March 4, 2014

Middle and Lower Chase River Dams Progress Update
Agenda

- Introduction and Methodology
- Mitigation conceptual Designs and Relative Costs
- Site Investigation Summary and Findings
  - Concrete Core
  - Downstream Shell
- Contaminants
- Hydrology Update
- Seismic/ Structural Update
- Failure Modes and Inundation Scenarios
  - Dam Breach (Middle Dam)
  - Inundation Model Scenarios Evaluated
  - Downstream Consequences and Risk
Focused effort in February on evaluating the options related to remediating the Lower Dam only (rather than a wider range of options including remediating the Middle Dam as well).

As outlined in our presentation on January 21, the dams operate as a system, with the stability of the Lower Dam controlling the downstream consequences. Under any dam remediation scenario, remediation of the Lower Dam will be required (ie it is not enough to remediate the Middle Dam alone).

Design of the Lower Dam to sustain the release associated with the failure of the Middle Dam (either due to seismic or a storm event) needs to consider all applicable failure modes for the dams.

This fundamental assessment of failure modes allows the remediation to be tailored to satisfy the critical failure modes consistent with satisfying dam safety requirements.

The Options Assessment phase (Phase 2) focused on comparing remediation alternatives for the Lower Dam only.
Focused effort on Lower Dam remediation options, included developing the risk assessment to determine if Lower Dam remediation will meet the dam safety requirements. As discussed at our meeting, the risk model required input, including,

- Additional inundation model runs – based on scenarios involving a remediated Lower Dam. Updated hydrology inputs were developed by Golder. Assessment of the failure modes associated with seismic loading was carried out.
- Downstream consequences were assessed based on these inundation model runs.
- The risk model was run based on these inputs and the dam safety assessed based on CDA Guidelines.
While the risk assessment is geared towards addressing the dam safety risks, this assessment will be based on satisfying the remaining objectives of the Technical Committee, namely,

- The respective objectives of the City, Snuneymuxw First Nation, the Colliery Dam Park Preservation Society and the community;
- Environmental concerns, including fisheries habitat and ecology;
- Cost-effectiveness; and
- Having a timely permanent solution in place by no later than 2015 and ideally in 2014.

The risk based approach that we are following has made it possible to achieve the desired dam safety improvements while optimizing the level of effort (ie by focusing only on the Lower Dam remediation).

The assessment provided herein includes input from Herold Engineering and Associated Engineering.
4 Mitigation conceptual designs and relative costs developed

Increase spillway capacity and/or allow overtopping of the dam (reinforce downstream face of dam)
- Option 1: Enlarge Existing Spillway
- Option 2: Swale (Auxiliary Spillway)
- Option 3: Labyrinth Spillway
- Option 4: Overtop Dam (Soil Stabilization)

Possibility to look into combination of above options

Access road required for options (likely larger than existing trails)

Based on a conservative flow requirement (175 m3/sec) – discussed later
Design Option 1: Enlarge Existing Spillway

- Similar footprint to Klohn’s original design ~48.5 m wide total
- Enlarged spillway area ~3200 m², total spillway area ~4000 m²
- Typical broad crested weir
- No water allowed to overtop the Lower dam (zero freeboard).
- The existing spillway remains in place and altered to widen to the South.
- Does not require a specialist contractor.
- Does not address contaminated soil in the downstream shell.
- Loss of Habitat (~3200 m²): Requires permanent removal of vegetation and soil to expose soil/rock surface to design elevation.
- Minimal maintenance required for spillway following a design event
- Requires a substantial bridge to span entire spillway
- Some modeling will be required to refine weir coefficient, optimize design and set specific spillway geometries.
Design Option 1: Enlarge Existing Spillway Plan
Design Option 1: Enlarge Existing Spillway Section
Design Option 2: Swale (Auxiliary Spillway)

- ~90 m wide crest width with 5:1 slopes south of existing spillway.
- The existing spillway (capacity of 35 m$^3$/s) would remain in place, largely unaltered, but an additional auxiliary spillway would be excavated on the right (southern) abutment.
- Swale invert would be higher than the existing spillway invert.
- No water allowed to overtop the Lower dam (zero freeboard).
- The area could be landscaped with grass, possibly ‘designed’ tree growth.
- Does not require a specialist contractor.
- Does not address contaminated soil in the downstream shell.
- Loss of Habitat (~10,100 m$^2$): Requires temporary removal of vegetation and soil to expose soil/rock surface to design elevation.
- Auxiliary spillway may receive damage during storm events that activate the spillway. Occasional maintenance costs to repair.
Design Option 2: Swale (Auxiliary Spillway)
Plan
Design Option 2: Swale (Auxiliary Spillway) Section
Design Option 3: Labyrinth Spillway

- Footprint ~20m wide total chute at location of existing spillway (to replace existing spillway – different design that would meet the capacity requirements).

Labyrinth spillway (example)
Design Option 3: Labyrinth Spillway

- Total Wall height ~3 m, so the top of slab (or rock) would need to be 3 m lower than the existing top of concrete slab at the control section.
- Does not require a specialist contractor.
- Water level must be drawn down during construction.
- Does not address contaminated soil in the downstream shell.
- Loss of Habitat (~850 m²): Requires removal of vegetation, soil and rock to a depth of ~3m.
- No maintenance costs to repair labyrinth spillway after a design event.
- The existing spillway structure would be destroyed and replaced – it is reportedly on the Heritage Register.
- New bridge required.
Design Option 3: Labyrinth Spillway Section
Design Option 4: Overtop Dam

- Involves hardening the downstream shell material of the Lower Dam to allow water to overtop the dam during a design event and flow along the downstream side to the creek.
- ‘Hardening” done by deep soil mixing the cinder and ash layer from surface down to about ~5m with a binder.
- Power mixer arm attaches onto an excavator which is connected to a tank with the binder mix.

ALLU stabilization system set up (schematic)
Design Option 4: Overtop Dam

- Membrane laid down followed by a gravel drainage layer.
- Open graded asphalt will be the top layer with seeded top soil to allow grass to grow for aesthetics.
- Requires a specialist contractor.
- Addresses the contamination found in the ash and cinder layer during the site investigation by containment if required/desired.
- No disposal required for cinder/ash material.
- Requires build up of trail running south from existing spillway along reservoir and training/confine walls/armoring to ensure funneling of water over downstream side of dam.
- Loss of Habitat (~3000 m$^2$): Requires removal of vegetation and soil in the area of the existing downstream side of the dam.
- Maintenance costs may be required after a design event.
Design Option 4: Overtop Dam

- Normal Operating Level of Reservoir
- Soil Stabilization Zone
- Proposed Approximate Ground Surface
- Vertical Well for Drainage
- Sand and Gravel Berm as per 1983 Asbuilts
- Topsoil and Seeded for Grass Growth
- Soil Stabilization
- Open Graded Asphalt
- Gravel
- Membrane

NOT TO SCALE

DETAIL 1
### Cost Inclusions and Exclusions Options 1 & 2

<table>
<thead>
<tr>
<th>Option Name</th>
<th>Cost Inclusions</th>
<th>Cost Exclusions</th>
<th>Cost (Class 2, -20% to +50%)</th>
</tr>
</thead>
</table>
| Option 1: Enlarged Spillway | - Mobilization  
- Laydown/ Crane pad  
- Access road, clear and grub  
- Stripping and rework existing spillway wall  
- Base, concrete, backfill  
- Rework walking trail  
- Bridge allowance  
- Siltation | - Detailed design  
- Construction management  
- Owners costs  
- Contingency  
- No contamination in excavation materials  
- No environmental, archeological etc. assessments | $2,589,000 |
| Options 2: Swale | - Mobilization  
- Access road, clearing  
- Silt control  
- Stripping and stockpile organics  
- Excavate & dispose silt, sediments  
- Excavate and relocate rock to dam toe  
- Replace organics  
- Landscape and hydoseed  
- Remove access road and site cleanup | - Detailed design  
- Construction management  
- Owners costs  
- Contingency  
- No contamination in excavation materials  
- Maintenance required after design event  
- No environmental, archeological etc. assessments | $1,345,000 |
## Cost Inclusions and Exclusions Options 3 & 4

<table>
<thead>
<tr>
<th>Option Name</th>
<th>Cost Inclusions</th>
<th>Cost Exclusions</th>
<th>Cost (Class 2, -20% to +50%)</th>
</tr>
</thead>
</table>
| Option 3: Labyrinth | • Mobilization  
• Siltation control  
• Laydown/ crane pad  
• Access roads, clear and grub  
• Stripping and base prep  
• Rework existing spillway  
• Concrete works  
• Backfill  
• Rework walking trail  
• Bridge allowance | • Detailed design  
• Construction management  
• Owners costs  
• Contingency  
• No contamination in excavation materials  
• No environmental, archeological etc. assessments | $2,592,000 |
| Option 4: Overtop Dam | • Mobilization  
• Access road, clearing  
• Silt control  
• Shallow soil mixing  
• Excavate and dispose lowered area  
• Membrane and cap  
• Vertical drainage wells  
• Landscape and hydrosed  
• Berm enhancement  
• Remove access road and site cleanup | • Detailed design  
• Construction management  
• Owners costs  
• Contingency  
• Possible armouring required on existing spillway  
• Maintenance required after design event  
• Only soil in downstream shell that will be included in shallow soil mixing is contaminated – all other material excavation, reworking, enhancement, disposal is “clean”  
• No environmental, archeological etc. assessments | $1,487,000 |
Option 1: Enlarge Existing Spillway

- Large potential environmental impact on right bank of existing spillway.
- Requires additional permitting through DFO and FLNRO through existing Fisheries Act and Water Act.
- Potential salvage implications for rare or sensitive amphibians and shrew in forested / wetted areas.
- Requires removal of trees in existing older mature forest, bird windows.
- Requires small environmental overview assessment, EMP and permitting to support design process.
Option 2: Swale (Auxiliary Spillway)

- Consistent issues as outlined above in Option 1 (Enlarge Existing Spillway).
- Large potential environmental impact on right bank of existing spillway and SE slope area.
- Requires additional permitting through DFO and FLNRO through existing Fisheries Act and Water Act.
- Potential salvage implications for rare or sensitive amphibians and shrew in forested / wetted areas.
- Requires removal of trees in existing older mature forest, bird windows.
- Requires environmental overview assessment, EMP and permitting to support design process.
Option 3: Labyrinth Spillway

- Small environmental impact on / at existing spillway.
- Requires additional permitting through DFO and FLNRO through existing Fisheries Act and Water Act.
- Limited salvage implications for rare or sensitive amphibians and shrew in forested / wetted areas.
- Requires removal of few trees in existing older mature forest, bird windows.
- Requires small environmental overview assessment, EMP and permitting to support design process.
Option 4: Overtop Dam (Soil Stabilization)

- Consistent with issues as outlined above in Option 3 (Labyrinth Spillway)
- Moderate environmental impact on / at existing spillway, trail construction and clearing.
- Requires additional permitting through DFO and FLNRO through existing Fisheries Act and Water Act.
- Salvage implications for rare or sensitive amphibians and shrew in forested / wetted areas.
- Requires removal of few trees in existing older mature forest, bird windows and trail.
- Requires environmental overview assessment, EMP and permitting to support design process.
- Ministry of Environment should be notified at start and following completion of work (soil excavation).
## Comparison of Design Options

<table>
<thead>
<tr>
<th>Option Name</th>
<th>Advantage</th>
<th>Disadvantage</th>
<th>Cost (Class 2, -20% to +50%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enlarged Spillway</td>
<td>• Does not require specialist contractor&lt;br&gt;• Minimum maintenance after design event</td>
<td>• Loss of ~3200m² of habitat&lt;br&gt;• Does not address contaminated soil&lt;br&gt;• Requires long bridge (included in the cost)</td>
<td>$2,589,000</td>
</tr>
<tr>
<td>Swale</td>
<td>• Area could be landscaped (aesthetics, habitat)&lt;br&gt;• Does not require specialist contractor</td>
<td>• Loss of ~10100m² of habitat&lt;br&gt;• Does not address contaminated soil&lt;br&gt;• Maintenance required after design event</td>
<td>$1,345,000</td>
</tr>
<tr>
<td>Labyrinth</td>
<td>• Minimum maintenance after design event&lt;br&gt;• Small footprint (aesthetics)</td>
<td>• Loss of ~850m² of habitat&lt;br&gt;• Does not address contaminated soil&lt;br&gt;• Requires bridge (included in the cost)</td>
<td>$2,592,000</td>
</tr>
<tr>
<td>Overtop Dam</td>
<td>• Area can be reseeded for grass growth (aesthetics)&lt;br&gt;• Addresses contaminated soil</td>
<td>• Loss of ~3000m² of habitat&lt;br&gt;• Requires specialist contractor&lt;br&gt;• Maintenance required after design event&lt;br&gt;• Requires raising section of trail&lt;br&gt;• Possible armouring required on existing spillway</td>
<td>$1,487,000</td>
</tr>
<tr>
<td>-------------------</td>
<td>----------</td>
<td>----------</td>
<td>----------</td>
</tr>
<tr>
<td>Enlarged Spillway</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Swale</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labyrinth</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overtop Dam</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Summary of Investigation

- Objectives of Investigation
  - Collect information on properties of dam fills
  - Collect information on dam foundations
  - Collect information on concrete core
  - Install water level monitoring instruments
  - Determine dam zonation
Summary of Investigation

- Carried out February 11 to 14, 2014
- A track mounted Diamond drill rig (Cabo Drilling Corp.) drilled the concrete core wall
A track mounted Sonic Drilling Rig (Mud Bay Drilling Ltd.) drilled into the downstream dam fills.
Summary of Investigation

- The drilling of both areas was carried out concurrently

View of drilling rigs looking North

View of drilling rigs looking South
Summary of Concrete Core Drilling (PQ Coring)

Purpose of the investigation was to:

- Observe the condition of the concrete core.
- Confirm the possible presence and condition of reinforcement.
- Collect concrete core samples for:
  - Evaluation of concrete conditions and
  - Possible further laboratory strength testing (for assessing the core wall condition and response to earthquake induced deformations).
- Provide a hole for delineating the variation in thickness of the concrete core wall at depth and possibly detect reinforcement near the core holes in a separate (later) geophysical survey.
Summary of Concrete Core Drilling (PQ Coring)

- Coring was carried out by diamond drilling.
- The drill uses a diamond encrusted drill bit to drill through the rock.
- PQ sampler used (outside diameter of 122 mm).
- Providing 85 mm diameter continuous core samples.

- The concrete wall thickened from 0.3 m wide to 1.2 m wide at a depth of 0.6 m below crest elevation.
- The full width of the wall was exposed to ensure the hole was centered before drilling.

- Concrete core was collected in core boxes and transferred to the Golder warehouse for potential further laboratory testing of strength properties.
- The core holes were capped and left open for testing (later date).
- Water is injected into the drill pipe to wash out the rock cuttings produced by the bit and also to reduce the heat produced due to friction which causes less wear and tear of the bits.
Risk Management Plan (RMP)

Dam safety concerns were considered in the drilling of all the boreholes.

Risk: The corehole could deviate and not stay within the concrete core (daylight)

- **RMP:** Survey the coreholes at minimum of 5 m intervals to verify that the holes don’t deviate beyond 2% off vertical (0.3 m).
  - If deviation could not stay within 2% off vertical, abandon corehole.
  - Provisions were in place for grouting the coreholes in the event that the drilling deviated more than 2% from vertical.

- Coreholes did not deviate more than 2%, RMP never implemented.

Risk: Corehole instability - If very poor quality concrete was encountered, to such a degree that the stability of the borehole could not be maintained, borehole collapse could occur which could lead to increased seepage through the core.

- **RMP:** Maintain drilling fluid pressures within the hole to increase stability.
  - If instability in hole encountered, abandon corehole.
  - Provisions were in place for grouting the coreholes in the event that instability was encountered.

- Coreholes were not found to be unstable, RMP never implemented.
Risk Management Plan (RMP)

Risk: Loss of drilling fluids – excessive loss of fluids may have an adverse impact on the core and on the environment (although losses would be expected to be to the downstream side of the dam, rather than into the reservoir).

- **RMP**: Provisions were in place for grouting the coreholes in the event that instability was encountered.
- **Result**: Excessive fluid loss did not occur during drilling, RMP never implemented.

Risk: Long term borehole stability in question – if, at the end of drilling, it appears that the borehole is not sufficiently stable to remain open until the additional down-hole testing is completed at a later date, there is a risk that the borehole may collapse in the intervening period.

- **RMP**: Provide support to the borehole by means of a standpipe or casing, or grout the borehole in accordance with the risk management plan.
- **Result**: At the end of drilling boreholes were sufficiently stable and therefore left open.

Risk: Concrete damage due to vibrations.

- **RMP**: Use diamond drilling methods, which have minimal vibrations that could cause damage.
- **Result**: No damage to concrete observed.
Section B-B’ (through coreholes)
CH14-02

- CH14-02 Drilled Feb 11 and 12, 2014
- Hole located in the center of the reservoir wall
- Core was observed to be in good condition with no signs of
  - Deterioration
  - Voids
  - Honeycombing
- Core recovery was on average 96%
- Bedrock Encountered at 17.8 m (Elev. 55 m)
- Water introduced to corehole for drilling was measured at 2.53 m below ground surface at 6 pm February 13, 2014 and was measured at 2.82 m below ground surface at 7.30 am February 14, 2014.
Reinforcement was encountered at depths:
- 14.27 m
- 15.65 m
- 16.15 m
- 16.81 m
- 17.07 m
- 17.37 m
A layer of finer material was encountered at a depth of 7.9 m (potentially representative) of a cold joint at that location.

Due to time constraints, the corehole was advanced 0.8 m into bedrock.
CH14-03 Drilled Feb 13 and 14, 2014.
Hole located at the South End of the reservoir wall.
Core was observed to be in good condition with no signs of
- Deterioration
- Voids
- Honeycombing
Core recovery was on average 96%.
Water introduced to corehole for drilling was observed to have reduced overnight, the exact amount of water loss was not measured however.
Bedrock Encountered at 9.1 m (Elev. 63.8 m).
Reinforcement was encountered between 0.3 and 1.8 m (exact location is unknown as core became lodged within the drill shoe; when the core was recovered it was broken up with relative locations of pieces unknown).
A location of level breakage was observed at depths of 2.1 and 4.0 m, which may have indicated cold joints.
CH14-01 was not completed due to time constraints
Purpose of the investigation was to:

- Observe the soil/fill material in the downstream shell and develop a profile of internal layering.
- Collect soil samples for environmental contaminant testing for characterization of coal waste used for upper fills.
- Collect soil samples for laboratory testing of properties including grain size distribution, plasticity and moisture content (later).
- Profile underlying foundation.
- Identify “water table,” and other possible variations in water saturation.
- Provide a hole for estimating the p and s wave velocities in the fill material in a separate (later) geophysical survey.
Summary of Downstream Dam Fill Drilling (Sonic Drilling)

Sonic drilling utilizes a dual-cased single tube core barrel system that employs high frequency mechanical vibration (Sonic vibration) to obtain continuous core samples of the soils.

- First the core barrel was vibrated to advance the hole 1.5 m.
- The casing was then advanced over the core barrel.
- The soil entered the core barrel providing 102 to 122 mm diameter continuous core samples.
- The core barrel and drill rods were removed.
- The continuous sonic core sample was vibrated out of the core barrel directly into a plastic sample bag before being transferred into wooden core boxes.
- The sonic cores recovered from each borehole were logged in the field, and taken to Golder’s sample storage facility at where the cores were further examined and photographed.
Section C-C' (through sonic holes)
SH14-04

- Drilled with 150 mm core barrel and 178 mm casing.
- Recovery in the following materials:
  - Cinders and slag was on average 80%
  - Rockfill and Random variable fill (contains Concrete) was 20 to 80%
  - Fine grained fill was on average 50%
  - Bedrock was on average 100%

NOTE: The sonic drilling method tended to “pulverize boulder and cobble sized particles” while advancing through the Rockfill and fine grained fill strata.
- Monitoring Well installed and screened in Rockfill.
- Ground water not encountered during drilling.
<table>
<thead>
<tr>
<th>Description</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Cinders and Slag,</td>
<td>0</td>
</tr>
<tr>
<td>Rockfill and Random Variable Fill (Contains concrete)</td>
<td>3.66</td>
</tr>
<tr>
<td>Fine Grained Fill</td>
<td>16.46</td>
</tr>
<tr>
<td>Bedrock</td>
<td>19.51</td>
</tr>
</tbody>
</table>

The table shows the depth of each layer in meters.
SH14-05 Drilled Feb 11 and 12, 2014.
Drilled with 101 mm core barrel and 120 mm casing.
Recovery in the following materials:
- Cinders and slag was on average 80%
- Rockfill and Random variable fill was 10 to 60%
- Fine grained fill was on average 80%
- Bedrock was on average 100%
3” PVC pipe installed in the hole to carry out future geophysical survey.
Ground water not encountered during drilling.

NOTE: The sonic drilling method tended to “pulverize boulder and cobble sized particles” while advancing through the Rockfill and fine grained fill strata, as well as tending to “pulverize” the upper weathered bedrock.
### Dam Fill Profile

<table>
<thead>
<tr>
<th>Description</th>
<th>Depth m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Cinders and Slag</td>
<td>0</td>
</tr>
<tr>
<td>Rockfill and Random Variable Fill</td>
<td>7.32</td>
</tr>
<tr>
<td>Fine Grained Fill</td>
<td>15.39</td>
</tr>
<tr>
<td>Bedrock</td>
<td>21.64</td>
</tr>
</tbody>
</table>
SH14-06 Drilled Feb 13 and 14, 2014.
Drilled with 150 mm core barrel and 178 mm casing.
Recovery in the following materials:
- Cinders and slag was on average 50%
- Rockfill and Random variable fill was on average 90%
- Bedrock was on average 80%
No installation in this hole. Hole grouted upon completion.
Ground water not encountered during drilling.

NOTE: The sonic drilling method tended to “pulverize boulder and cobble sized particles” while advancing through the Rockfill and fine grained fill strata.
### Dam Fill Profile

<table>
<thead>
<tr>
<th>Description</th>
<th>Depth m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Cinders and Slag</td>
<td>0</td>
</tr>
<tr>
<td>Rockfill and Random Variable Fill</td>
<td>3.66</td>
</tr>
<tr>
<td>Bedrock</td>
<td>17.53</td>
</tr>
</tbody>
</table>
**Issue:** Dam reported to contain coal slag fill.

**Literature:** Coal slag could potentially contain metals and hydrocarbon concentrations (potentially leachable concentrations).

**Previous KCB Testing:** “Contamination testing on various materials - Cinders, Ash (classified as “clean”).” (Test results not available)
Testing: Samples obtained during drilling of dam and from within the inferred coal slag material tested for:
- metals concentrations
- extractable petroleum hydrocarbon concentrations
- polycyclic aromatic hydrocarbon concentrations
- toxicity characteristic leaching procedure (TCLP)

Standards:
- BC MoE Contaminated Sites Regulation (Park Land use*)
  SSFs\(^1\): Intake, Toxicity, AW\(^2\), DW\(^3\)
- Hazardous Waste Regulation (LQS\(^4\))

*Given understanding of current dam location
\(^1\)SSF = Site Specific Factor
\(^2\)AW = Aquatic Life – freshwater
\(^3\)DW = Drinking Water
\(^4\)LQS = Leachate Quality Standards
Other Site-specific factors may be found to be applicable, based on further study/analysis of conditions.
Section C-C’ (samples taken in cinder and slag)
Rush samples of slag fill tested from 1st drilled hole (SH14-05)

<table>
<thead>
<tr>
<th>Sonic Hole Name</th>
<th>Sample</th>
<th>Start Depth (m)</th>
<th>End Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SH14-05</td>
<td>E1</td>
<td>0.8</td>
<td>1.1</td>
</tr>
<tr>
<td>SH14-05</td>
<td>E3</td>
<td>3.7</td>
<td>4.0</td>
</tr>
<tr>
<td>SH14-05</td>
<td>E5</td>
<td>6.7</td>
<td>7.0</td>
</tr>
</tbody>
</table>

Barium and/or arsenic concentrations were detected in all three samples that exceeded CSR Park Land Use (PL) soil standards. Concentrations also exceeded CSR Industrial Land Use (IL) soil standards, for the site-specific factors inferred to be applicable.

Extractable Petroleum Hydrocarbon (LEPH, HEPH) concentrations and selected Polycyclic Aromatic Hydrocarbon (PAH) concentrations (benzo (a) anthracene, naphthalene) exceeded CSR PL standards in one of three samples.

TCLP results indicated that material would not be classified as a Hazardous Waste, based on metals and hydrocarbon* leachability.

*Benzo(a)pyrene leachability
Questions:

- TCLP is for assessment of Hazardous Waste potential. Only boron, calcium, iron and magnesium concentrations were detected in TCLP leachate. What about leachate under less aggressive conditions (i.e., from precipitation)?

- Regulatory Jurisdictions – where do provincial and/or federal standards / guidelines apply with respect to the site? (soil, groundwater, surface water, soil vapour, sediment?)
Follow-Up Analyses for Relevant Samples (3 Sonic Holes):

- Metals analysis of composite of slag fill material*

- Hydrocarbon analysis (EPH, PAH) of composite of slag fill material

- Synthetic Precipitation Leaching Procedure (SPLP) on composite of slag fill material (to assess leachate from exposure to simulated precipitation)

* Three boreholes completed within dam, samples collected from each borehole within slag fill zone, all samples composited with composite analyzed.
Reported metals and hydrocarbon concentrations detected in the composite sample were generally consistent with results obtained for the initial three, discrete sample analyses (Samples from SH14-05).

- Arsenic concentration detected in composite sample exceeded CSR PL and CSR IL soil standards, for the site-specific factors inferred to be applicable.
- Extractable Petroleum Hydrocarbon (LEPH, HEPH) concentrations and one Polycyclic Aromatic Hydrocarbon (PAH) concentration (naphthalene) exceeded CSR PL standards in composite sample.
- SPLP results indicated that material does leach metals and hydrocarbons, but likely at concentrations less than CSR AW freshwater standards.
Environmental Assessment of Cinder Slag Fill Considerations

Considerations:

- Contaminated soil is present, and if it is found to be detrimentally affecting human health or the environment, then this would indicate the need for remedial action.
  - Is there a wider problem? Further characterization required to confirm or refute other possible contamination present and other pathways that may be affected.
- However, what if contaminated soil is **not** found to be detrimentally affecting human health or the environment?
  - Is it an acceptable liability?
  - Can it be left in-place (with/without controls*)?
  - Does it need to be removed (for another reason)?
  - There are risk management measures that could be implemented to secure and contain the slag fill, and isolate it from contact/exposure.
- To answer these questions will require further investigation, analyses and risk assessment.

* For example: covering / encapsulation
### Update on Hydrology and Hydraulic Analyses

<table>
<thead>
<tr>
<th>Task</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference data acquisition</td>
<td>Complete</td>
</tr>
<tr>
<td>Watershed &amp; sub-watershed (4) delineations</td>
<td>Complete</td>
</tr>
<tr>
<td>Hydrologic soil group determinations</td>
<td>Complete</td>
</tr>
<tr>
<td>Landuse and Curve Number analysis (accounting for future alterations)</td>
<td>Complete</td>
</tr>
<tr>
<td>Time of Concentration analysis</td>
<td>Complete</td>
</tr>
<tr>
<td>Wet-season baseflow analysis</td>
<td>Complete</td>
</tr>
<tr>
<td>24-hour annual frequency (2 through 50,000-year) rainfall analysis</td>
<td>Complete</td>
</tr>
<tr>
<td>Probable Maximum Precipitation (PMP) rainfall analysis</td>
<td>Complete</td>
</tr>
<tr>
<td>Stage-storage curve analysis (Parkway, Middle Dam, Lower Dam)</td>
<td>Complete</td>
</tr>
<tr>
<td>Nanaimo Parkway culvert rating curve analysis</td>
<td>Complete</td>
</tr>
<tr>
<td>Hydrologic Engineering Center (HEC) – Hydrologic Modeling System (HMS) Model</td>
<td>Complete</td>
</tr>
<tr>
<td>1,000-year and PMP hydrographs developed and provided to AE</td>
<td>Complete</td>
</tr>
</tbody>
</table>
Revised Hydrology and Hydraulic study complete. Summary and comparison to WMC’s 2002 study below:

<table>
<thead>
<tr>
<th></th>
<th>WMC 2002</th>
<th>Golder 2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Watershed = 20 km²</td>
<td>Watershed = 21 km²</td>
<td></td>
</tr>
<tr>
<td>Hydrologic Soil Groups Accounted for: No</td>
<td>Hydrologic Soil Groups Accounted for: Yes</td>
<td></td>
</tr>
<tr>
<td>CN&lt;sub&gt;ARCIII&lt;/sub&gt; = 95</td>
<td>CN&lt;sub&gt;ARCIII&lt;/sub&gt; = 84 (composite)</td>
<td></td>
</tr>
<tr>
<td>Sub Watersheds: 2</td>
<td>Sub Watersheds: 4</td>
<td></td>
</tr>
<tr>
<td>Nanaimo Parkway modeled: No</td>
<td>Nanaimo Parkway modeled: Yes</td>
<td></td>
</tr>
<tr>
<td>Baseflow to Lower Dam: 7 m³/sec</td>
<td>Baseflow to Lower Dam: 1.6 m³/sec</td>
<td></td>
</tr>
<tr>
<td>PMF Peak Flow to Lower Dam: 198 m³/sec</td>
<td>PMF Peak Flow to Lower Dam: 162 m³/sec</td>
<td></td>
</tr>
<tr>
<td>1,000-year Peak Flow to Lower Dam: 68 m³/sec</td>
<td>1,000-year Peak Flow to Lower Dam: 107 m³/sec</td>
<td></td>
</tr>
</tbody>
</table>
Middle and Lower Chase River Dams
Updated Hydrology & Hydraulics

PMP Hydrographs

- WMC 2002 Peak Lower Dam Outflow: 198 m$^3$/sec
- Peak Lower Dam Outflow: 162 m$^3$/sec
1000-Year Hydrographs

- Peak Lower Dam Outflow: 107 m$^3$/sec
- WMC 2002 Peak Lower Dam Inflow: 68 m$^3$/sec

Flow (m$^3$/sec) vs. Time (hours)
Characterization of Concrete Core

Concrete Quality
- Generally good – no visible zones of poor quality (generally uniform)
- No significant voids, (visible in the small mm range), etc
- No honeycombing, no AAR was evident
- Construction joints present – but generally tight
Characterization of Concrete Core

Reinforcement
- Two bars intersected (3/4” square twist) – appear to be lapped
  - Likely indication of reinforcement throughout entire wall – either on both u/s and d/s faces, or in middle of dam
  - 30” spacing (as indicated by surface GPR)
- No sign of carbonation / deterioration
Structural Considerations and Seismic Response of Lower Dam

- Characterization of Concrete Core
  - Foundation
    - Bedrock – good quality conglomerate
    - Very good quality bedrock/concrete contact
    - Indicates that careful construction controls must have been in place.
Failure Modes – shown for 1:3000 year EQ

1. Toppling
   - Low likelihood for Lower Dam – insufficient displacement
2. Cascading Failure – overtopping and toppling
   - Remediation required to control – addressed later
3. Post Seismic Internal Erosion
   - Further evaluation (next slide)
Lower Dam response to EQ (based on 2010 SVA (EBA))

- EBA indicated cracking could be severe due to influence of construction joints, honeycombing, poor quality concrete, lack of reinforcement, etc
- We now know the concrete is in significantly better condition than previously expected - cracking likely to occur, but will not be as severe as expected (further analysis would be required to determine extent)
- Dam core has already experienced a large EQ (1946, 0.14g, 125 year return period), with no visible damage (MWH, 2014 DSR)
  - Maximum bending moment at 9.5 m depth (based on a average height of 14.5 m) – maximum depth of persistent cracking
  - Confinement at this depth will limit displacement and crack development (opening)
- **FM 3 – Cracking, Internal erosion and instability of downstream shell**
  - As indicated earlier, cracking in core will be limited
  - Coal waste will deflect (and crest will settle about 0.5 m), but displacement of rock fill is limited
  - Increased seepage may result in increased water levels in fills and potential piping/erosion of coal waste.
  - Destabilization of rock fill very unlikely – therefore dam breach due to this failure mode very unlikely.
EQ Failure Modes – preliminary conclusions
- Failure modes due to Toppling and Post Seismic Internal Erosion are considered to be unlikely failure modes, based on current studies.
- Failure due to Cascading (overtopping and subsequent toppling) – low likelihood, provided Lower Dam can be remediated to accommodate cascading failure – see subsequent slides.
Failure Modes and Inundation Scenarios

- Evaluate Lower Dam release hydrographs (i.e., hydrograph of flows downstream of Lower Dam) – assuming Lower Dam does not fail.
- Develop series of scenarios, which represents extreme conditions.
- These scenarios are used to bound the risk assessment.
- Scenarios considered are,
  1. Seismic – fast breach (10 min)
  2. Seismic – slow breach (150 min)
  3. PMF – fast breach (10 min)
  4. PMF – slow breach (150 min)
  5. 1000 yr – fast breach (10 min)
  6. 1000 yr – slow breach (150 min)
  7. 1000 yr – no breach
  8. PMF – no breach
Seismic ‘Sunny-Day’ Breach

Notes

- Normal Pool, Base Inflow
- Earthquake causes significant damage, immediately initiating breach formation
- Sand and gravel material on downstream shell quickly erodes
- Core wall fails quickly
- Upstream shell material, consisting of rock fill, erodes more slowly, therefore significantly controlling the rate of breach formation
- Significant uncertainties:
  - Breach development time?
  - Result in full height breach?
  - Enough volume in reservoir to sustain eroding flow?
Storm Event Overtopping Breach

Notes

- High flows exceed spillway capacity and overtop dam
- Erosion initiates on slope or at toe and propagates upstream (Head-Cut)
- Core wall prevents further upstream propagation of head-cut erosion
- Material downstream of core wall continues to erode
- Core wall fails in sections causing a ‘stepped’ release of water from reservoir
- Significant uncertainties:
  - Rate of erosion?
  - Number of ‘steps’?
  - Would failed core wall ‘armor’ against erosion of next zone?
## Middle and Lower Chase River Dams
### Failure Modes and Inundation Scenarios

**Characteristics Affecting Breach Development**

<table>
<thead>
<tr>
<th>Seismic ‘Sunny-Day’ Breach</th>
<th>Storm Event Overtopping Breach</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Earthquake parameters (magnitude, duration, etc.)</td>
<td>• Storm parameters (magnitude, duration, distribution, season, etc.)</td>
</tr>
<tr>
<td>• Reservoir level / inflow at time of earthquake</td>
<td>• Overtopping flow (depth, duration, velocities, etc.)</td>
</tr>
<tr>
<td>• Damage to core wall (severity, extent of toppling, etc.)</td>
<td>• Time of breach initiation with relation to storm hydrograph</td>
</tr>
<tr>
<td>• Erosion resistance of ground cover (grass &amp; root zone)</td>
<td>• Erodibility of various zones of shell materials</td>
</tr>
<tr>
<td>• Reaction of core wall to evolving loading conditions</td>
<td>• Reaction of core wall to evolving loading conditions (variable head, variable shell material support)</td>
</tr>
<tr>
<td>• Wall failure (when, how, where does the failed wall or wall section end up?)</td>
<td></td>
</tr>
</tbody>
</table>

March 5, 2014
Summary of Predicted Breach Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breach Formation Time(^1)</td>
<td>Two times were chosen to bound the likely range</td>
</tr>
<tr>
<td></td>
<td>Fast: 10 minutes     Slow: 150 minutes</td>
</tr>
<tr>
<td>Breach Initiation Timing:</td>
<td>Breach initiated at peak of storm hydrograph</td>
</tr>
<tr>
<td>Breach Formation Development:</td>
<td>Stepped formation development in consideration of the failure mechanics</td>
</tr>
<tr>
<td></td>
<td>of the core wall (the same as in the prior studies by AE)</td>
</tr>
<tr>
<td>Breach Depth:</td>
<td>11.3 meters (full height of dam to the bottom of the reservoir)</td>
</tr>
<tr>
<td>Breach Bottom Width:</td>
<td>12 meters (approximate height of dam and also approximate valley bottom width)</td>
</tr>
<tr>
<td>Breach Side Slopes:</td>
<td>1:1</td>
</tr>
<tr>
<td>Breach Top Width:</td>
<td>34.6 meters</td>
</tr>
</tbody>
</table>

\(^1\)These parameters were developed from a review of available literature and case studies of historic dam failures with similar characteristics (case studies indicate Breach Formation Times ranging from 15 minutes to 8+ hours with the majority being in the 30 minutes to 2 hour range)

Scenario 1 – Middle Dam Fast breach – max 75 m³/sec

Scenario 2 – Middle Dam Slow breach – max 24 m³/sec
Failure Modes and Inundation Scenarios – Storm Events

- **Scenario 3** – PMF, Middle Dam Fast breach – max 310 m³/sec
- **Scenario 4** – PMF, Middle Dam Slow breach – max 175 m³/sec
- **Scenario 5** – 1000 year, Middle Dam Fast breach – max 255 m³/sec

Conservatively assumes breach initiates at peak of flood hydrograph.
Failure Modes and Inundation Scenarios – No Middle Dam Breach

- **Scenario 7** – 1000 year, Middle Dam No breach – max 110m³/sec
- **Scenario 8** – PMF, Middle Dam No breach – max 160 m³/sec
Key Conclusions

- Comparison to 2013 AE inundation study - remediation of Lower Dam results in,
  - Seismic (Sunny Day) Scenario.
    - AE model predicted approximately 1000 m3/sec peak flood flow (cascading failure)
    - With LD Remediation – peak flood flow approx 75 m3/sec
  - PMF Scenario
    - AE model predicted approximately 1200 m3/sec peak flood flow
    - With LD Remediation – peak flood flow approx 300 m3/sec
  - 1000 year flood
    - AE model predicted approximately 1100 m3/sec peak flood flow
    - With LD Remediation – peak flood flow approx 250 m3/sec

- The current key Dam Safety concern (which drives the Dam Classification) is the Sunny Day Failure.
  - If Lower Dam flood routing capacity can be increased, cascading failure can be prevented.
  - Increase in spillway capacity to 75 cumec, would be sufficient to pass a conservative (ie fast) Middle Dam breach and not trigger cascading failure.
Mitigation Conceptual Design Options Criteria

- Preliminary Design criteria used for conceptual design options includes passing:
  - Seismic event – fast breach (10min) of Middle Dam only
  - Probable Maximum Flood (PMF slow breach – 150 min)
- The criteria is likely conservative – to be updated with final risk assessment

![Graph showing flow rates over time with a dashed line at 175 m³/s]