2013Google, Imagery Mar 29, 2009

March 4, 2014

Middle and Lower Chase River Dams Progress Update

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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

Approach and Methodology

- 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.

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Approach and Methodology

- 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.

Approach and Methodology

- 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

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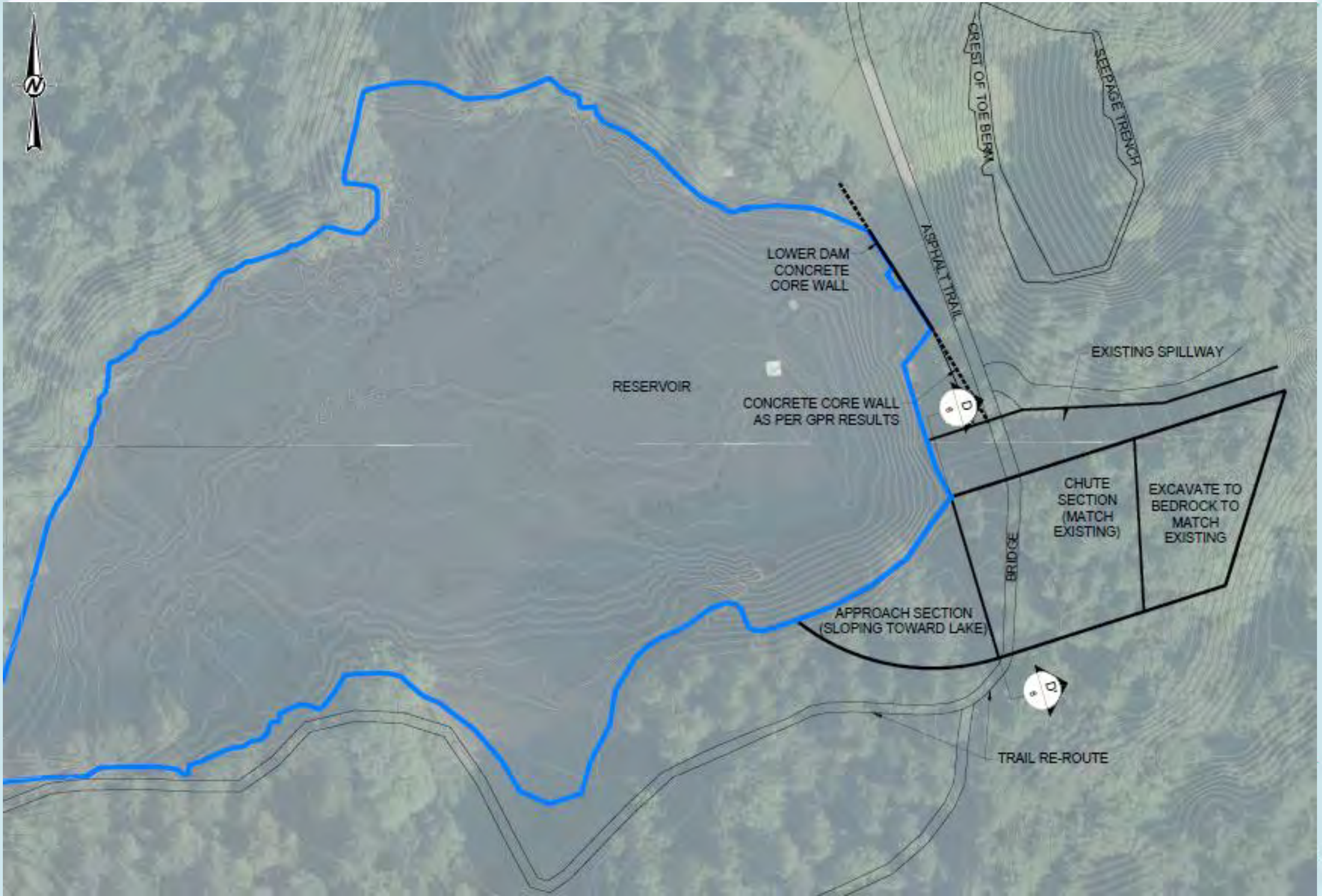
Mitigation Conceptual Design Options

- 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

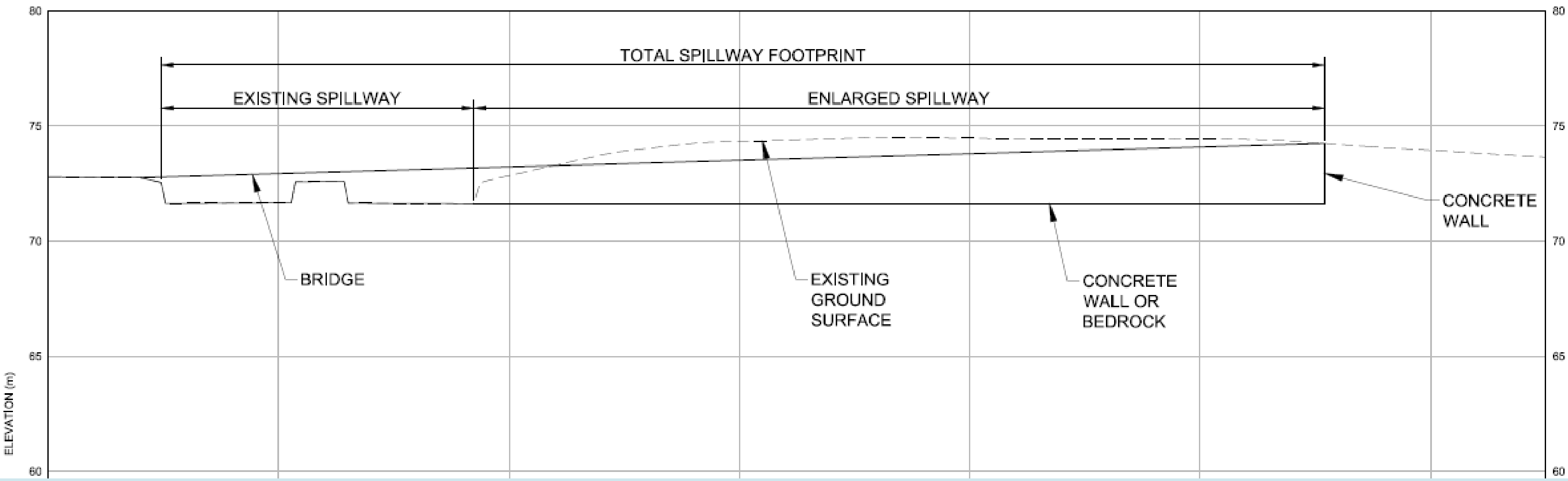
Design Option 1: Enlarge Existing Spillway

- Similar footprint to Klohn's original design ~48.5 m wide total
- Enlarged spillway area ~3200 m^2, total spillway area ~4000 m^2
- 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 m^2): 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



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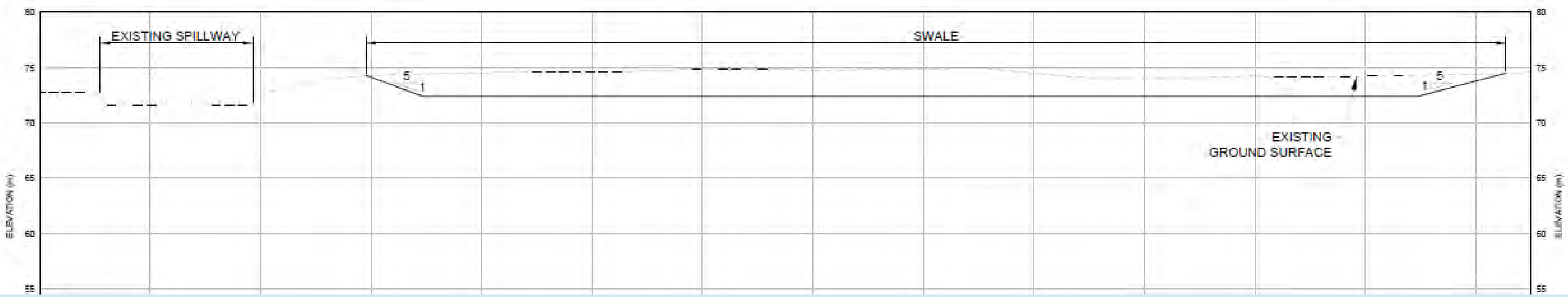
Design Option 2: Swale (Auxiliary Spillway)

- ~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



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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)

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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 m^2): 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.

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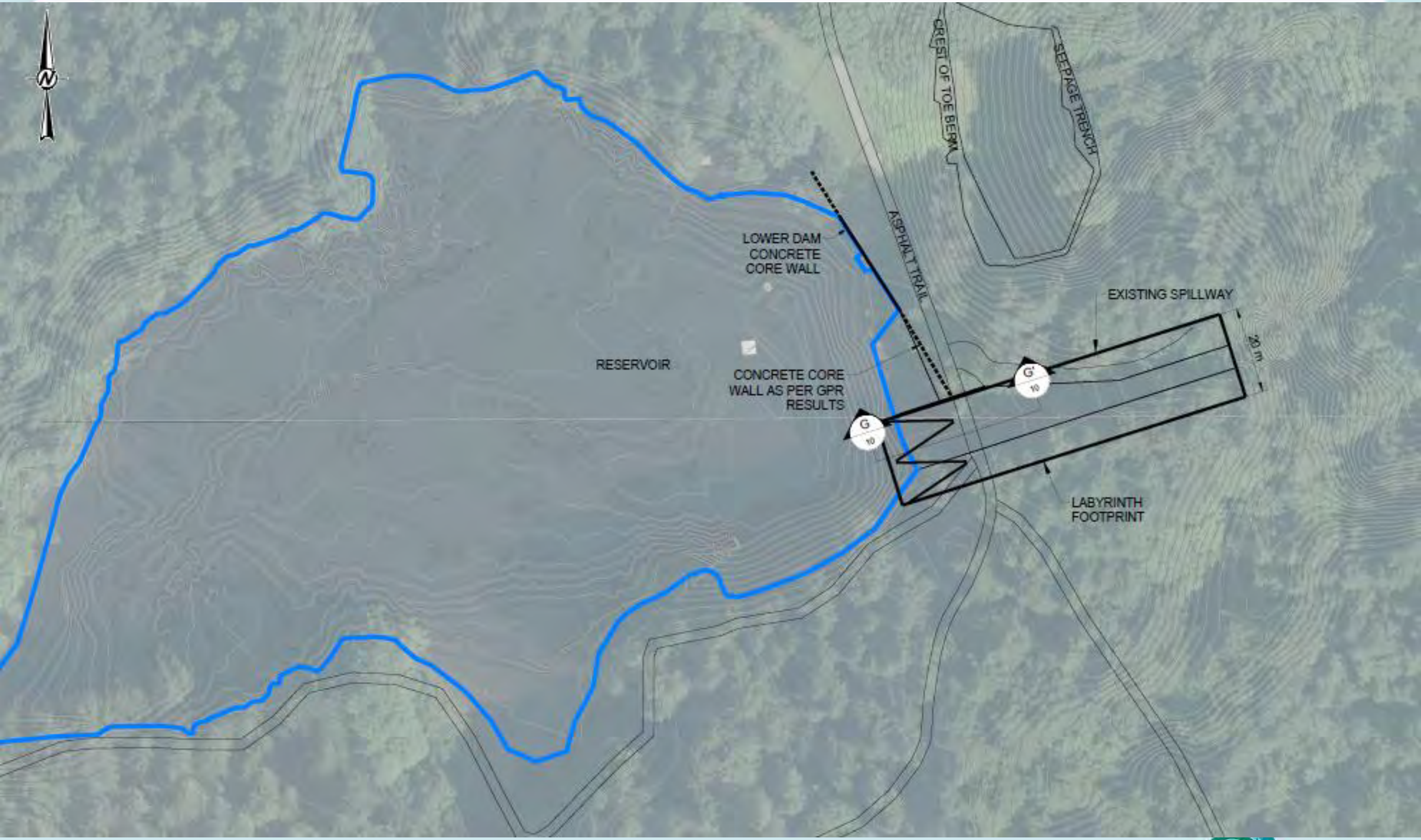
Design Option 3: Labyrinth Spillway Plan



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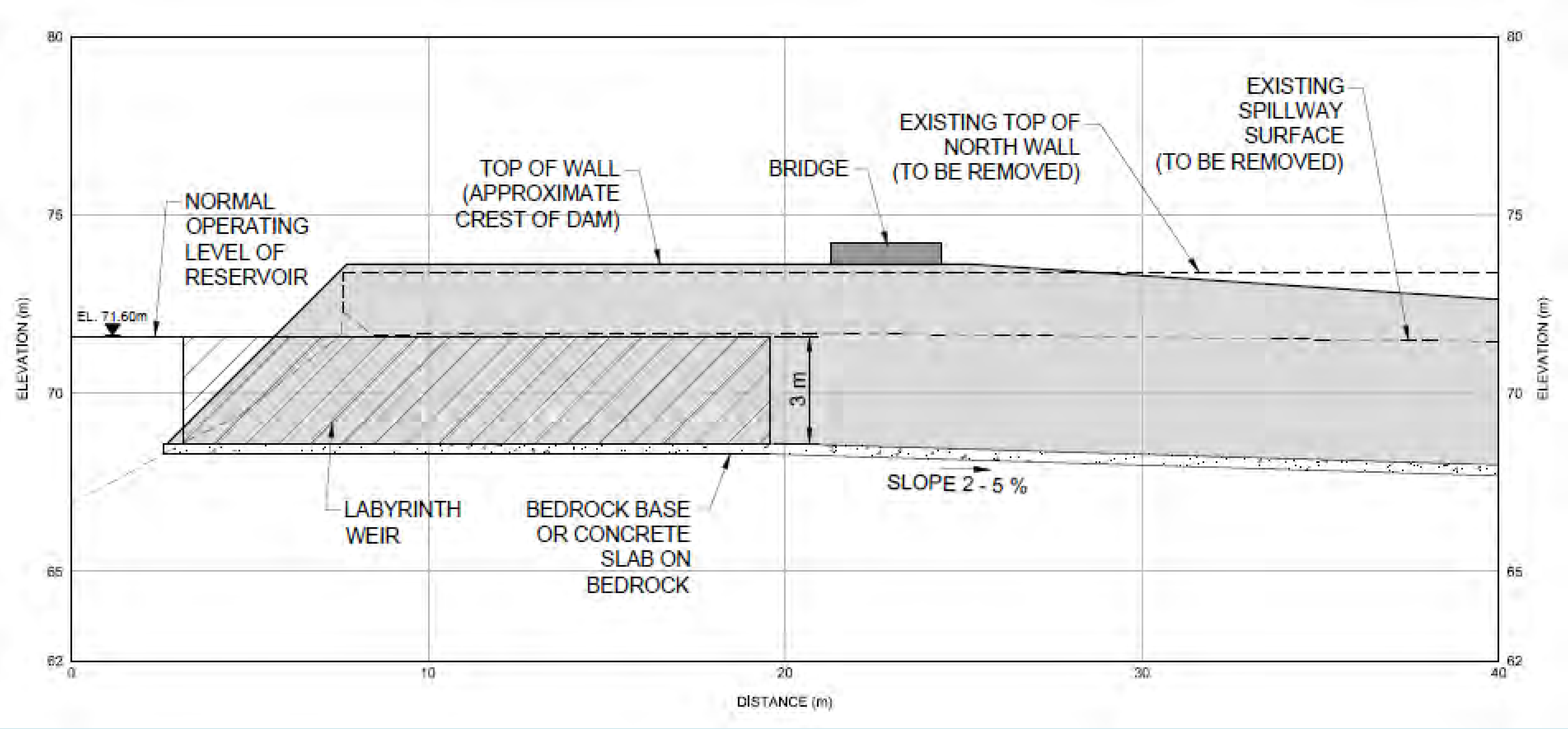
Design Option 3: Labyrinth Spillway Section



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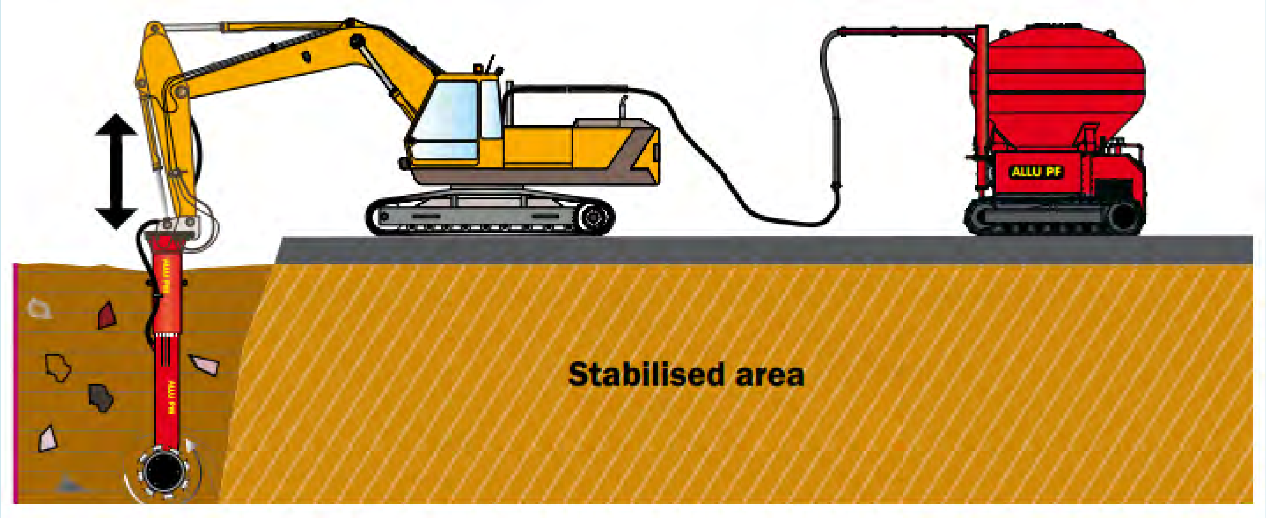
Design Option 4: Overtop Dam

- 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.

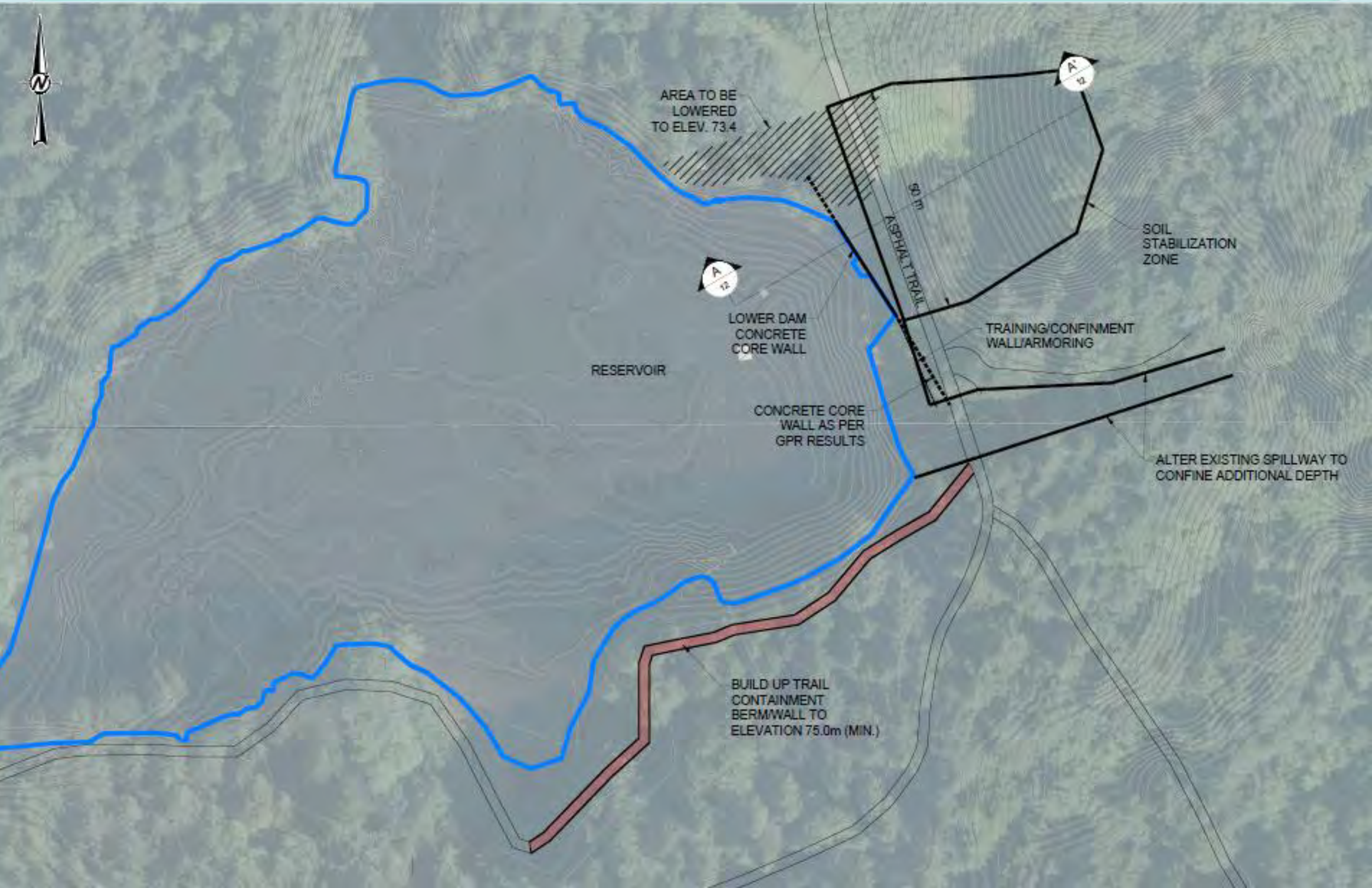


ALLU stabilization system set up (schematic)

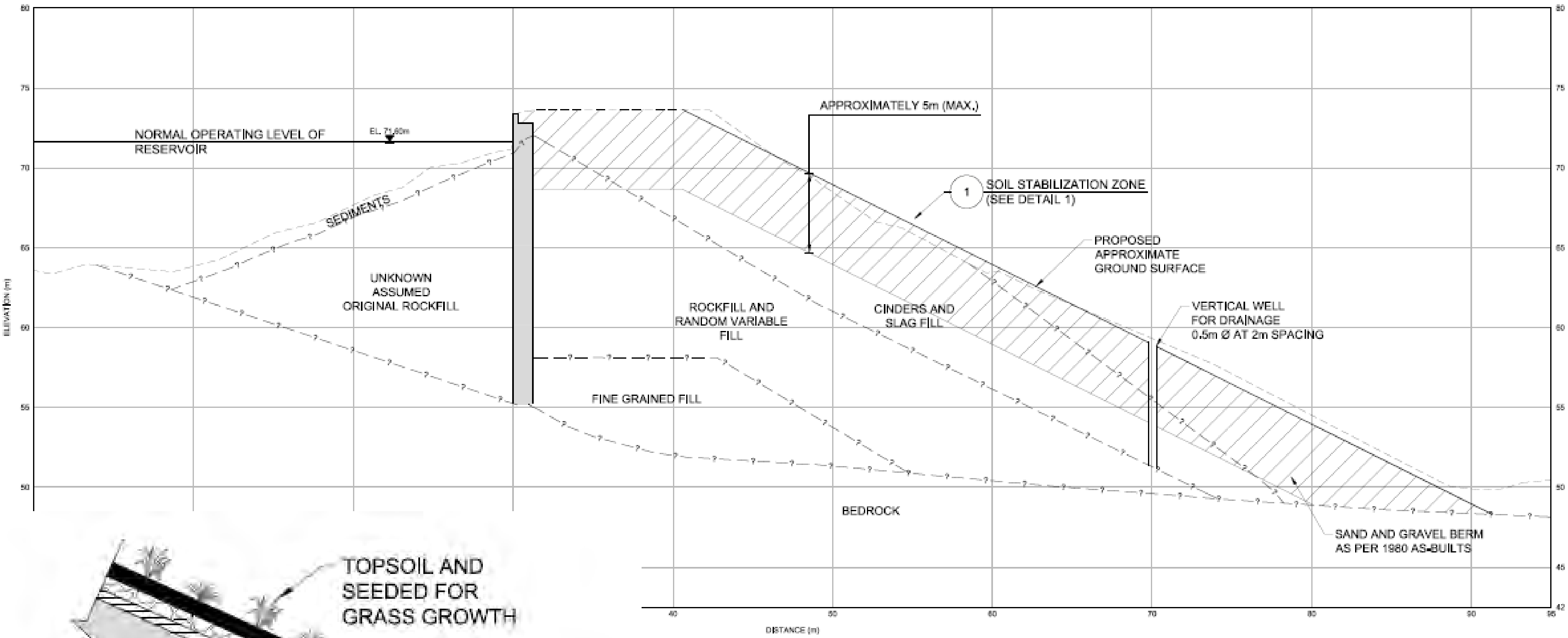
Design Option 4: Overtop Dam

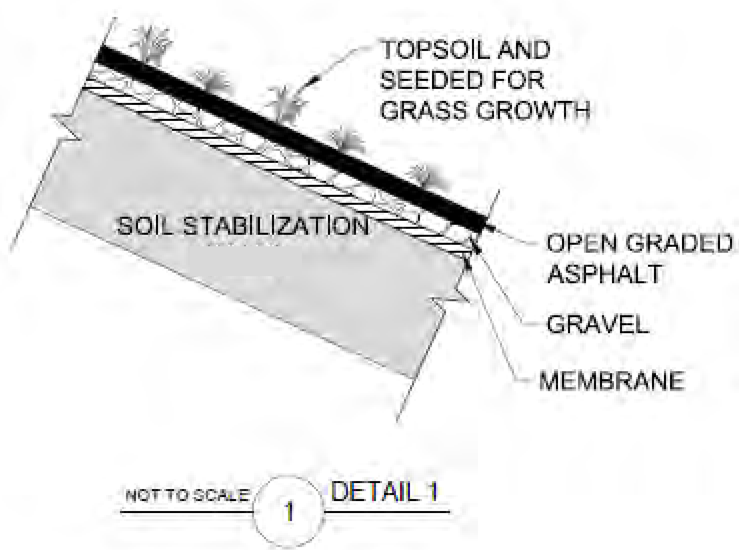
- Membrane laid down followed by a gravel drainage layer.
- Open graded asphalt will be the top layer with seeded top soil to allow grass to grow for aesthetics.
- Requires a specialist contractor.
- Addresses the contamination found in the ash and cinder layer during the site investigation by containment if required/desired.
- No disposal required for cinder/ ash material.
- Requires build up of trail running south from existing spillway along reservoir and training/ confinement 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 Plan



Design Option 4: Overtop Dam





Cost Inclusions and Exclusions Options 1 & 2

Option Name`	Cost Inclusions	Cost Exclusions	Cost (Class 2, -20% to +50%)
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 hydroseed • 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

Option Name`	Cost Inclusions	Cost Exclusions	Cost (Class 2, -20% to +50%)
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 hydroseed • 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

Environmental Issues and Assessment Approaches for Permitting: Option 1

<u>Option 1: Enlarge Existing Spillway</u>

- 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.

Environmental Issues and Assessment Approaches for Permitting: Option 2

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.

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Environmental Issues and Assessment Approaches for Permitting: Option 3

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.

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Environmental Issues and Assessment Approaches for Permitting: Option 4

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).

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Comparison of Design Options

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

Design Options –Construction Schedule

Option Name	Mar 2014	Apr 2014	May 2014	June 2014	July 2014	Aug 2014	Sept 2014	Oct 2014	Nov 2014	Comment
Enlarged Spillway										Fisheries window (June 15 – Sep 15) – need extension
Swale										Fisheries window does not apply
Labyrinth										Fisheries window (June 15 – Sep 15) – need extension
Overtop Dam										Fisheries window does not apply

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

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Summary of Investigation

- A track mounted Sonic Drilling Rig (Mud Bay Drilling Ltd.) drilled into the downstream dam fills

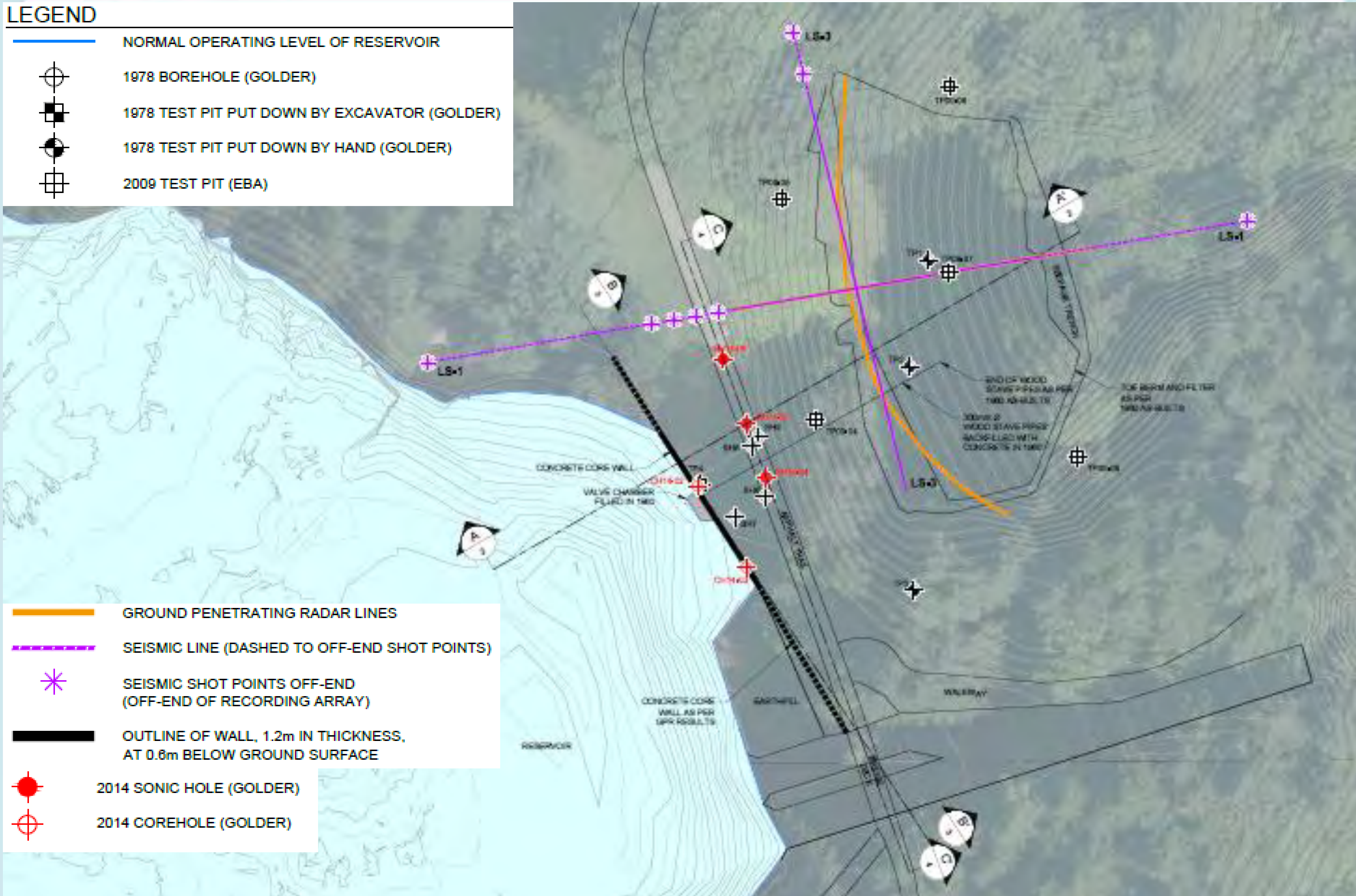
Summary of Investigation

View of drilling rigs looking North

- The drilling of both areas was carried out concurrently

View of drilling rigs looking South

Borehole Location Plan



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.

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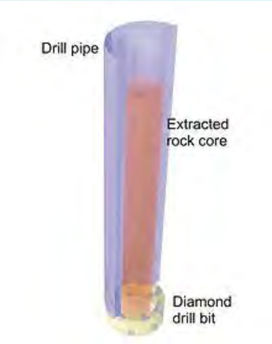
Summary of Concrete Core Drilling (PQ Coring)



- 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)

<u>Risk:</u> 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).

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

<u>Risk:</u> 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.

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

<u>Risk</u>. Concrete damage due to vibrations.

- <u>RMP</u>. Use diamond drilling methods, which have minimal vibrations that could cause damage.
- <u>Result</u>. No damage to concrete observed.

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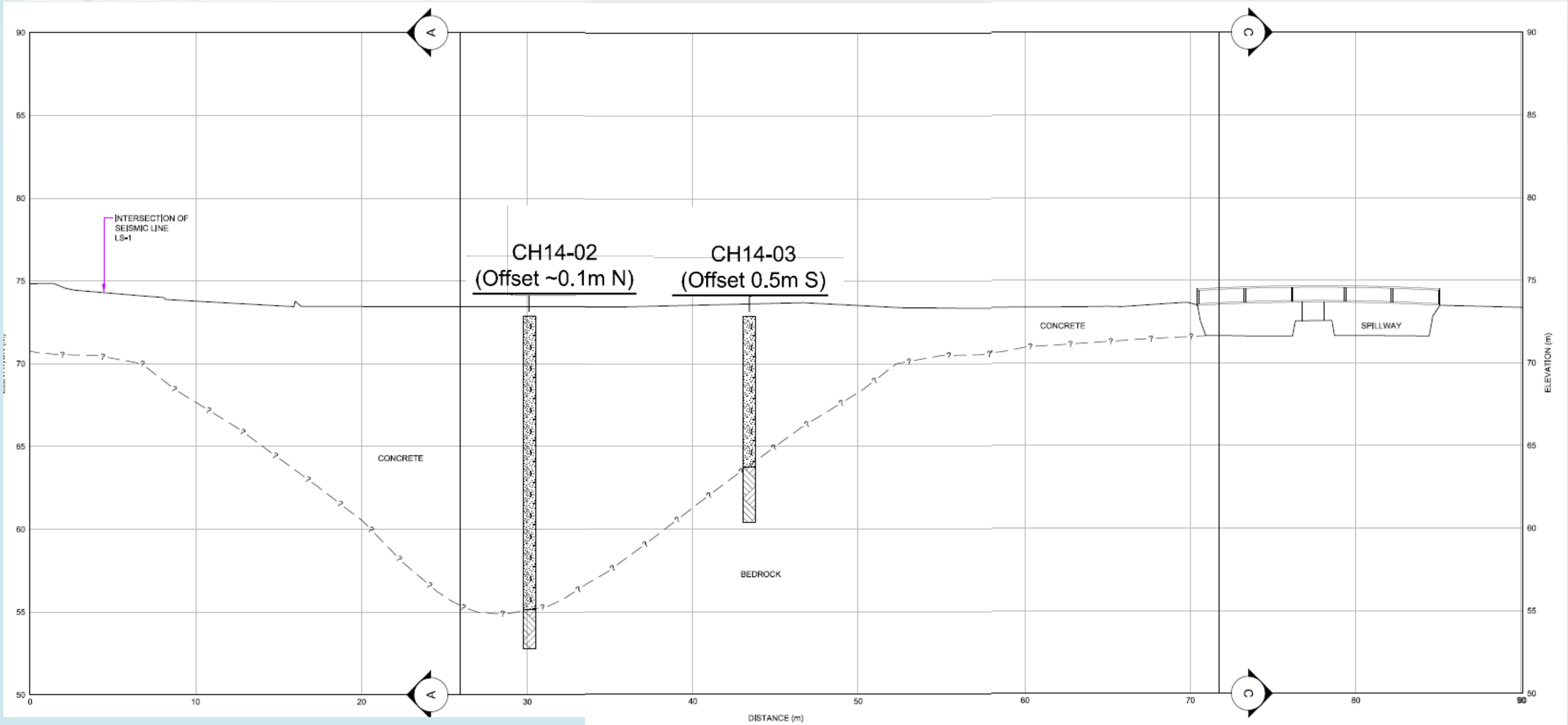
Section B-B' (through coreholes)



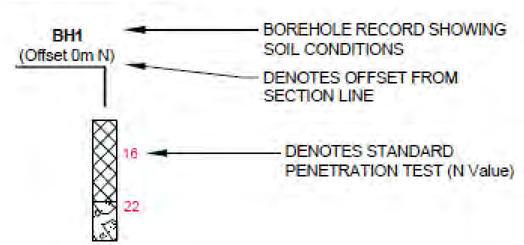
LEGEND

———	EXISTING GROUND SURFACE
— —? —	INFERRED STRATIGRAPHY BOUNDARY

LITHOLOGY GRAPHIC LEGEND

- CINDERS AND SLAG FILL
- RANDOM VARIABLE FILL
- ROCKFILL
- CONCRETE
- FINE GRAINED FILL
- BEDROCK

PROFILE LEGEND



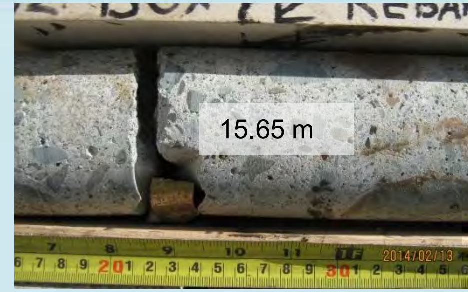
CH14-02

- 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.

CH14-02

- Reinforcement was encountered at depths:
  - 14.27 m
  - 15.65 m
  - 16.15 m
  - 16.81 m
  - 17.07 m
  - 17.37 m



CH14-02

- 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

- 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).

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CH14-03

- 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).

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CH14-03

- A location of level breakage was observed at depths of 2.1 and 4.0 m, which may have indicated cold joints.

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CH14-01

- CH14-01 was not completed due to time constraints

Summary of Downstream Dam Fill Drilling (Sonic Drilling)

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.

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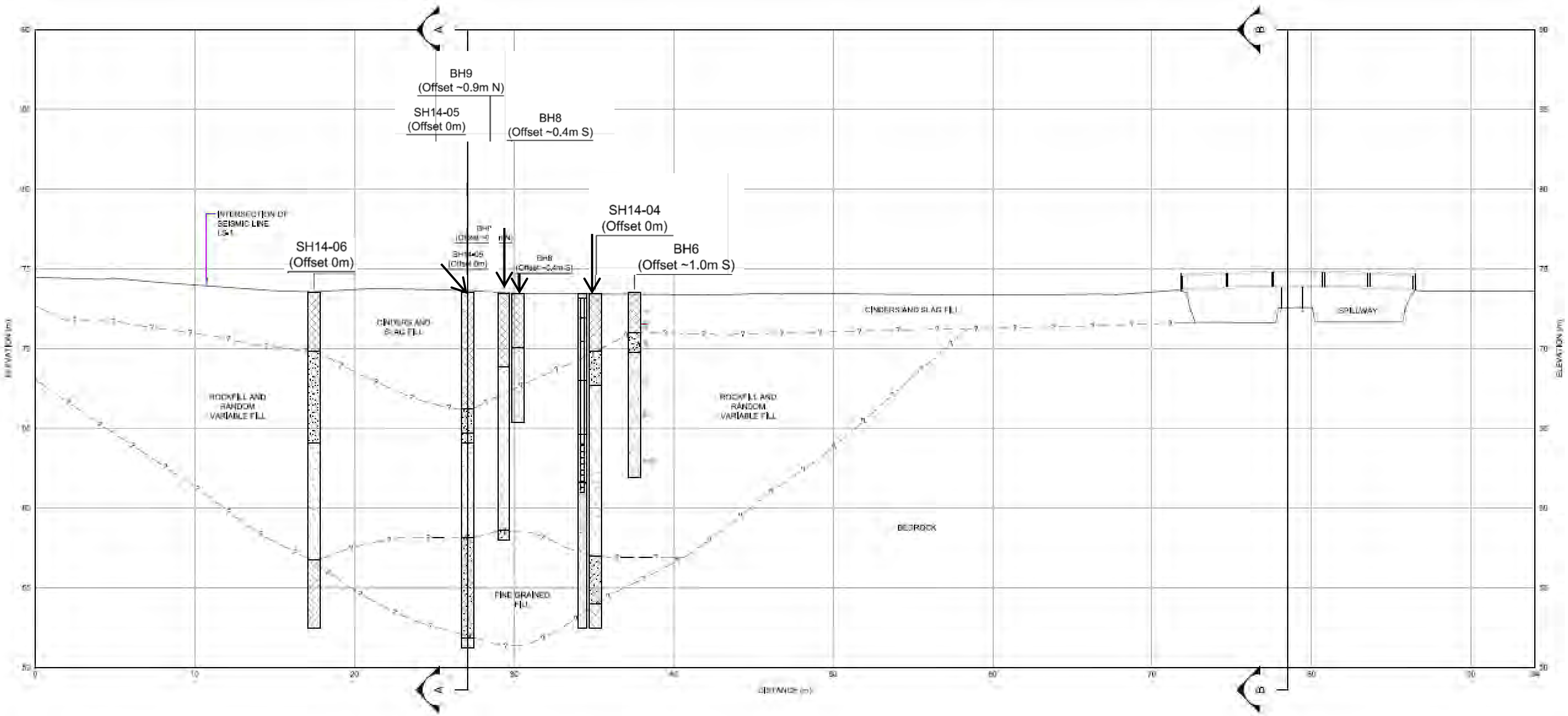
Summary of Downstream Dam Fill Drilling (Sonic Drilling)

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)



LEGEND

————	EXISTING GROUND SURFACE
— —?—	INFERRED STRATIGRAPHY BOUNDARY

LITHOLOGY GRAPHIC LEGEND

CINDERS AND SLAG FILL

RANDOM VARIABLE FILL

ROCKFILL

CONCRETE

FINE GRAINED FILL

BEDROCK

PROFILE LEGEND

BH1
(Offset 0m N)

BOREHOLE RECORD SHOWING SOIL CONDITIONS

DENOTES OFFSET FROM SECTION LINE

DENOTES PIEZOMETER INSTALLATION

18

22

DENOTES STANDARD PENETRATION TEST (N Value)

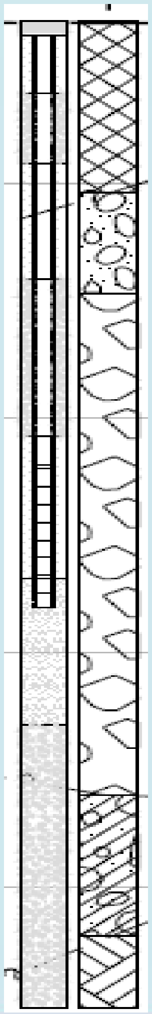
SH14-04

- SH14-04 Drilled Feb 12 and 13, 2014.
- 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.

SH14-04

- Monitoring Well installed and screened in Rockfill.
- Ground water not encountered during drilling.



0m	
0.30 m	Concrete Encased Flush Mount Well Cover
1.52 m	Pea Gravel
3.05 m	Bentonite Chips
5.49 m	Pea Gravel
8.84	Bentonite Chips
11.89	Pea Gravel
12.80	Filter Sand
21.03	Bentonite Chips

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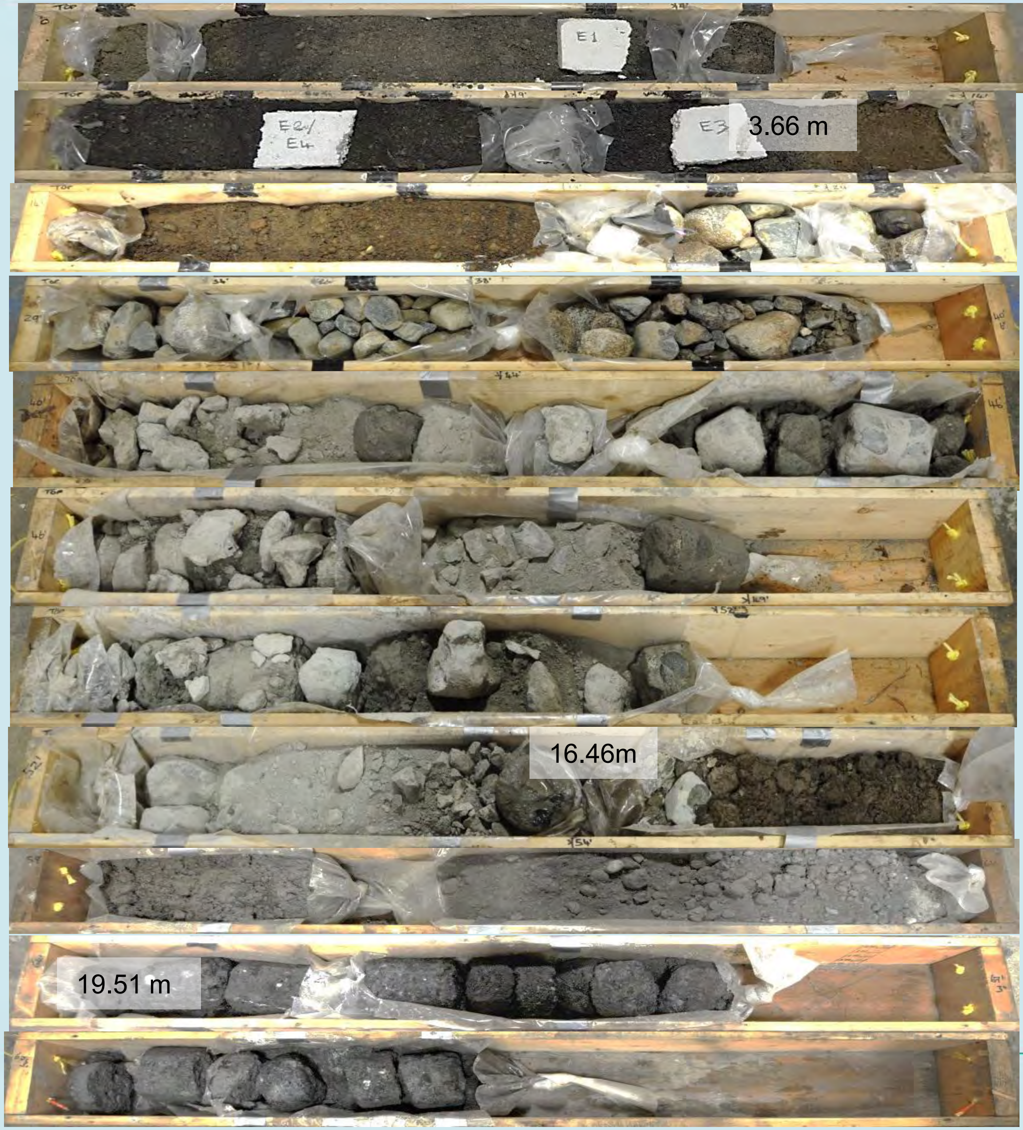
SH14-04



Dam Fill Profile		
Description	Depth	
	m	
Black Cinders and Slag,	0	3.66
Rockfill and Random Variable Fill (Contains concrete)	3.66	16.46
Fine Grained Fill	16.46	19.51
Bedrock	19.51	21.03

SH14-05

- 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.

SH14-05

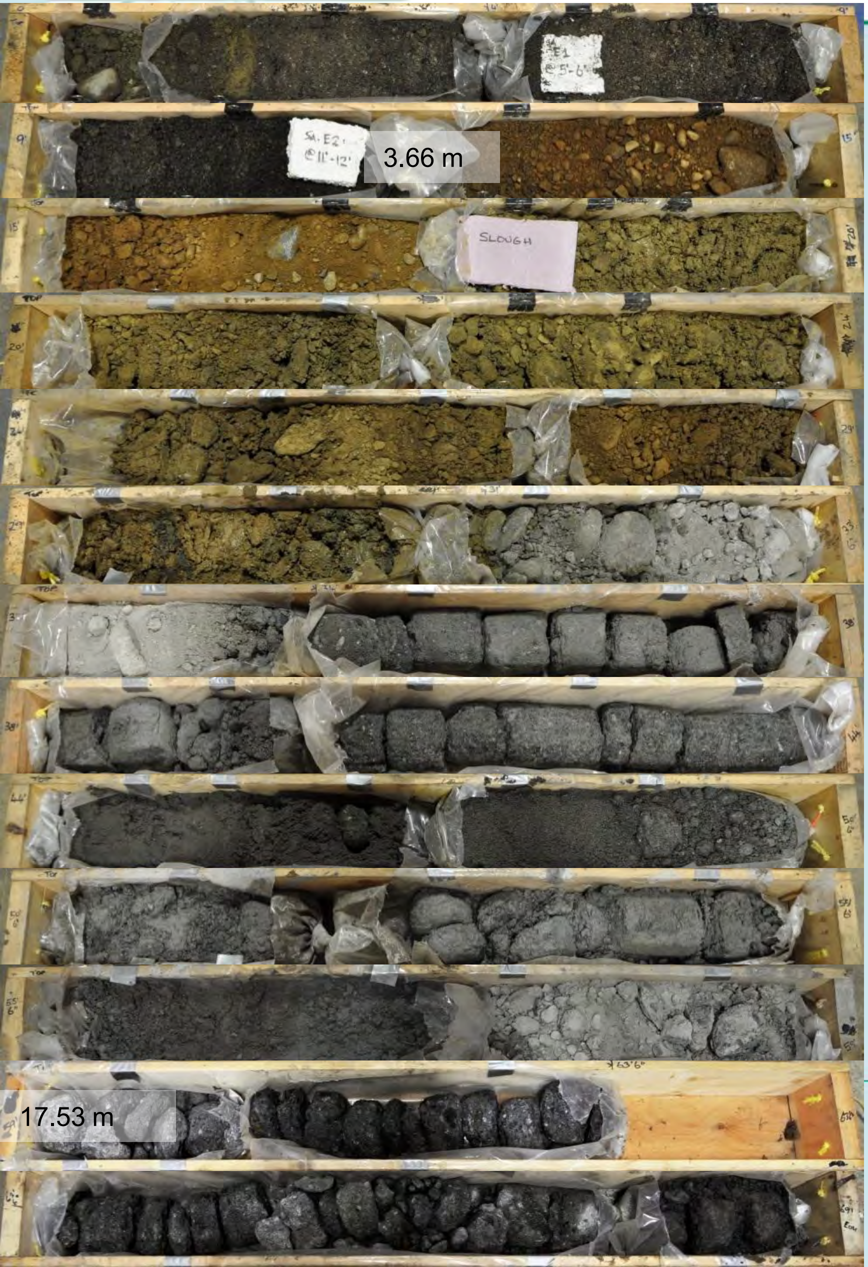
Dam Fill Profile		
Description	Depth m	
Black Cinders and Slag	0	7.32
Rockfill and Random Variable Fill	7.32	15.39
Fine Grained Fill	15.39	21.64
Bedrock	21.64	22.25

SH14-06

- 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.

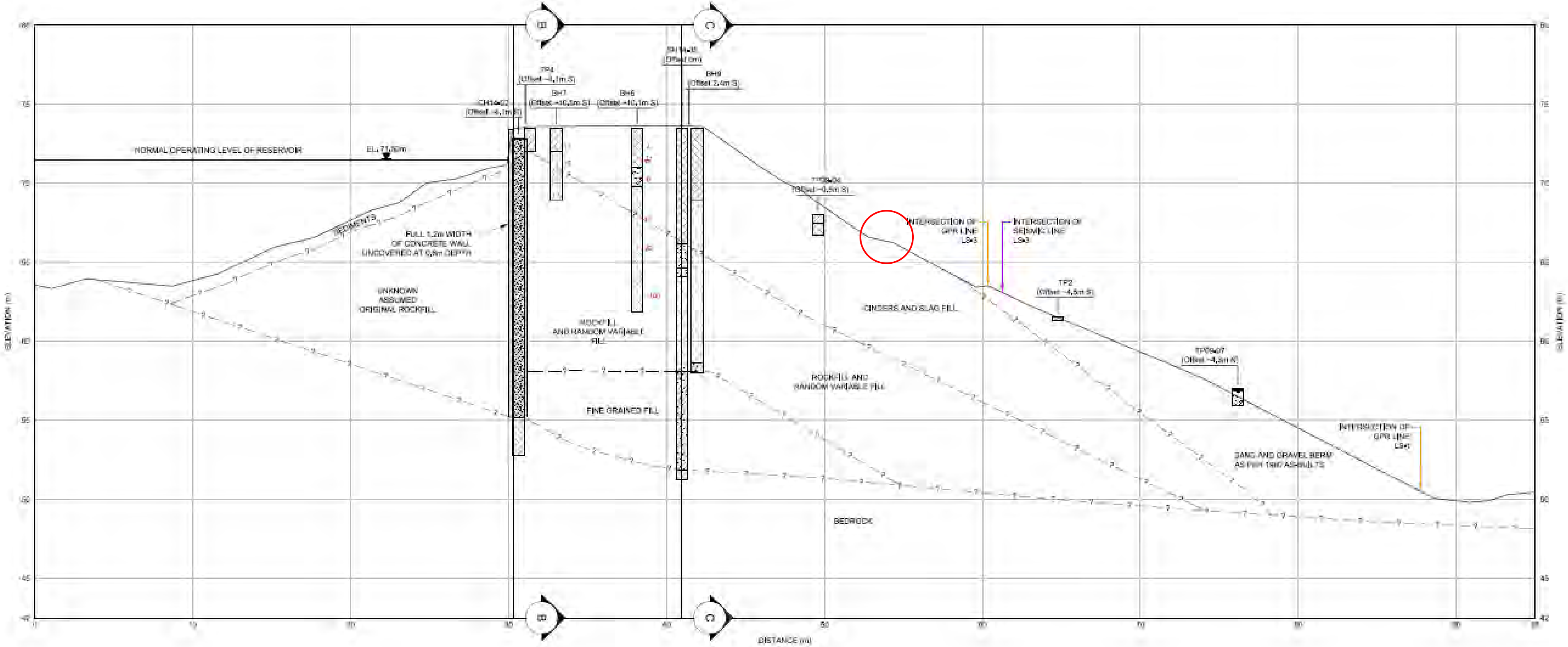
NOTE: The sonic drilling method tended to “pulverize boulder and cobble sized particles” while advancing through the Rockfill and fine grained fill strata.

SH14-06



Dam Fill Profile		
Description	Depth	
	m	
Black Cinders and Slag	0	3.66
Rockfill and Random Variable Fill	3.66	17.53
Bedrock	17.53	21.03

Section A-A’



LEGEND

———	EXISTING GROUND SURFACE
— —?—	INFERRED STRATIGRAPHY BOUNDARY

LITHOLOGY GRAPHIC LEGEND

CINDERS AND SLAG FILL

RANDOM VARIABLE FILL

ROCKFILL

CONCRETE

FINE GRAINED FILL

BEDROCK

PROFILE LEGEND

BH1
(Offset 0m N)

16

22

BOREHOLE RECORD SHOWING SOIL CONDITIONS

DENOTES OFFSET FROM SECTION LINE

DENOTES STANDARD PENETRATION TEST (N Value)

Environmental Assessment of Cinder Slag Fill

- **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)

Environmental Assessment of Cinder Slag Fill

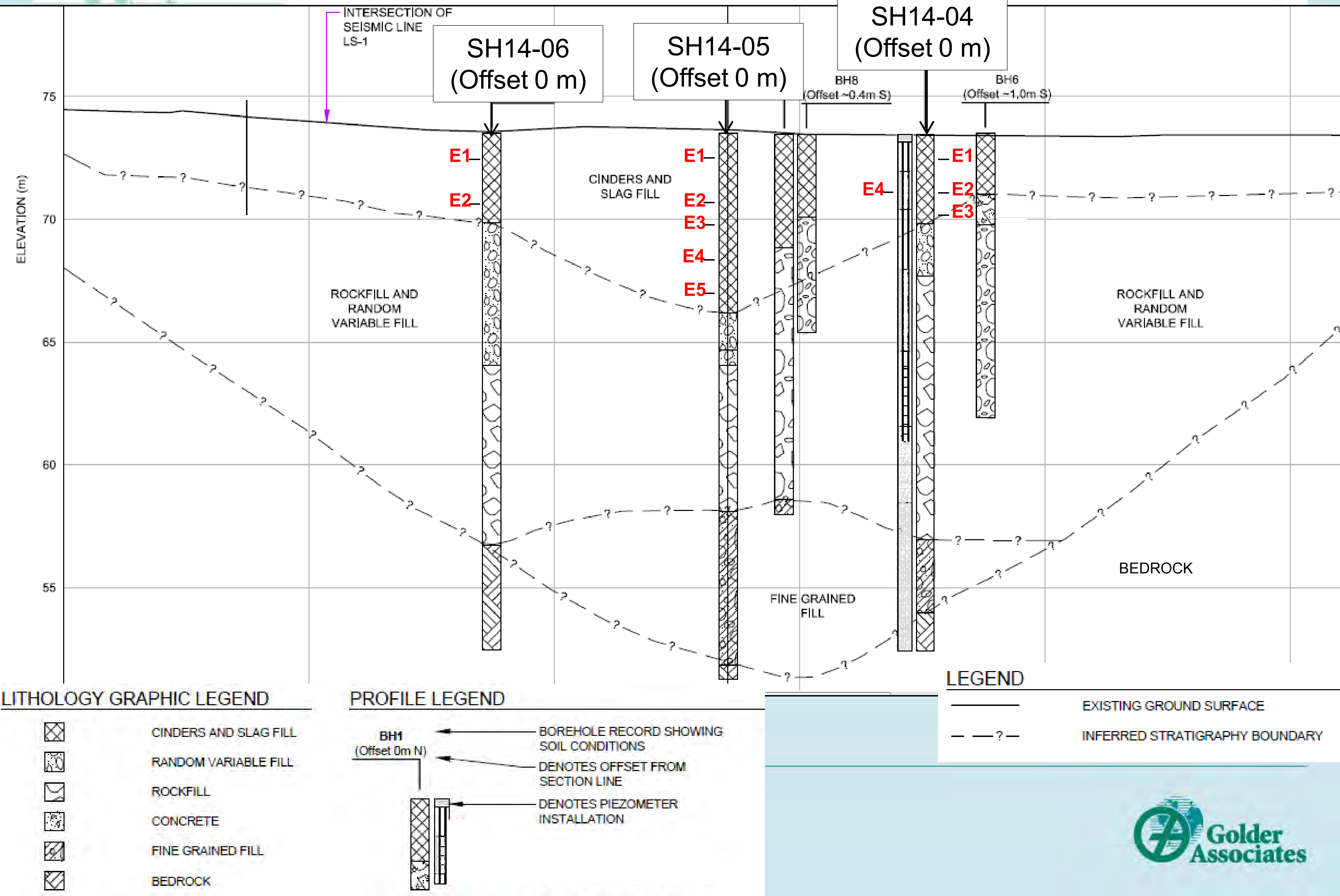
- **Testing**: Samples obtained during drilling of dam and from within the inferred coal slag material tested for:
  - metals concentrations
  - extractable petroleum hydrocarbon concentrations
  - polycyclic aromatic hydrocarbon concentrations
  - toxicity characteristic leaching procedure (TCLP)

- **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)



Environmental Assessment of Cinder Slag Fill Summary of Results

- Rush samples of slag fill tested from 1st drilled hole (SH14-05)

Sonic Hole Name	Sample	Start Depth (m)	End Depth (m)
SH14-05	E1	0.8	1.1
SH14-05	E3	3.7	4.0
SH14-05	E5	6.7	7.0

- 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

Environmental Assessment of Cinder Slag Fill Follow-Up

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?)

Environmental Assessment of Cinder Slag Fill Follow-Up

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.

Environmental Assessment of Cinder Slag Fill Summary of Results – Follow-Up Analyses

- 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:

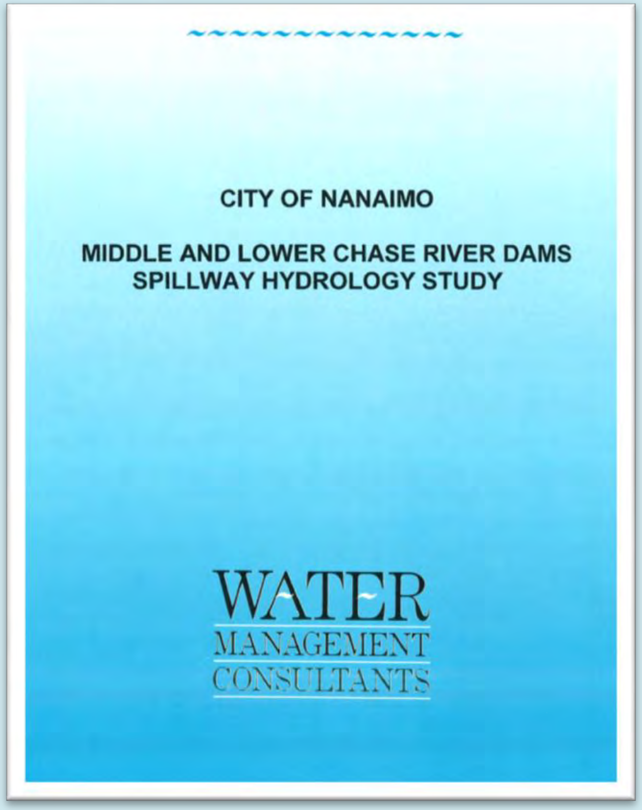
- Contaminated soil is present, and if it is found to be detrimentally affecting human health or the environment, then this would indicate the need for remedial action.
  - Is there a wider problem? Further characterization required to confirm or refute other possible contamination present and other 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

Middle and Lower Chase River Dams Updated Hydrology & Hydraulics

Update on Hydrology and Hydraulic Analyses
Reference data acquisition: Complete
Watershed & sub-watershed (4) delineations: Complete
Hydrologic soil group determinations: Complete
Landuse and Curve Number analysis (accounting for future alterations): Complete
Time of Concentration analysis: Complete
Wet-season baseflow analysis: Complete
24-hour annual frequency (2 through 50,000-year) rainfall analysis: Complete
Probable Maximum Precipitation (PMP) rainfall analysis: Complete
Stage-storage curve analysis (Parkway, Middle Dam, Lower Dam): Complete
Nanaimo Parkway culvert rating curve analysis: Complete
Hydrologic Engineering Center (HEC) – Hydrologic Modeling System (HMS) Model: Complete
1,000-year and PMP hydrographs developed and provided to AE: Complete

Middle and Lower Chase River Dams
Updated Hydrology & Hydraulics


CITY OF NANAIMO

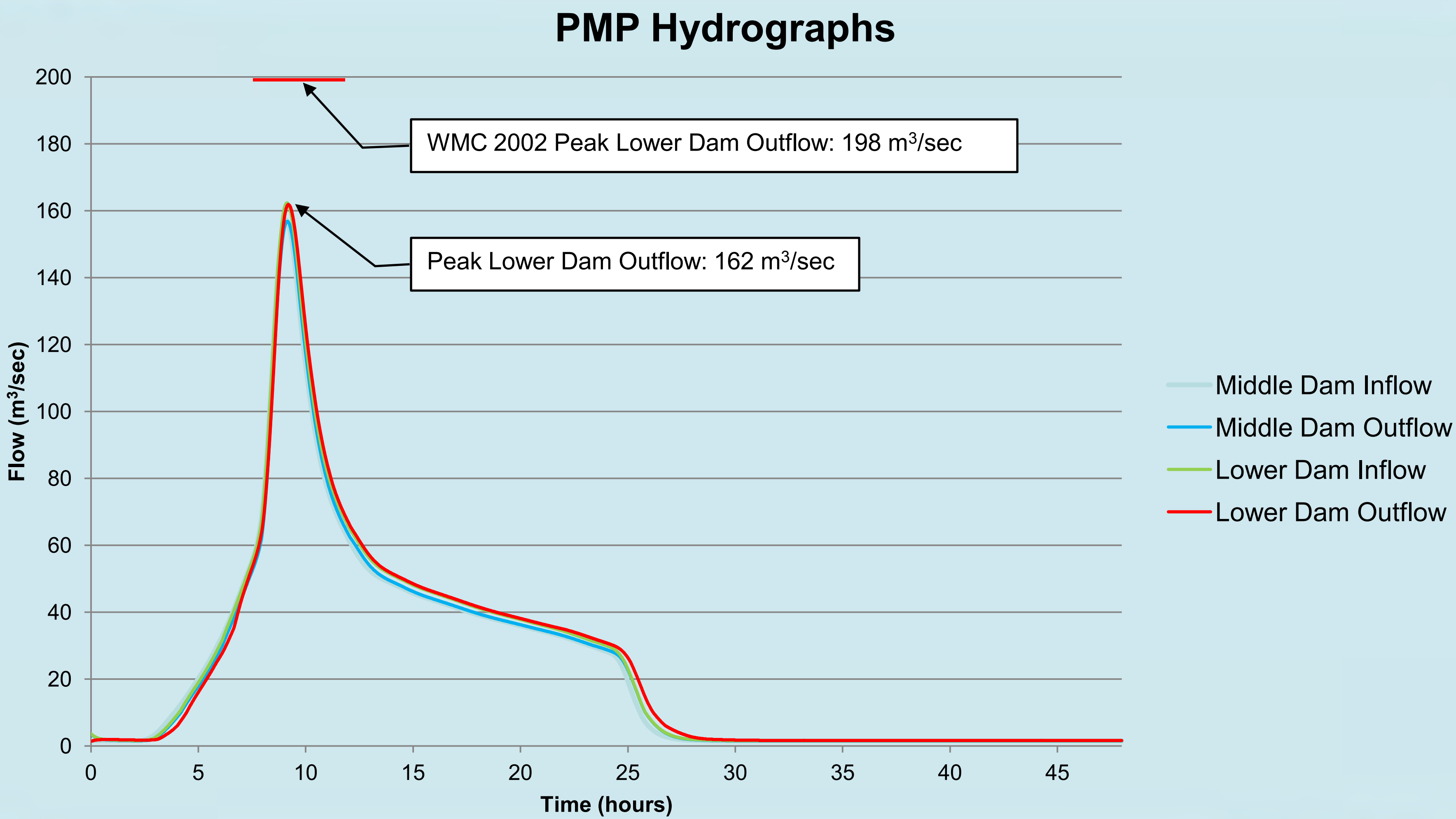
MIDDLE AND LOWER CHASE RIVER DAMS
SPILLWAY HYDROLOGY STUDY

WATER
MANAGEMENT
CONSULTANTS

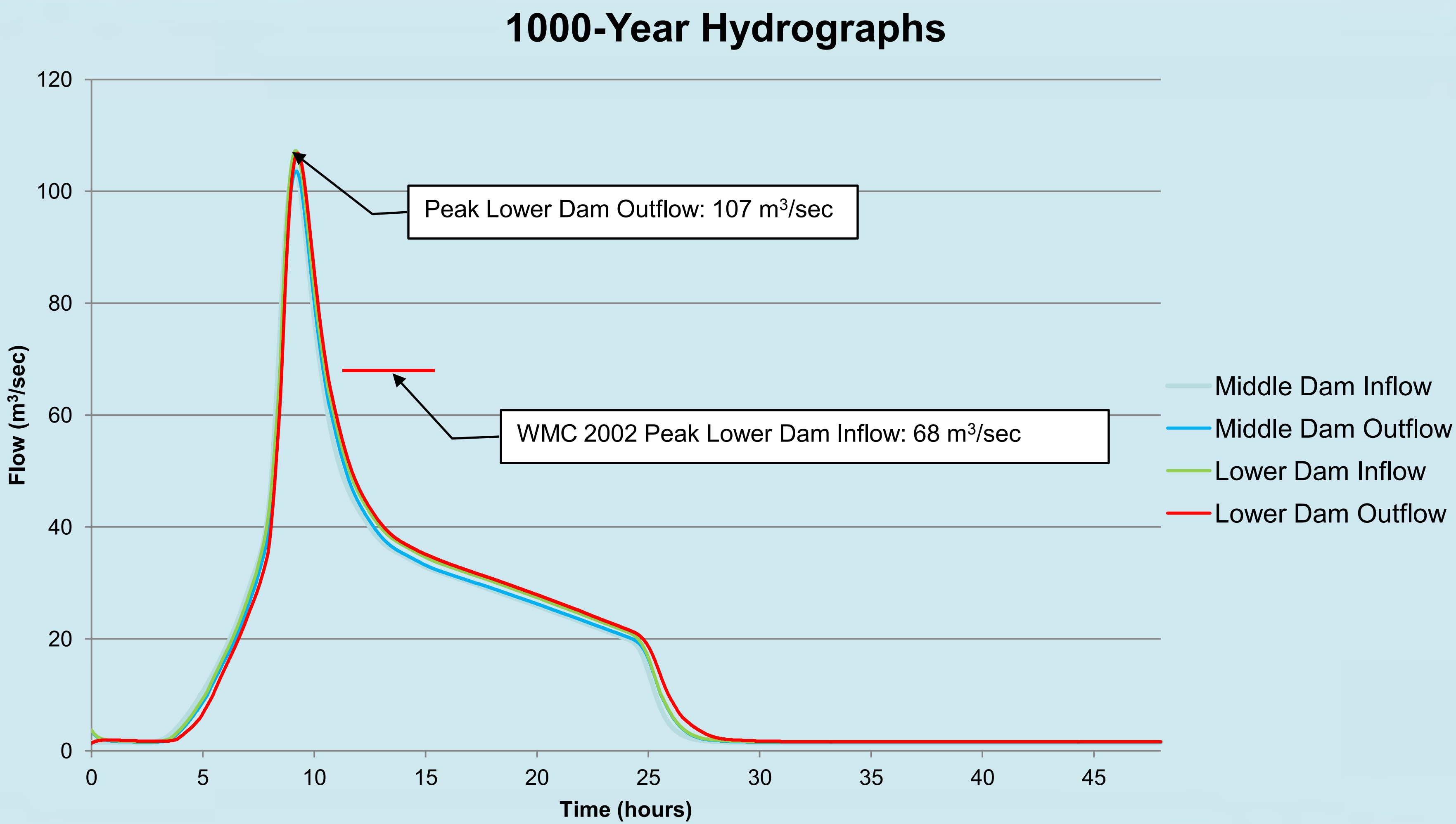
Revised Hydrology and Hydraulic study complete.
Summary and comparison to WMC's 2002 study below:

WMC 2002	Golder 2014
Watershed = 20 km^2	Watershed = 21 km^2
Hydrologic Soil Groups Accounted for: No	Hydrologic Soil Groups Accounted for: Yes
CN_{ARCIII} = 95	CN_{ARCIII} = 84 (composite)
Sub Watersheds: 2	Sub Watersheds: 4
Nanaimo Parkway modeled: No	Nanaimo Parkway modeled: Yes
Baseflow to Lower Dam: 7 m^3/sec	Baseflow to Lower Dam: 1.6 m^3/sec
PMF Peak Flow to Lower Dam: 198 m^3/sec	PMF Peak Flow to Lower Dam: 162m^3/sec
1,000-year Peak Flow to Lower Dam: 68 m^3/sec	1,000-year Peak Flow to Lower Dam: 107 m^3/sec

Middle and Lower Chase River Dams
Updated Hydrology & Hydraulics



Middle and Lower Chase River Dams
Updated Hydrology & Hydraulics



Structural Considerations and Seismic Response of Lower Dam

- 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

Structural Considerations and Seismic Response of Lower Dam

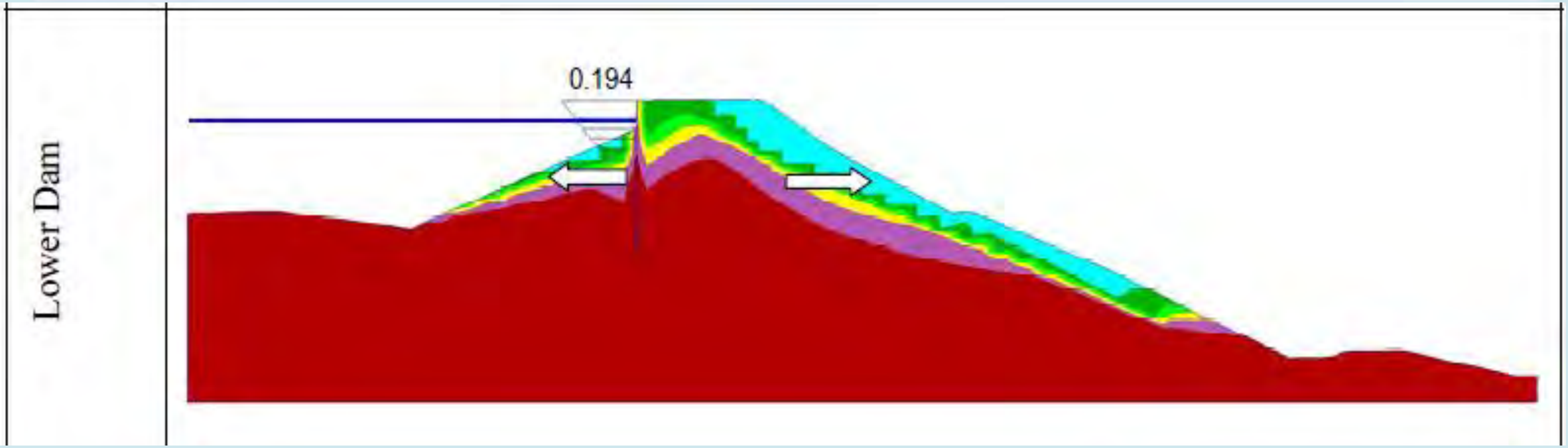
- Characterization of Concrete Core
  - Reinforcement
    - Two bars intersected (3/4” square twist) – appear to be lapped
      - Likely indication of reinforcement throughout entire wall – either on both u/s and d/s faces, or in middle of dam
      - 30” spacing (as indicated by surface GPR)
    -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

Reinforcement

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.

Structural Considerations and Seismic Response of Lower Dam

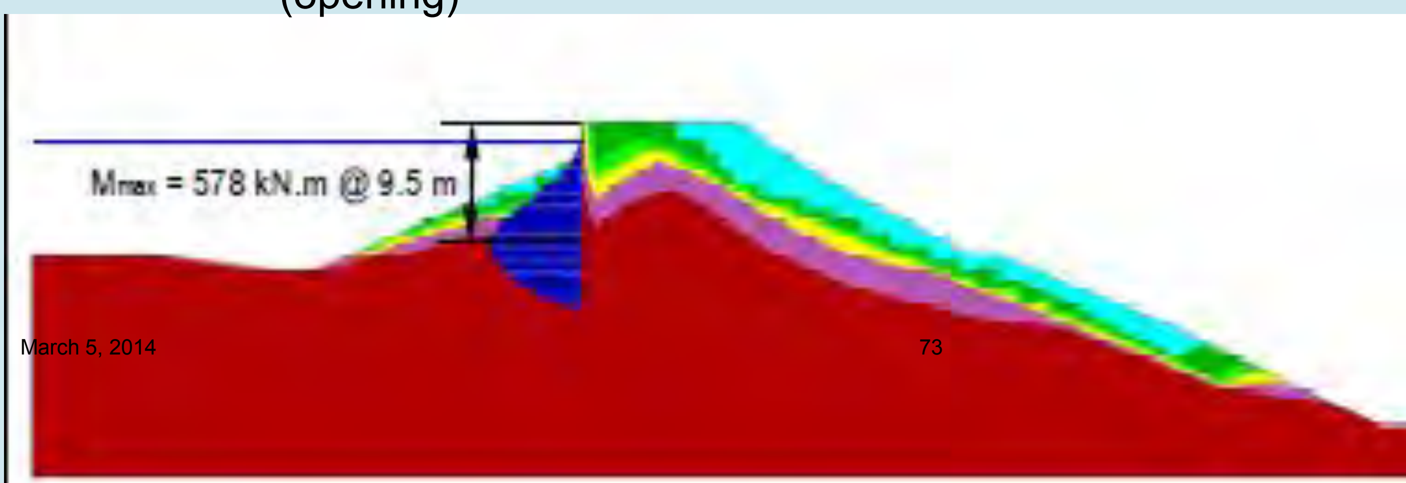


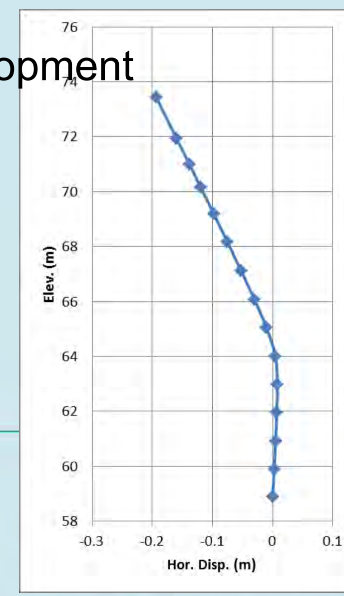
- Failure Modes – shown for 1:3000 year EQ
  1. Toppling
     - Low likelihood for Lower Dam – insufficient displacement
  2. Cascading Failure – overtopping and toppling
     - Remediation required to control – addressed later
  3. Post Seismic Internal Erosion
     - Further evaluation (next slide)

Structural Considerations and Seismic Response of Lower Dam

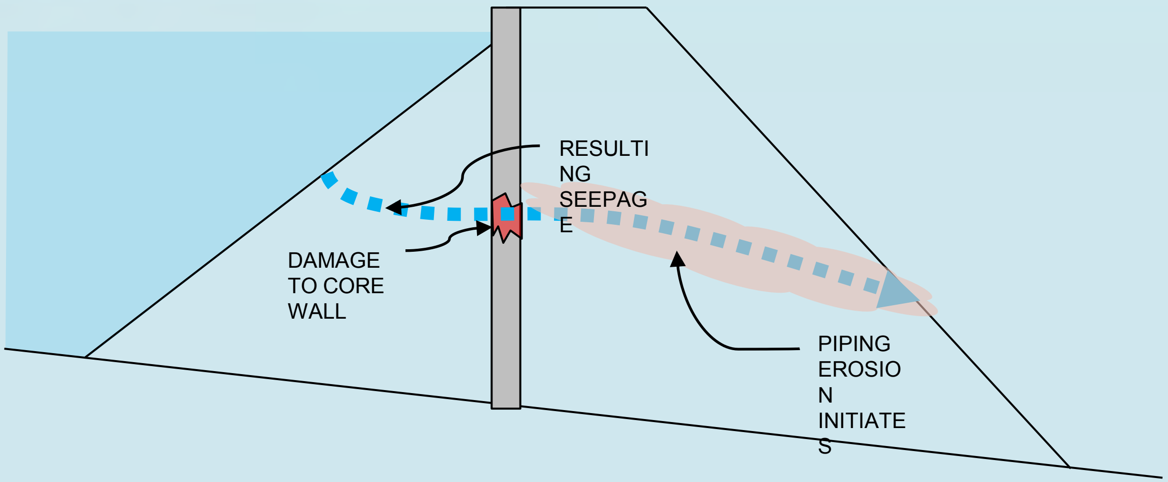
Lower Dam response to EQ (based on 2010 SVA (EBA))

- 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)



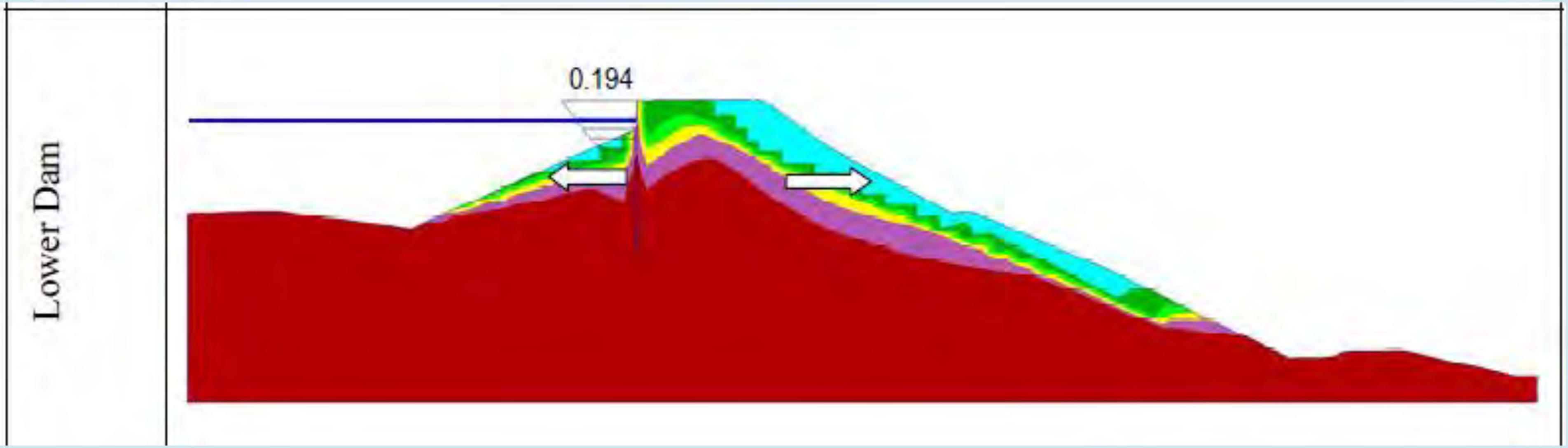


Structural Considerations and Seismic Response of Lower Dam



- 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.

Structural Considerations and Seismic Response of Lower Dam



- 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.

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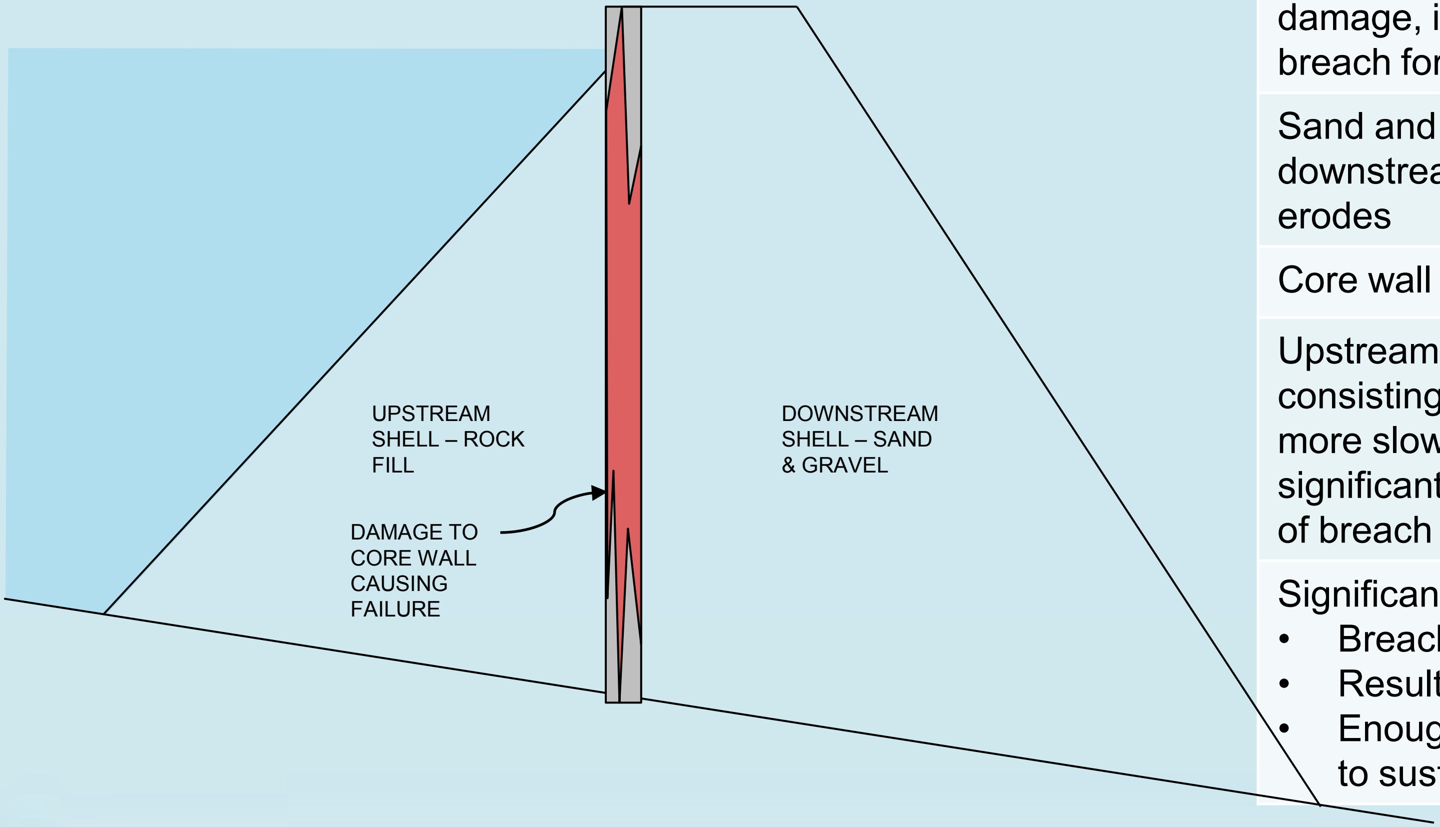
Failure Modes and Inundation Scenarios

- Evaluate Lower Dam release hydrographs (ie 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

Middle and Lower Chase River Dams
Failure Modes of Middle Dam

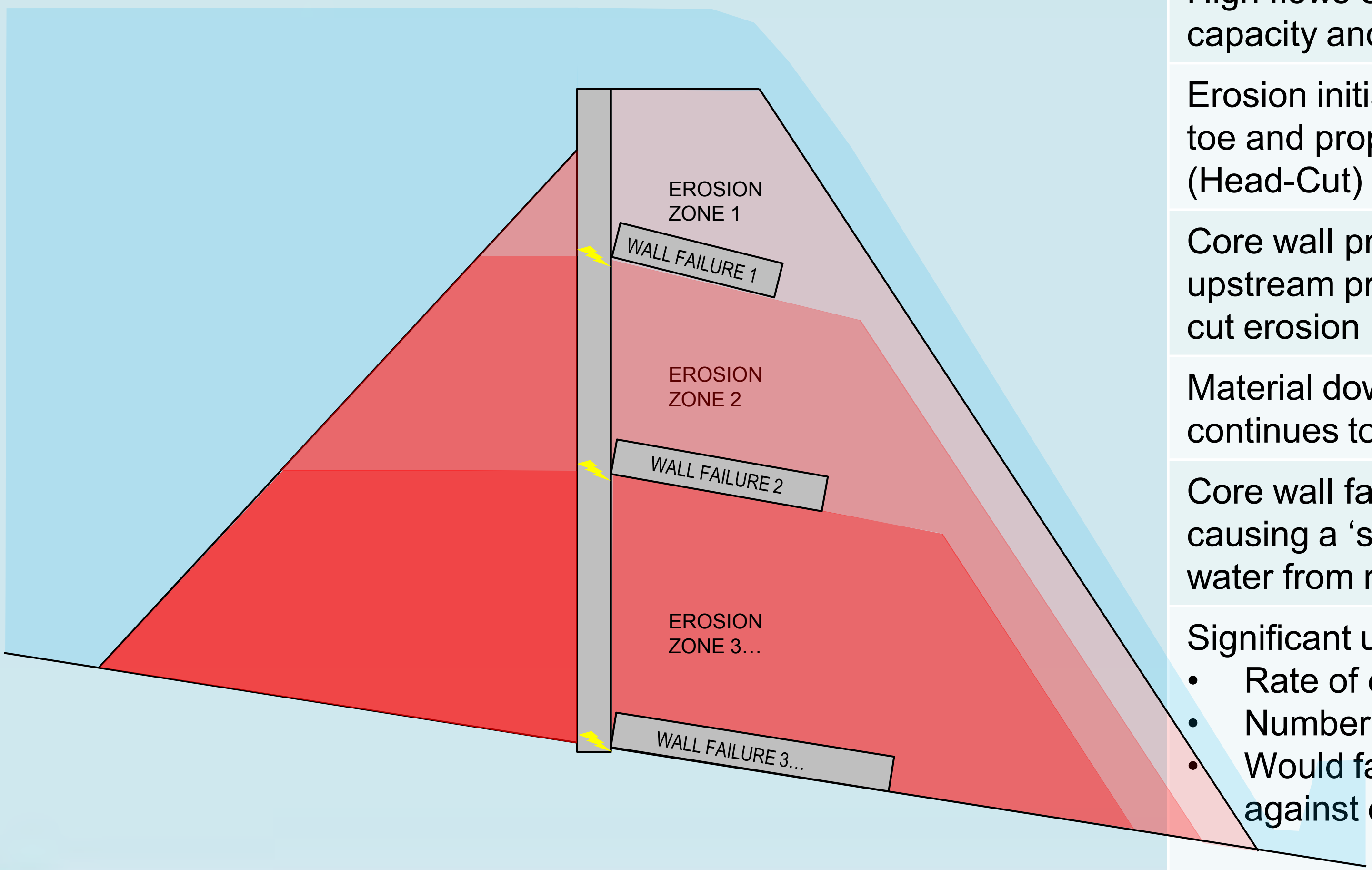
Seismic 'Sunny-Day' Breach



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?

Middle and Lower Chase River Dams
Failure Modes and Inundation Scenarios

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?

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Middle and Lower Chase River Dams
Failure Modes and Inundation Scenarios

Characteristics Affecting Breach Development

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

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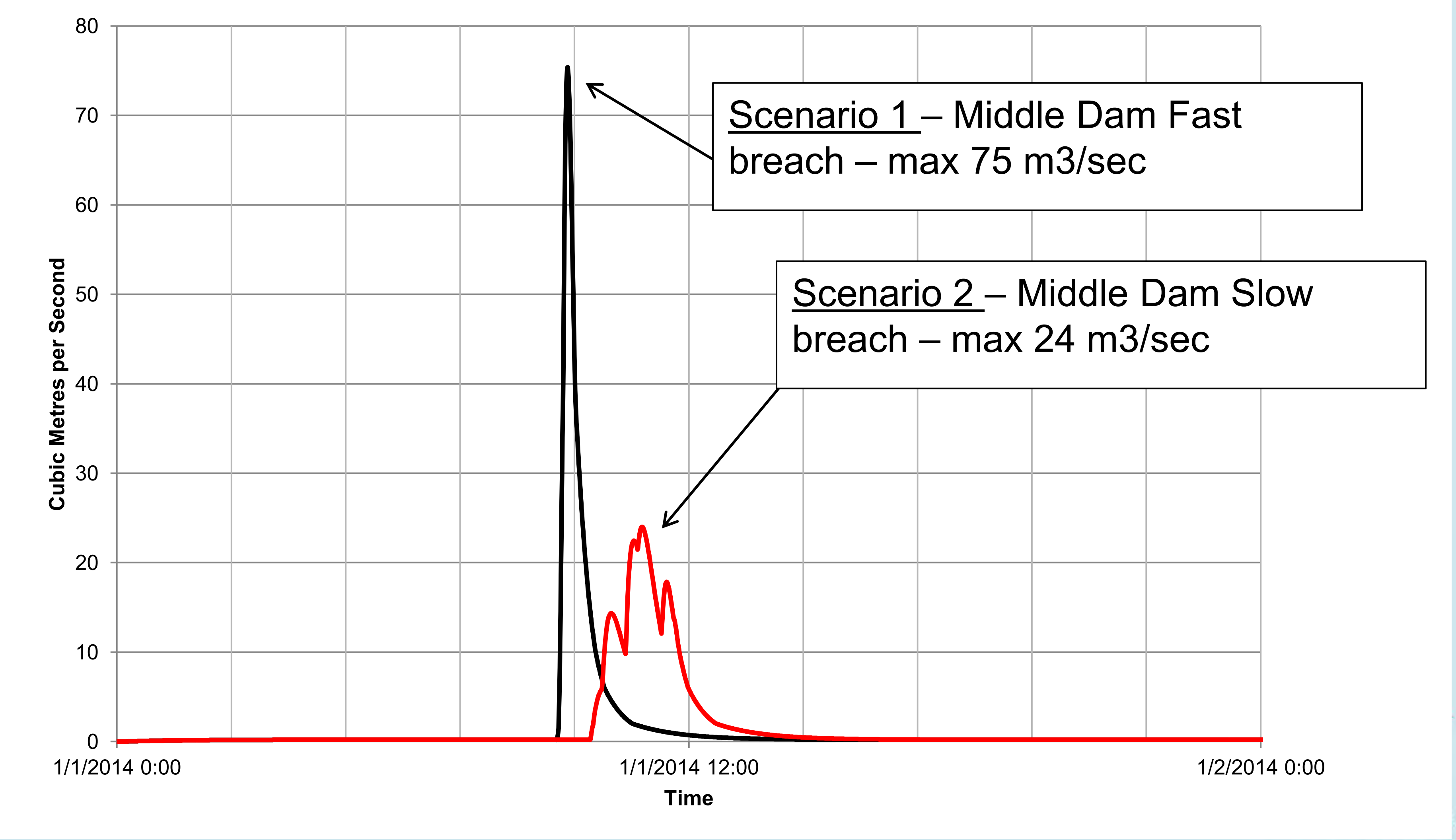
Middle and Lower Chase River Dams
Failure Modes of Middle Dam

Summary of Predicted Breach Parameters	
Breach Formation Time[1]:	Two times were chosen to bound the likely range Fast: 10 minutes Slow: 150 minutes
Breach Initiation Timing:	Breach initiated at peak of storm hydrograph
Breach Formation Development:	Stepped formation development in consideration of the failure mechanics of the core wall (the same as in the prior studies by AE)
Breach Depth:	11.3 meters (full height of dam to the bottom of the reservoir)
Breach Bottom Width:	12 meters (approximate height of dam and also approximate valley bottom width)
Breach Side Slopes:	1:1
Breach Top Width:	34.6 meters

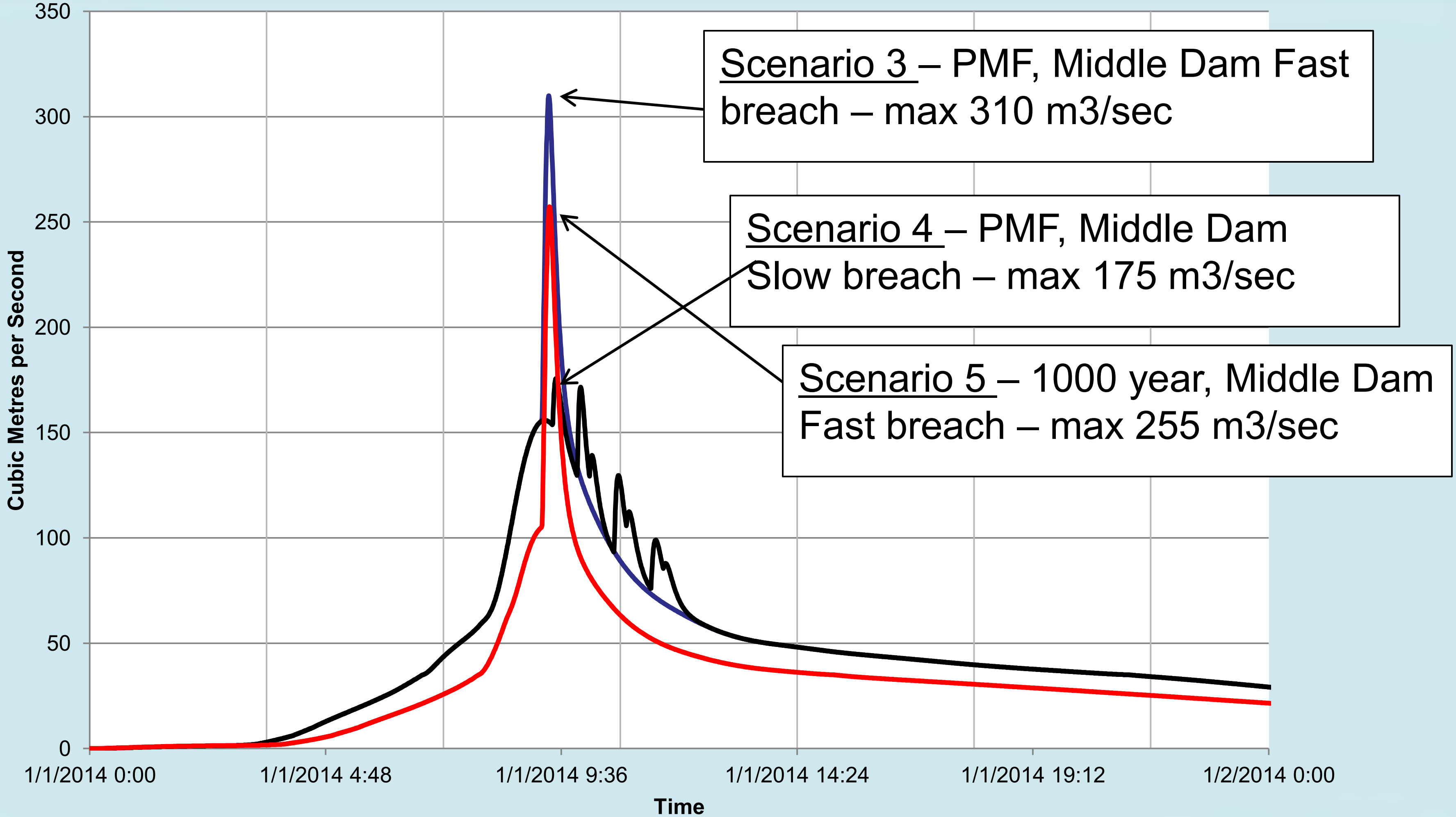
[1]These parameters were developed from a review of available literature and case studies of historic dam failures with similar characteristics (case studies indicate Breach Formation Times ranging from 15 minutes to 8+ hours with the majority being in the 30 minutes to 2 hour range)

- *Prediction of Embankment Dam Breach Parameters – A literature Review and Needs Assessment*, DSO-98-004, Dam Safety Research Report, Tony L. Wahl, U.S. Department of the Interior, Bureau of Reclamation, Water Resources Laboratory, July 1998
- *Uncertainty of Predictions of Embankment Dam Breach Parameters*, Journal of Hydraulic Engineering, Tony L. Wahl, U.S. Department of the Interior, Bureau of Reclamation, Water Resources Laboratory, May 2004

Failure Modes and Inundation Scenarios – Sunny Day (EQ)

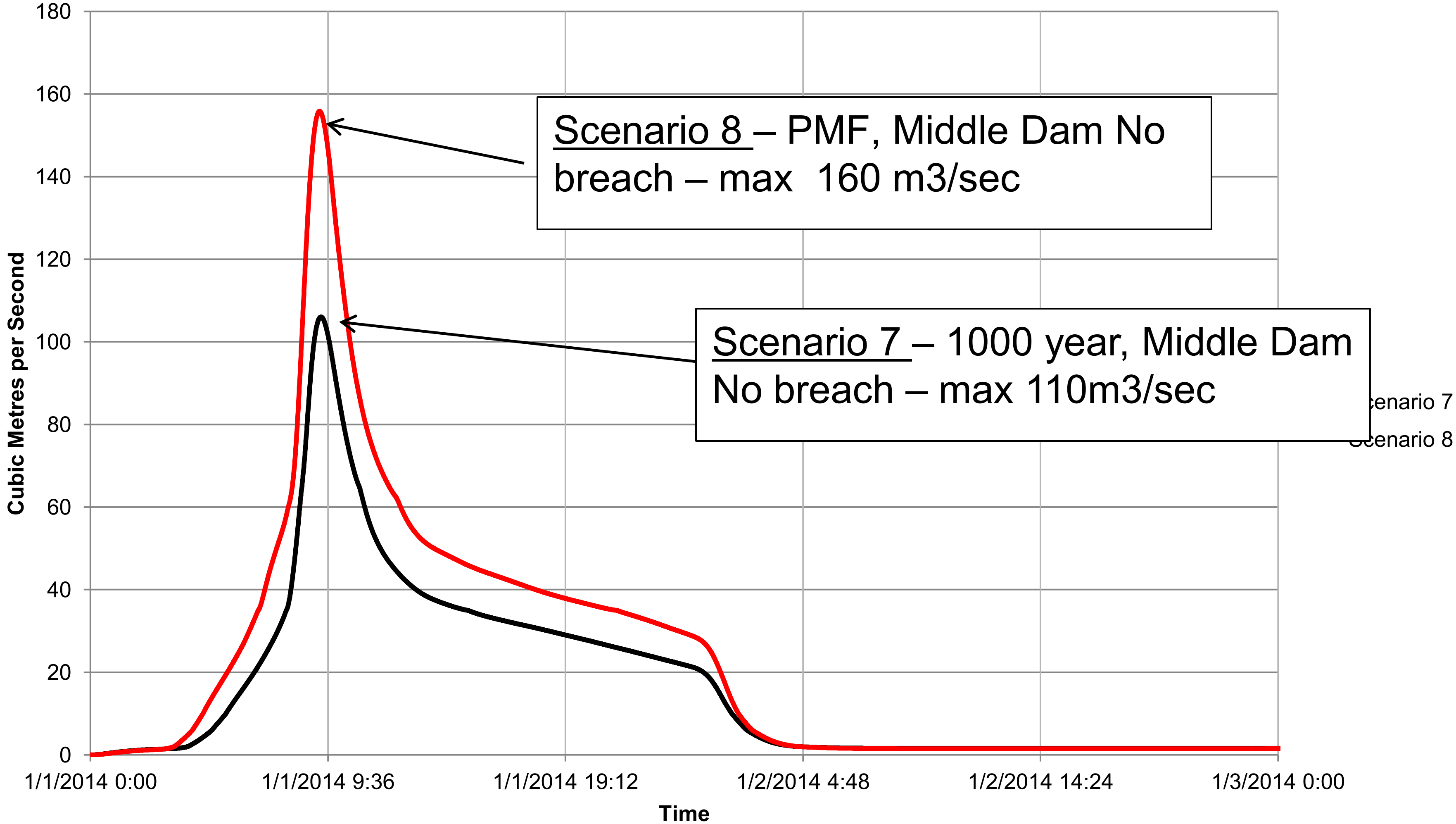


Failure Modes and Inundation Scenarios – Storm Events



Conservatively assumes breach initiates at peak of flood hydrograph

Failure Modes and Inundation Scenarios – No Middle Dam Breach



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Failure Modes and Inundation Scenarios –

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