Klohn Crippen Berger

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City of Nanaimo
2020 Labieux Road
Nanaimo, British Columbia
B9T 6J9

Bill Sims, A.Sc.T.
Manager, Water Resources

Dear Mr. Sims:

Re-Assessment of Options
Middle and Lower Chase Dams
Nanaimo, BC

1 INTRODUCTION

1.1 General

Klohn Crippen Berger (KCB) has been retained by the City of Nanaimo (the City) to assist with engineering and environmental consulting services towards the removal of the Middle and Lower Chase Dams. The removal of the dams was ordered by City Council in October 2012 to address the public safety hazard (e.g. loss of life) posed by the dams to the high school, daycare and residential neighbourhood located a short distance downstream. The hazards are due to the subject dams and their spillways being inadequate to permit the dams to safely impound their reservoirs under the seismic and flood loading conditions established by the British Columbia Water Act – Dam Safety Regulation.

Various studies have been completed on the subject dams. As a result of these studies, the dams are classified as Extreme consequence dams and are viewed by the British Columbia Dam Safety Branch as the two highest hazard dams in the province of British Columbia.

1.2 Project Background

A detailed description of the dams and their methods of construction will not be repeated herein. The reader is referenced to the EBA Engineering Consultants Ltd. seismic hazard assessment report dated April 14, 2010 for this information.

Upon recognition of the potential loss of life associated with flood or seismically induced overtopping failure of both dams, City Council ordered the removal of the dams. This decision included direction to renaturalize the reservoir bottoms to restore the pre-impoundment conditions in the park and convert the park into a forested ravine park.

Klohn Crippen Berger Ltd. • Suite 301, 2627 Ellwood Drive • Edmonton AB T6X 0P7 • CANADA
780.444.0706 t • 780.481.2431 f • www.klohn.com

In January 2013 the City requested KCB to conduct a conceptual cost estimating study of the rehabilitation and replacement options. The results of this work were presented in a report titled "Middle and Lower Colliery Dams, Conceptual Costing of Rehabilitation and Replacement Options" dated April 30, 2013. This study was peer reviewed by Hatch and the results of their peer review was presented in their report titled "Cost Estimate Peer Review, Final Report For Colliery Dams Rehabilitation/Renewal" dated May 1, 2013.

Upon review of the removal/renaturalization, rehabilitation and replacement options and costs the decision to remove and renaturalize the subject dams was overturned on May 13, 2013 when the decision was made by City Council to remove the subject dams in late summer/early fall 2013 and replace them with new dams in 2014. Accordingly, the dam removal work was issued for tender on June 12, 2013 and City staff were ready to award the work to the successful bidder on July 8, 2013.

While City staff and KCB took steps towards engagement of the Snuneymuxw First Nation (SFN) on the specific topic of dam removal and renaturalization during the months between October 2012 and May 2013, no formal engagement occurred advising the SFN of the change in plans to remove and rebuild the dams prior to the May 13 decision to remove and rebuild the dams. Several discussions were held with the SFN thereafter. Discussion of the May 13, 2013 City Council decision resulted in the City and SFN reaching an agreement on July 8, 2013 to re-assess options for addressing the public safety risks posed by the subject dams in a manner that also addressed concerns about the Chase River and associated fish and fish habitat and the SFN's interests in the same.

2 SCOPE OF WORK FOR RE-ASSESSMENT OF OPTIONS

KCB's work plan developed in late July 2013 for the re-assessment process included the following overall tasks:

Short Term Mitigation Options (over winter 2013/2014)

- Discuss acceptable short term mitigation with Dam Safety Branch;
- Assess practicality of lowering the spillways at both Middle and Lower Chase Dams to address or partially address the flooding and seismic hazards.

Long Term Mitigation Options (after winter 2013/2014)

- Re-assess design basis for rehabilitation;
- Conduct additional analyses to assess impact of revised design basis for rehabilitation;
- Estimate costs associated with new dams constructed downstream of existing dams;
- Consider impact of failure mode of concrete core walls within Lower Dam to reflect presence of reinforcing steel confirmed in late winter 2013 in a field investigation directed by KCB. The focus of this study would be the impact on the inundation study conducted by Associated Engineering Ltd. as part of this re-assessment process;

- In addition to the work completed by KCB, additional analyses were to be completed by Associated Engineering Ltd., pertaining to the inundation study presented in their report titled "Chase River Dam Breach, Flood Inundation Study" dated September, 2012. The results of these analyses will be reported separately by others; and,
- After preparation of the work plan in late July 2013, the City requested KCB comment on the impact of each of the options considered by City Council on May 13, 2013 on the fisheries in the Chase River.

3 SHORT TERM MITIGATION OPTIONS

KCB addressed three topics related to short-term safety mitigation options, related to the 2013/2014 winter season.

Dam Safety Branch Tolerance for Risk Over the Winter 2013/2014

In a number of letters from the Dam Safety Branch to the City and related phone calls between the two parties, the Dam Safety Branch (DSB) has reiterated the need for the City to take action to mitigate the identified risks with these dams. As the end of the 2013 low-water season approaches and the start of long term risk-mitigation work continues to be delayed, the possibility exists that only limited or temporary mitigation efforts can be implemented before river flows increase in October.

A KCB letter report dated July 17, 2013 addressed the practical challenges, extreme costs and environmental impacts of installing and operating temporary pumping to keep the lakes dewatered through winter flood events up to 21 m^3/s (approximately 1:25 year).

In a phone conversation on July 26, 2013, Robin FitzGerald, P.Eng. (KCB) and Glen Davidson (DSB) discussed the temporary measures discussed in the following paragraphs to mitigate the existing dam safety risks, which have been suggested by various parties.

Lock Block Wall Addition to Dam Crest

A lock block wall (suitably sealed with geomembrane or similar) along the dam crest would increase the maximum water level and increase the maximum discharge capacity of the spillway (before dam overtopping). The spillway capacity limitation applies particularly to the Lower Dam spillway; under existing conditions a flood will overtop the spillway side-walls at approximately 25 m^3/s and overtop the dam crest at approximately 35 m^3/s.

A 2-tier lock-block wall (approximately 1.5m high) would increase the Lower Dam crest to approximately elevation 75 m. However, to make this effective in increasing the flood capacity of the Lower Dam spillway, the required work would include the following:

- The crest wall would need to extend to the El. 75m ground contour, approximately 150 m SW of the spillway and to the El. 75 m contour north of the dam, an overall wall length of approximately 230 m.

- In order to allow the water level to exceed the existing dam crest and be contained by the lock-block wall, a certain amount of foundation preparation will be required to stabilize the lock-block wall and reduce seepage. However, this will not address the implications for dam crest stability (see below).
- An additional 100 m of 2-tier lock-block wall would be needed to increase the side-wall height of the spillway to accommodate the extra discharge flow. There are many challenges in designing and building such a wall so that it can dependably contain the turbulent flow in the spillway chute.
- Unless the existing pathway bridge is demolished, it will act as a severe restriction on flows above 35 m^3/s (as reported in Water Management Consultants' 2002 spillway capacity study).

It is important to realize that a lock block wall scheme can only partially address the spillway capacity deficiencies. This course of action does not address the seismic stability risks, since no improvements are made to the dam structure and normal lake water levels are maintained at their existing spillway elevation. Indeed, the addition of the lock-block wall (and the possibility of lake levels above the crest of the existing dam) has adverse implications for both the static and seismic stability of the dams:

- The lock block wall represents an additional load on the crest of the dam, which has not been assessed to date in terms of slope stability.
- In a seismic event, the additional weight of the lock-block wall would significantly reduce the performance of the existing dam(s).
- Any seepage from reservoir water levels above the top of the existing concrete core walls could decrease the static stability of the steep downstream slopes. Therefore an impermeable geomembrane on the lock-block wall would have to tie into and be seales to the existing concrete core wall.

Lowering of Spillways

KCB prefers the lowering of the spillway inlets and channels to create additional freeboard and improve spillway hydraulic performance, instead of temporarily installing lock blocks on the crest of the dams. One variant of this option (as a permanent alteration in combination with dam rehabilitation, Option VH1) was discussed in the KCB Options Costing report dated April 30, 2013.

One advantage of this approach is that the reservoir normal water levels would be lowered by up to 3.0 m, which will reduce the stored volume in each dam by approximately 50% and provide enough freeboard for the deepened spillways to accommodate the design flood and eliminate the flood hazard posed to the school, daycare and residential neighbourhood downstream of the dams. This solution is more reliable and safe than the temporary lock block freeboard dyke placed on the dam crest. The drawback of this approach is that the spillway structures would be destroyed in the process, including the Lower Dam spillway structure which has recognized historical value and is on the Heritage Register.

While this approach does not directly address the seismic hazard assessment, it does reduce the volume of water within the reservoirs. As a result, the risk to the downstream public is partially addressed by reducing the amount of water that could be released and also by broadening the width of dam that is actively impounding water at normal reservoir levels. In the latter point, this tends to make the dam more robust and less likely to breach with the water at the reduced reservoir level.

The conceptual cost estimates related to this short term mitigation option have been compared to the conceptual design and cost estimates for the permanent work addressed (as a component of Option VH1) in KCB's April 30, 2013 report. As a temporary measure, some aspects of the work such as construction of replacement bridges over the spillways, can be dropped from the scope of work. In addition, the requirements for overall demolition, excavation (overburden and rock) and new concrete spillway weirs and sidewalls have been revisited. The cost of this temporary measure, including the same level of contingency and overhead costs (engineering etc.) as used previously, would be in the order of $2,000,000

Associated Engineering Ltd. is currently reviewing the inundation modeling conducted in 2012 and has advised the City and KCB that they will include assessment of the impact on reservoir lowering on the consequences of failure.

Lowering the water level in the reservoirs will result in shallower water which will impact the water quality in that it will likely become warmer in the summer months, with possible impact on the organisms living within the reservoirs.

Stabilization of the dams to meet a design basis that results in minimal post-seismic event damage was also addressed in the KCB Options Costing report dated April 30, 2013. However, as a short term mitigation, lowering the reservoirs with deepening the spillways will on its own provide some degree of mitigation against the consequences of the seismic failure mode.

Further review of the results of the inundation study being conducted in parallel with KCB's work will be required to provide further comment on the impact of this proposed method of public safety risk reduction.

4 LONG TERM MITIGATION OPTIONS

4.1 Review of Design Basis for Rehabilitation Option

4.1.1 Design Basis versus Design Standards

For the conceptual cost estimating in KCB's April 2013 Options Costing study of rehabilitation and replacement options, the design basis was that the dams would safely impound their reservoirs during and after the design seismic event. The City requested that the rehabilitation work be conducted so that minimal maintenance and repair would be required afterwards.

It is important to note that this is a separate consideration to the design standards established in the BC Dam Safety Regulation for Extreme Consequence classification dams, specifically:

- Engineering Design Ground Motion – 1:10,000 seismic event; and,
- Inflow Design Flood – Probable Maximum Flood.

What the design basis does effect is the degree of deformation experienced by the dam during the seismic event and, consequently, potential damage to the structure that is associated with the selected design. It was the City's logic, that given the extent of damage and destruction that the City would experience during a major seismic event, the City should concentrate its resources on post-disaster recovery of infrastructure, buildings and community facilities, rather than having to deal with severely damaged dams requiring immediate attention to maintain public safety downstream. The design concept for rehabilitation presented in KCB's report dated April 30, 2013 was prepared so that the likelihood of cracking occurring in the concrete walls and surrounding jet grouted zone of fill was unlikely. Similarly, the extent of rock fill berms placed upstream and downstream of the dams was sized so that there was minimal chance of the concrete wall and jet grouted zone becoming unsupported due to sliding and settlement of slope fill materials. Implementation of this rehabilitation design concept would allow the rehabilitated dams to safely impound their reservoirs during and after the seismic event.

4.1.2 Sequence of Development of Design Bases for Rehabilitation Option

The evolution of the design bases and increase of the subject dams Classification from High in 2008 to Extreme (revised in 2012) for rehabilitation of the subject dams is responsible for the perceived volatility in the estimated costs for the rehabilitation option.

The initial cost estimate for rehabilitation of the subject dams was presented in the EBA Seismic Hazard Assessment report. This repair method consisted of berming the upstream and downstream sides of the dams with rock fill, similar to the method used for the Westwood Lake retrofit in 2008. The estimated cost for this work, not considering a number of unknowns at the time, and not including various project costs such as dewatering, environmental aspects and design, was $2,500,000 for both dams. Inherent in this design was that damage to the concrete walls was considered likely during the design seismic event and that major maintenance and/or removal would be required after a large seismic event. It was EBA's recommendation that the City should be cautious about adopting such a repair method for the Chase River dams due to the high demand that will be placed on City staff in a post-seismic disaster response period. The City concurred with this recommendation. It is also important to note that this method of seismic stabilization did not address the inadequacy of the spillways.

The updated design concepts for dam rehabilitation, presented in KCB's report dated April 30, 2013, for minimal maintenance after the design seismic event and including the costs of addressing the inadequacy of the spillways, resulted in a project cost estimate for the rehabilitation of both dams of $23,600,000, including contingency allowances. Because this project cost estimate included spillway modifications, environmental issues, dewatering and diversion, design, City costs etc., the actual work on the dam structures represented only 42% of this overall cost.

4.1.3 Assess Implications of a Reduced Design Basis for Rehabilitation Design

A preliminary revised design basis was adopted for the preparation of a rehabilitative design concept wherein cracking of the existing concrete core wall and jet grout zone would occur during the design seismic event. A series of preliminary analyses were conducted to assess the impact of the seismic events that correspond to the 1:5,000 and 1:10,000 year seismic events. The preliminary analyses were conducted to provide insight on the suitability of the reduced design basis to result in the rehabilitated dams being able to safely impound their reservoirs during and after the design seismic event. These seismic events correspond to the Very High and Extreme classifications referred to in the BC Dam Safety Regulation and the Canadian Dam Association – Dam Safety Guidelines (2007).

The rehabilitation design (jet-grouting and buttressing) and seismic failure analysis were re-run to allow wall cracking and displacements of the concrete walls up to half their width. The deformation limits adopted for the latest assessment of rehabilitation are presented as follows:

- Middle Dam: allowable displacement 300 mm (vs. a maximum of 25mm used in “no damage case”); and
- Lower Dam: allowable displacement 600 mm (vs. a maximum of 25mm used in “no damage case”).

A minimum thickness of jet grouting of 2.0 m on both sides of the wall is adopted for the revised design basis. This thickness and deflection tolerances were selected based on engineering judgment and experience with design of dams and rehabilitation of dams to create a minimum width of jet grout and concrete wall “core”.

Associated Engineering Ltd. (Associated) is currently re-running the inundation analysis to include various comments and findings made since that work was originally completed in 2012. The results of this work are not available to KCB at this time. One of the options being considered in that analysis is the permanent lowering of the reservoirs through lowering the spillway inverts for both dams by 3.0 m. It is believed this will reduce the Classification of both dams (subject to confirmation upon completion of the inundation analysis) to Very High which entails at 1:5,000 year design seismic event.

Recognizing that the unsupported concrete wall faces on the upstream side of each of the subject dams exacerbates the damage experienced by the dams during a large seismic event, KCB included a rock fill buttress to provide upstream confinement for the concrete wall. A downstream buttress was not included in the analysis and it was demonstrated that from a seismic stability perspective (i.e. stability during, not after, the seismic event), a downstream toe berm was not required. However, the rehabilitation of the dams must be conducted so that the dams continue to safely impound their reservoirs (i.e. do not discharge their reservoirs in an uncontrolled manner) after the seismic event. The need for downstream toe berms will be discussed further in terms of post-seismic event stability later in this letter.

KCB again considered the contribution of the reinforcing steel on the flexural strength of the Lower Dam wall as part of this analysis and has again concluded that it has negligible impact on the response of the concrete wall to seismic loading. The impact of the reinforcing steel on the inundation study (in terms of dam failure timing) is currently being considered by Associated.

Post-seismic event stability for the case that concrete wall and jet grout zone cracking occurs is discussed in the following section with regard to the need for downstream toe berms.

The design cross sections for Middle and Lower Dam for the revised design basis is presented in Figure 1. Note that downstream rock fill berms are not shown. The need for these berms will be discussed later in this letter.

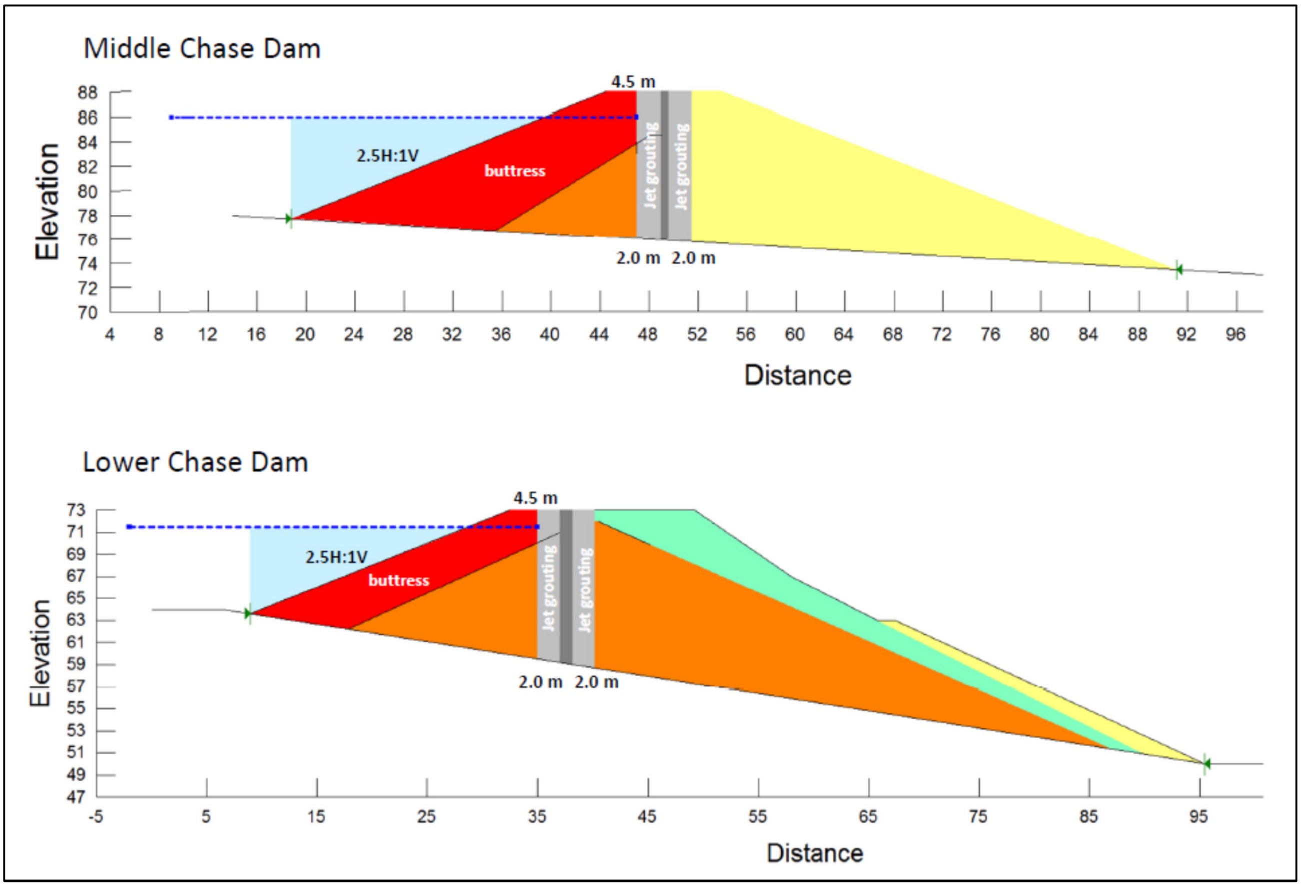

Figure 1: Revised Dam Rehabilitation Cross-Sections (Allow EQ Damage)

The results of the analysis conducted by KCB are summarized as follows:

<u>Middle Dam</u>

- The Middle Dam concrete walls and jet grouted zones will crack for the both 1:5,000 and 1:10,000 seismic events;
- The 1:5,000 year seismic event (with reservoir lowered by 3.0 m) will result in deformations in the order of 25 mm and 30 mm in upstream and downstream directions respectively;

- The 1:10,000 year seismic event (with reservoir at current elevation) will result in deformations in the order of 132 mm and 68 mm in upstream and downstream directions respectively;
- The seepage rates that result from the calculated deformations and anticipated degree of cracking will be quite high, in the order of several cubic meters per second.

<u>Lower Dam</u>

- The Lower Dam concrete walls and jet grouted zones will crack for the both 1:5,000 and 1:10,000 seismic events;
- The 1:5,000 year seismic event (with reservoir lowered by 3.0 m) will result in deformations in the order of 40 mm and 30 mm in upstream and downstream directions respectively;
- The 1:10,000 year seismic event (with reservoir at current elevation) will result in deformations in the order of 135 mm and 70 mm in upstream and downstream directions respectively; and
- The seepage rates that result from the calculated deformations and anticipated degree of cracking will be quite high, in the order of several cubic meters per second.

Preliminary analysis of the amount of seepage that will result from the damage to the concrete wall and jet grouted zones in both dams has not been completed. However, indications from the analysis completed to date are that the walls and jet grouted zones will experience enough damage to cause high rates of post seismic event seepage that KCB believes will destabilize the downstream shells of the dams after the seismic event. Consequently, downstream rock fill berms will be required to maintain post-seismic stability and safe impoundment of the reservoirs. The implication of increased seepage is discussed further in Section 4.1.4.

The implications posed by the seepage that develops through the dams after experiencing the design seismic event is that the stability of the dams will be reduced. This is discussed further in the following sections and requires additional measures to be implemented to maintain post-seismic stability.

4.1.4 Post Seismic Stability Considerations

It is difficult to assess the condition of the dams after the design seismic event has occurred, with the reduced rehabilitation measures described above implemented. As a minimum, KCB expects the following:

- The preliminary analysis indicates there would be increased seepage through the dams due to cracking and displacement of the concrete core wall and jet grout zones. A detailed seepage analysis of the post-seismic condition has not been completed;
- The permanent and temporary deformations experienced during the earthquake will likely result in cracking of the crest and exposed concrete elements;

- The unbuttressed portions of the downstream slope will deform and have some cracking and possible evidence of displacement corresponding to potential crack locations in the concrete core wall and jet grout zone. In the case of Lower Dam, if no buttressing was implemented, the loosely placed coal waste would experience significant settlement and downslope deflections; and, importantly
- The variabilities with the dam fill materials, in-situ treatment of the fill, the concrete wall and foundation materials may result in other signs of deformation and damage that are not possible to predict, even during a detailed design and analysis work.

In the case of Middle Dam, seepage through the sand and gravel downstream shell would cause internal and toe erosion of the downstream shell fill (sand and gravel), causing loss of the support of the damaged jet grout zone and concrete wall. Given the potential for failure of the Middle Dam to cause a cascade dam failure, it is KCB's opinion that a downstream rock fill toe berm and filter zone are required to minimize the potential for piping. Depending on the results of a detailed seepage analysis, the rock fill toe berm should include drainage measures such as rock fill backfilled trench drains with drainage pipes in the downstream shell as a mitigation against post seismic instability initiated by high seepage rates. This would be in addition to the toe berm and filter zone.

In the case of Lower Dam, the original rock fill downstream shell was left in place and covered with coal waste placed as part of railway construction across the crest of the dam. A filter was placed on the lower portion of the Lower Dam downstream slope in 1980. However, the deformations experienced during the seismic event combined with the loose nature of the underlying coal waste fill will result in the filter being damaged to the point where it will no longer meet its design intent.

The fine grained nature of the coal waste will initially impede seepage exiting the downstream toe of the dam, with further destabilization of the downstream shell. It is also important to consider that the 1978 drilling investigation conducted by Golder Associates Ltd. encountered zones of sand and gravel within the rock fill, as discussed in EBA's 2010 report. Given the likelihood of high post-seismic event seepage rates, it is KCB's opinion that these fine zones would likely erode with corresponding settlement and deflection of the downstream shell. Therefore, it is KCB's opinion that a rock fill toe berm and filter/transition zone should be placed on the downstream of Lower Dam with drainage provided for the downstream shell of the dam. This would require removal of the coal waste material on the downstream face of the dam.

Detailed analysis of the impact of cracking of the Middle and Lower Dam concrete walls and jet grouted zones and its impact on seepage rates and the post-seismic stability of the dams would be required if the City authorized detailed design of this concept for either or both dams. KCB recommends that additional seepage analysis will be required to confirm the extent of drainage measures required at Middle Dam and to verify that a toe berm and removal of the coal waste at Lower Dam is required.

4.1.5 Discussion on Limitations of Analysis

The City may elect as part of this re-assessment process to adopt a design basis that permits damage during a seismic event that requires immediate attention/repair or, possibly, subsequent removal and reconstruction. Any rehabilitation work conducted on the dams should be designed and constructed to prevent an uncontrolled discharge of the reservoirs during or after the design earthquake to protect the public downstream of the dams.

Adopting a design basis that allows for cracking of the concrete wall and jet grouted fill zones during the design seismic event will result in the subject dams experiencing higher rates of seepage than experienced to date. Rock fill berms that can accommodate the increased seepage rates will be required on the downstream side of the dams to maintain the stability of the dams.

The analysis conducted to date of the revised design basis concept is preliminary. Additional detailed analysis and design work will be required to take this concept to final design and construction. During that process additional refinements will occur which could result in cost increases.

It is difficult to reliably predict the extent of cracking that may occur as it will depend on the existing variability of the fill materials, the unknown nature of the original concrete wall construction and the inherent variability associated with in-situ treatment of natural and fill materials in place. Regarding the variability in the concrete walls, the features of concern for rehabilitative design are more focused on variability in concreting techniques that may have caused cold joints, honeycombing, as opposed to strictly relating to an oversimplified emphasis on the strength of the limited amount of exposed intact concrete.

It is also difficult to reliably predict the amount of seepage and increase in phreatic surface in the downstream shell that will develop as a result of cracking of structural elements within a dam. The combination of these two difficulties challenges any reliable estimation of the impact of cracking which will require detailed parametric analysis to bracket an expected range of post seismic event performance. This work should be conducted as part of any future detailed design and analysis phase for this option.

It is important to recognize that geotechnical computer modeling (or physical modeling for that matter) of a given dam is conducted to gain insight into the performance of that particular structure under idealized loading conditions with idealized properties for the fill, structures and foundation materials. Computer and physical modeling cannot be relied upon to provide exact answers and predictions. As a result, all such geotechnical modeling requires engineering judgment and experience in dam engineering to be brought to bear to assess how the computer modeled behavior would apply to the subject dam in reality. Conservatism in such interpretations is warranted, especially when the consequences of failure include loss of life at a school, daycare and residential neighborhood located a short distance downstream from the subject dam(s).

If upon implementing the revised design basis rehabilitation works, the City experiences a large seismic event, the City would have to inspect the dams immediately to assess the severity of damage and leakage. Immediate inspections after a severe seismic event would be required for any dam, rehabilitated or not. A decision would then have to be made regarding the need for evacuation of the inundation area. Depending on the severity of damage and leakage, the City may have to choose between rehabilitation, rebuilding or removal of the dams.

4.1.6 Estimated Costs of Dam Rehabilitation (Reduced Design Basis)

The direct work to rehabilitate the dam structures (including jet grouting and rock-fill buttressing) makes up only one component of the overall project cost estimates presented in KCB's April 30, 2013 Options Costing Report. Therefore, reductions in jet grouting and buttressing, resulting from a revised design basis, do not significantly change the magnitude of costs for the overall rehabilitation project costs, which also address spillway modifications, environmental mitigation, landscape reinstatement and project overhead costs such as design and engineering.

The reduced Design Basis allows for a reduction in the size of the jet-grout zone in each dam. However, as discussed above, there is still a need for upstream buttressing (for seismic stability of the core walls) and significant toe berms (to manage post-earthquake seepage through the cracked core). Therefore the estimated volume of rock/gravel fill for each dam is only reduced by 15-20% compared with the "no damage" design presented in April 2013.

Note that, at this level of analysis, the conceptual rehabilitation work scope and costs are intentionally the same for the 1:5,000 year and 1:10,000 year design level. This amount of damage sustained by the dams will vary between the two events.

Comparison with KCB April 30, 2013 estimates:

Extreme Classification, 1:10,000 year Seismic Event
Middle Dam: Jet grout, buttress etc. reduces from $3.7mil (no damage) to $1.8mil (allow damage)
Lower Dam: Jet grout, buttress etc. reduces from $6.1mil (no damage) to $2.9mil (allow damage)

Very High Classification, 1:5,000 year Seismic Event
Middle Dam: Jet grout, buttress etc. reduces from $2.6mil (no damage) to $1.8mil (allow damage)
Lower Dam: Jet grout, buttress etc. reduces from $6.0mil (no damage) to $2.9mil (allow damage)

Overall project cost estimates (including spillways):

> Option EXT 1 – Rehabilitate both dams, maintain existing lake levels:
> reduces from **$23.6 mil** (no EQ damage) to **$17.8 mil** (allow damage).
>
> Option VH1 – Rehabilitate both dams, lower both reservoirs by 3m:
> reduces from **$17.8 mil** (no EQ damage) to **$13.1 mil** (allow damage).

4.2 Estimated Costs of New Dams Downstream of Existing Dams

The initial rough order of magnitude cost estimates provided to the City in 2010 and early 2012 by EBA Engineering Consultants Ltd. were as follows:

- $10 million or more for two new dams (EBA, 2010); and,
- In the "tens of millions" (EBA, 2012).

The design concept for the new dams at this early stage in these considerations involved new concrete gravity dams *downstream* of the existing dams. The advantage of a concrete gravity dam in this application is that expansion of spillways and associated disruption of the park can be minimized by incorporating the spillway into the crest of the replacement dam.

During KCB's conceptual rehabilitation and replacement costing study, it was determined by KCB that cost savings for the replacement option could be achieved by removing the existing dams and rebuilding the replacement concrete dams within their footprints. The advantage of this approach is that the reservoir footprint area could be maintained (expanding reservoirs would entail additional regulatory/permitting hurdles) and, due to their lower height, length and concrete volume, the costs could be minimized. This was the option selected by City Council on May 13, 2013.

The drawback of this approach is that the removal of the dams, in conjunction with an intensive short term erosion and sedimentation control plan to be implemented until new dams are built, exposes the downstream Chase River to impact from sedimentation caused by a flood event that exceeds the short term design criteria (1:10 year flood event). This concern is exacerbated by a prolonged period between the proposed removal in 2013 and the replacement in 2014. Removal and replacement in the same year reduces, but does not eliminate, the sedimentation concern.

Constructing replacement dams downstream of the existing structures entails higher and longer dams, resulting in higher costs for the replacement dams. The following summaries (Table 1) result from applying the same cost estimating methodology to these new dam concepts as was used in the April 30, 2013 Options Costing report:

Middle Dam		
	RCC Dam in existing dam location	RCC Dam at downstream toe of existing dam
Crest Length	35 m	160 m
Upstream Face Height	12.1 m	16.3 m
Downstream Height	13.5 m	17.4 m
Concrete Volume	1550 cu.m.	8,550 cu.m.
Cost (New Dam Structure only)	$1,170,000	$5,500,000
Lower Dam		
	RCC Dam in existing dam location	RCC Dam at downstream toe of existing dam
Crest Length	30 m	160 m
Upstream Face Height	13.5 m	26.5 m
Downstream Height	16.0 m	28.0 m
Concrete Volume	3,000 cu.m.	19,000 cu.m.
Cost (New Dam Structure only)	$2,000,000	$11,100,000

Table 1: Comparison of RCC Dam locations

The advantage of constructing new dams downstream of the existing dams would be that mobilization of reservoir bottom sediments will not occur due to the existing dams being left in place during construction of the new dams. A water diversion system would likely only be required at Middle Dam due to the configuration of the Lower Dam spillway.

However, the overall project costs are increased substantially by building the new RCC dams further downstream due to increased height and increased length. A summary of new dam downstream costs is presented as follows:

Option VH4: Remove Middle Dam, Replace Lower Dam in existing location: $7,900,000

Option VH6 (new): Remove Middle Dam, Replace Lower Dam downstream: $18,000,000

Option EXT4: Replace both dams in existing locations: $8,600,000

Option EXT5 (new): Replace both dams downstream of existing locations $23,600,000

5 IMPACT OF OPTIONS ON CHASE RIVER FISH AND FISHERIES VALUES

A qualitative analyses of the impact on fish and fisheries values of the different options being considered surrounding the development or removal of the Lower and Middle Chase River dams is provided in this section. This assessment is based on the various biophysical studies conducted by KCB in 2012 and 2013 as well as the concepts previously and currently being considered for addressing the public safety hazard posed by the subject dams.

The fish values being considered are those promoting the reestablishment of native or naturalized trout and salmon species (salmonids). The fisheries values being considered is for recreational fishing potential. Additional considerations may be revealed through additional discussions with the Snuneymuxw First Nation.

5.1 Short Term Mitigation

Lowering spillways

Lowering spillways will reduce fish habitat and fisheries values in the short term. Both the littoral (near shore) and pelagic (central) habitat of the reservoirs will be reduced and compromised. Access for fishing might be hindered in some locations, as sediment of various thickness is expected in the exposed areas of the drained portions of the reservoir. Furthermore, steeper slopes associated with bedrock outcrops may also hinder access to the lakes in some location. Hindered access would need to be addressed with additional work to maintain public safety levels consistent with the current configuration of the park and reservoir shoreline.

5.2 Long Term Mitigation

Removal of Both Dams and Renaturalization

Fish: Dam removal and renaturalization of the stream and valley will provide the best alternative for the expansion and diversity of habitat of native species of fish, allowing salmon to move further upstream until they hit a natural impediment, and providing more spawning and fry rearing habitat for trout species. This option will also provide the best terrestrial diversity, allowing more natural ecozones and seral stages to develop in the valley and up the valley wall.

Fisheries: Fisheries values would change from less spin casting and bait fishing to more opportunity for fly fishing and short spin casts. FLNRO has been quite clear that the recreational fishing values of the existing reservoirs for spin casting fishers, especially children and elders, will require compensation should the reservoirs be removed permanently.

Removal of Both Dams and Construction of Concrete Gravity Dams at Existing Dam Locations

Fish: There will be a temporary loss of pelagic habitat while the water is drained and the dams are removed. The proposal is there will be no net loss of habitat from what is currently found as the smaller dam footprints and the reestablishment of the creek bed between the lower dam face and the lower dam spillway plunge pool will add stream habitat, and suggested improvements to the littoral zone would improve those habitats. Prolonging the removal and replacement process with two construction seasons, one for removal and one for replacement, however, will increase the length of short term impact on the habitat types found within the lower and upper dam construction zones and increase the possibility of sediment events on the lower Chase River. In this scenario and the ones following, maintaining the dams will maintain barriers to fish passage and further interrupt a natural flow of water through the Chase River valley.

Fisheries: There will be a two year loss of lake spin casting potential in both reservoirs, which should resume once the new dams are established and vegetation is reestablished. Improved littoral areas might enhance fishery values.

Rehabilitation of Both dams with Larger Buttressed Footprints

Fish: This approach will result in the net loss of habitat both in terms of stream habitat and pelagic habitat. The loss of this habitat will require compensation.

Fisheries: There will be at least a one year loss of lake spin casting potential during construction and revegetation. There will be permanent loss of stream fishery area, and temporary loss of lake spin casting potential in both reservoirs.

New Dams Downstream of Existing Dams (July 2013 Option)

Fish: This approach will result in net loss of stream habitat and an increase in pelagic habitat. If the old dams are lowered, a 'reef' structure for fish could be established. While this approach has less areal fish habitat impact than the rehabilitation option, there will still be a net loss of habitat for which compensation will be required.

Fisheries: There will be at least a one year loss of lake spin casting potential during construction and revegetation of disturbed ground (e.g. access roads, excavation slopes). There will be permanent loss of stream fishery area, but to a lesser extent than the rehabilitation option. There may be an increase of lake spin casting potential, depending on the design and access around the new dams, and the revised height of the older dams.

6 CLOSURE

Please do not hesitate to contact the undersigned if you have any questions or comments.

Yours truly,
KLOHN CRIPPEN BERGER LTD.

Robin FitzGerald, P.Eng.
Principal – Water Resources

Chris Gräpel, M.Eng., P.Eng.
Manager – Civil Projects

CKG: RJF