferdam during construction. The structure would be founded on rock and would include a small stilling basin followed by a heavy rock lined canal back to the river. There would be no change in the reservoir flood level. No engineering design difficulties were envisaged.

Option B required the construction of a long weir-controlled concrete side channel spillway, paralleling the left bank. The reservoir flood level would be increased by about 2 meters, and consequently the dam crest was also raised, and the existing spillway anchored to resist the increased water load. The side channel spillway was founded on rock, river gravel and on fill. The concrete lining was about 0.4m thick, heavily reinforced, and provided with an under-drainage system with cleanout provisions. The connection of the concrete lining to the existing dam and upstream blanket was quite sophisticated, involving the use of sheet steel piling, bentonite and a geotextile membrane.

The author was part of a 2-man review team. Cost estimates of the two options indicated costs to be essentially the same, the difference being less than 2%. Due to the anticipated design difficulties with Option B, the author strongly favored Option A, and due to the more simple operation, and less mechanical equipment, Tom, the other review member, favored Option B. The discussion, at times quite animated, continued over the best part of 2 days.

In the end Tom's opinion prevailed – why? – the author conceded when Tom argued that we should look at the two options from the viewpoint of the operators. Here some more background is required. The Bow River has not had a major flood since about 1900, and the largest recent flood occurred in 1932. Consequently there has been much development in the Bow River flood plain within Calgary. These areas will be well inundated at half the PMF flow; hence the operators would have to be very certain about their actions when opening the second spillway in Option A, causing further inundation.

The size of a major flood is not known with any degree of certainty. In fact, the opening of all spillway gates prematurely will cause a PMF, which might be avoided with more reliable information on flood flows. This will always be a dilemma for operators. Also, in the consequent flood enquiry, it might be shown that a different gate opening time or sequence would have reduced flood damage, thus opening the door to legal actions against the utility.

On the other hand, with Option B, once the main spillway gates are fully open, and the reservoir continues to rise, no further action is needed from an operating standpoint. Any further inundation is due to an “act of God” from unavoidable increased water flow in the side channel spillway. Another argument favoring this option, is that there is the distinct possibility that operating rules or instructions may not always be followed precisely by the operators, if their family are at risk during the flood event. Hence, any design with the least operating actions is to be favored.

An illustration of this was provided during a recent test of a flood action plan. One of the control center officials got so caught up in the exercise, that he took time out to phone family members on their cell phones, to ascertain that they were not in the flood danger zone – the old rule – family comes first! He became quite distraught when he could not reach two of his sons.

Conclusions.

Flood action plans, in addition to the usual assumptions for jammed phone and perhaps radio communications, washed out roads and bridges, should also make allowances for operators following their own “families come first” rules. Spillway designs requiring minimal operator involvement are preferable. Weirs are the obvious first choice, and perhaps a second choice would be use of manual or automatic “trigger” mechanisms to open some spillway gates on very high reservoir levels. An example is at the remote Ossokmanuan spillway, where the Churchill Falls (Labrador) Corporation is currently adding trigger mechanisms to the 17 large stoplog openings, reducing operating requirements to only one person, as will be discussed in the next presentation.

3. Spillway operations - a rapid response device

Synopsis.

As operating staff reduce in number due to automation, it may no longer be possible to respond to a flood event within an adequate time. Also, there may be instances where only one person is available to operate the spill facility. Where the spillway has stoplogs, as is common in old structures, then more than one person is needed for safe operation. This third presentation describes a simple device for installation in a stoplog spillway to provide a quick release of the logs by one person.

History.

Quick release stoplog mechanisms are not new. They have been used for many years, but somehow are not well known within the industry. One of the first recorded installations is at the Davis Bridge Spillway, built about 1925. (Creager & Justin; Hydroelectric Handbook, Pp. 511). They are incorporated in several powerplants, notably in some of the spillways designed by Harza Engineering of Chicago for Great Lakes Power. Some are fairly simple, where a bolt is cut to release the stoplogs. Others are quite sophisticated; wherein there are two triggers, the first being released with a mallet blow, which in turn releases the second. Such a device can be seen installed at the Moore Dam on the Connecticut River, in northwestern Vermont. It has never been used. At Moore, the stoplog openings are about 30 ft wide by 50 ft high, and closed with 4 intermediate vertical WF steel sections called ”needles” with 6 ft long timber stoplogs in between. To date the author has been involved with the design of three quick release mechanisms, the first being built into the St. Marguerite #2 dam just west of Seven Islands, Quebec. The second is at a dam in Lachute, Quebec, and the third, the largest, is described herein.

The Ossokmanuan spillway.

The Ossokmanuan Spillway forms part of the containing dams required for the Churchill Falls development in Labrador. It is located about 50km. west of Churchill Falls, and accessed in summer via a gravel road. There are 17 stoplog openings, with timber stoplogs spanning 16 ft, all with a height of 24 ft. In addition there are two larger gated openings, each equipped with a hoist. The logs are operated with a standard stoplog hoist. Power is obtained from an overhead line and an emergency diesel generator installed at the north end of the spillway. There is no accommodation at the spillway, and operators travel to the spillway by 4x4 truck or helicopter.

Recent PMF studies revealed that it would not be possible to open all the stoplog openings in sufficient time to release the flood, without seriously encroaching on the dam freeboard. One solution would be to install steel spillway gates with hoists. But the cost would be excessive; bearing in mind that the gates would only be used in near PMF situations. Another option would be to incorporate a rapid release mechanism, to quickly open the spillway, and this was the solution adopted.

Quick release mechanism.

The mechanism is very simple. It comprises a vertical WF steel section installed in the middle of the stoplog opening. It is held in place at the bottom by a reinforced steel angle anchored into the ogee concrete. At the top, the WF section has a flat steel plate with 2 holes through which there is an inverted U-shaped stainless steel bolt. Just above, the U-bolt passes through 2 plates on a beam connected to the spillway piers. The center WF section is released by jacking up the U-bolt. The design is simple. However, there are some precautions to be observed. These are:-

- On release, the moving WF section will forcefully eject the U-bolt. A suitable heavy protection plate is needed to limit U-bolt movement and protect the operator from injury.
- The timber stoplogs will rotate within their checks on each side of the opening. Hence, the fit should be loose, to avoid jamming the logs, and perhaps damaging the checks.
- The length of the logs needs to be closely controlled. The bearing width on the WF section is not large, and if the log is cut short, there is the danger that it could release. Sometimes, the ends need to be angled to avoid jamming on release, and still have sufficient bearing area.
- The jacking mechanism should not be easily accessible to vandals. Enclosing the mechanism in a locked steel cabinet restricts access to the U-bolt.

On release, the WF section rotates about the base angle, falls downstream and is lost along with the logs. The WF section can usually be recovered from the dry riverbed after passage of the flood. Replacement requires lowering of the water level to below the spill crest; hence the mechanism can only be used where this is possible. When flow depth is shallow, replacement in flowing water is possible as at the Davis dam. Installation of the mechanism was quite simple, and accomplished without lowering the upstream water level. The sill anchor for the WF section was installed in the dry behind the stoplogs. The contractor then anchored angles to the piers downstream of the stoplogs, to form a temporary check for logs, which were also supported in the middle by a steel section. The temporary logs were installed and flooded, the old logs removed, and the column and new short logs installed with the help of divers. As the contractor gained experience with the work, 3 bays were completed in a summer work season.

Operating experience.

One of the first questions asked by owners is whether the mechanism has ever been used, since it is difficult to test. At St. Marguerite, there are 6 quick release stoplog openings, and several have been released on two occasions. In most cases the steel WF section was retrieved from the riverbed downstream. The facility at Lachute has not been used. At Ossokmanuan, some thoughts are being given to devise a test where the water will not be released. It can be done by installing a temporary stop downstream, which would limit movement of the WF section. This would test the jacking operation, the only moving part in the mechanism. However, as mentioned previously, the main attraction of the mechanism, is the ability to be operated by one person.

Conclusions.

Quick release mechanisms for stoplogs are a viable low-cost alternative to the installation of gates, where the reservoir can be lowered to sill level for log replacement. They can be easily retrofitted to old stoplog spillways.

4. Design criteria for unit price and design-build contracts.

Synopsis.

There has been a recent trend towards design-build contracts in the hydro industry. The author has had experience with the traditional method of contracting for a consultant and then awarding construction contracts for the facility based on unit prices. Recently the experience has been with design-build contracts, both as an expert witness in consequent litigation, and as an advisor to owners. The experience has revealed some deficiencies with the application of “recognized hydro standards”, some of which affect dam safety.

The guidelines for this panel discussion concentrate on the effect increasing standards and knowledge of dam engineering have on power facilities. However, there is another side, and that is the decreasing standards used in some design-build contracts in an effort to cut costs. This will be the subject of this fourth part.

History.

Design-build contracts have only recently entered the industry. The first occurred about 15 years ago in California, where a large project was constructed. The author happened to be at a conference in Portland, Oregon, at the time and met a couple of mechanical engineers engaged by the owner to review drawings to ensure conformity with “hydro standards”. The engineer’s experience was in heating and ventilation, and this was their first hydro project. Needless to say they lamented the lack of “hydro standards”. At the time, they were reviewing the governor drawings, so the author asked how many pumps there were in the governor oil pressure system, and whether they were interconnected. The answer was only one pump and no interconnection. Since unwritten “hydro standards” call for the use of 2 pumps, or interconnection, the author was alerted to the change in standards with design-build contracts.

Most small hydro projects and a few large projects are now built under a design-build contract. Based on a rough analysis of anecdotal evidence, about half of the design-build contracts result in litigation, compared with less than 1 in 20 for unit price contracts. Most litigation is due to corner cutting and shaving of “hydro standards” in an effort to save costs. The extent can vary from inadequate foundation investigations, which result in a tunnel boring machine running into gravel, to inadequate spill capacity and undersized turbines.

“Hydro Standards” for small and large projects.

The governor anecdote encapsulates the dilemma of trying to apply “hydro standards”. They mostly exist in the experience of hydro engineers. They are not covered in detail such as in the ASME Boiler and pressure Vessel Code. Even such an important aspect as dam safety only has guidelines, and these are not legal requirements. No dam safety inspector is going to arrive during commissioning to inspect the work and provide an operating certificate. To illustrate just how vast the difference can be between unit price and design build contracts, the following two examples are provided.

The design-build example is for a power facility built within the last decade. It has an installed capacity of just over 20MW in a powerhouse with an integral intake, concrete dam with a spillway containing one small sluice gate, and about 12 stoplog openings. There is an earth flanking dam. During construction the following events occurred:-

- There was almost no foundation investigation.
- The cofferdam failed twice, in one instance flooding the powerhouse equipment.
- One of the generator rotors was dropped onto the repair bay.
- The sump pump clogged, again flooding the powerhouse and equipment.
- The contractor declared bankruptcy.
- The spillway concrete was so thin that the spillway vibrated on gate operation.

- There was no stoplog hoist. The intent was to rent a mobile crane from a contractor located about 100km away.
- The use of stoplogs was inappropriate, since the spring flood usually arrives with the logs still frozen in place, which resulted in overtopping the dam on one occasion.
- The upstream powerhouse wall, which contains the turbine thrust bearing anchors, deflects as the headpond level varies, causing problems with bearing alignment.
- The powerhouse leaked so badly, that a specialist contractor had to be engaged, and spent over 2 months grouting the concrete and foundation rock.
- There was no documentation of the design, and specifications in the design-build contract were minimal, not over 4 pages in total.

The facility was sold, and the new owners spent a considerable sum upgrading the facility. This example contrasts with that of a large facility built under a unit price contract. This project has over 1000MW, over 10 turbines in a powerhouse with an integral intake, a spillway with gates, and earth flanking dams. Construction was uneventful, and included:-

- Detailed foundation investigations.
- An extensive and detailed construction specification document of several hundred pages.
- Detailed records of construction and material analysis to check conformity with specifications.

There were no untoward incidents during construction, the project has operated without interruption for over 30 years, and the facility is still in excellent condition. No major expenditures have been necessary to upgrade the work.

Admittedly, this extreme experience with a small project was selected to illustrate the degree to which the application of construction and design standards can descend, in design-build contracts. Hopefully, it is not the norm. The prospect is that as hydro facilities are deregulated, and in an effort to maximize financial returns in a competitive market, the loose application of standards during construction of small hydro facilities, will unfortunately migrate to larger facilities. There does not appear to be any means of stopping this trend. Owners will just have to learn from experience. Tighter or more conservative guidelines are not the answer, if there is no regulation or incentive to apply the guides. Also, since every dam is unique, with different foundation conditions, different spillway capacity and different downstream consequences, it is impossible to cover every situation by means of guidelines, without using some engineering judgement. And engineering judgement is difficult to enforce in design-build contracts, where the contractor has every incentive to oppose any change, which will increase cost.

Conclusions.

In a deregulated and competitive industry, the application of more conservative standards may not have a significant effect on hydro facilities. Owners may not apply the standards if there is no legislation requiring the upgrading of old facilities to new standards, and with the more frequent use of design-build contracts, Owners will have a reduced ability to impose “hydro standards” during construction of the facility.

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