2013Google, Imagery Mar 29, 2009

May 12, 2014

Middle and Lower Chase River Dams Progress Update

DSS Findings

Based on Golder Associate's recent field investigation on Lower Chase River Dam and their subsequent engineering studies and risk analysis on both Middle and Lower Chase River Dams, our office expects it is appropriate to lower the failure consequence classification of the Middle Chase River Dam from extreme to ***high*** and the classification of the Lower Chase River Dam from extreme to ***very high***.

Please note that we cannot make final decisions based on oral and PowerPoint presentations. The expected changes to the failure consequence classification of these two dams are subject to a review of the consultant's final report documenting their studies and analyses. However, assuming that the oral and PowerPoint presentations are an accurate reflection of the final report we would consider it reasonable for you to begin planning based on the expected changes. The sooner we receive the consultant's report, the sooner a final decision can be made regarding consequence classification.

The CDA Guidelines (Table 6-1A) give initial target frequency levels for flood and earthquake hazards for dams where a risk informed approach is being used. As stated in the Guidelines, these target levels are designed to form the basis for consideration and discussion between the Owner and Regulator. It may be appropriate to adjust some of these target levels up or down based on the principle of decreasing the risk to "As Low as Reasonably Practicable" (ALARP). This approach allows the Owner to take into consideration all of the uncertainties in their analyses and propose which hazard frequency levels they feel are appropriate for design. Therefore, the next steps from our perspective are for you to complete your analyses, conceptual design work and preliminary pricing, and then provide us with proposed design hazard frequency levels. At that point we can have a discussion and agree upon what will be acceptable design levels.

DSS Findings

Table 6-1A: Flood and Earthquake Hazards, Risk-Informed Approach

(Target Levels for Initial Consideration and Consultation between Owner and Regulator)

2013 Revision

Dam Class [note 1]	Minimum Annual Exceedance Probability (AEP) of the Natural Hazard [note 2]	Societal Risk Target
Low	1/100	
Significant	1/1000	
High	1/2475	$(1/N)x10^{-3}$ [note 3]
Very High	1/10,000	$(1/N)x10^{-3}$ [note 3]
Extreme		$(1/N)x10^{-3}$ [note 3]

This table addresses two major natural hazards only, and does not consider the many other types of hazards that must be considered in dam safety assessments

Acronyms: AEP, annual exceedance probability; N, number of fatalities

Note 1. As defined in Dam Classification (Section 2.5.4).

Note 2. AEP levels for floods and earthquakes are the mean estimates of the hazard.

Note 3. Simple extrapolation of flood statistics beyond 10^{-3} AEP is not acceptable. The given AEP values should be based on detailed probabilistic assessments and definition of uncertainty bounds. Results should be compared against Probable Maximum Flood and Maximum Credible Earthquake values and their associated uncertainty (where available).

Golder Associates

DSS Findings

2013 Revision

Table 6-1B: Flood and Earthquake Hazards, Standards-Based Assessments

(Target Levels for Initial Consideration and Consultation between Owner and Regulator)

Dam Class [note 1]	Annual Exceedance Probability – Floods [note 2]	Annual Exceedance Probability - Earthquakes [note 3]
Low	1/100	1/100
Significant	Between 1/100 and 1/1000 [note 4]	Between 1/100 and 1/1000
High	1/3 between 1/1000 and PMF [note 5]	1/2475 [note 6]
Very High	2/3 between 1/1000 and PMF [note 5]	1/2 between 1/2475 [note 6] and 1/10,000 or MCE [note 5]
Extreme	PMF [note 5]	1/10,000 or MCE [note 5]

This table addresses two major natural hazards only, and does not consider the many other types of hazard that must be considered in dam safety assessments.

Acronyms: PMF, probable maximum flood; AEP, annual exceedance probability; MCE, maximum credible earthquake

Note 1. As defined in Table 2-1, Dam Classification (Section 2.5.4)

Note 2. Simple extrapolation of flood statistics beyond 10^{-3} AEP is not acceptable.

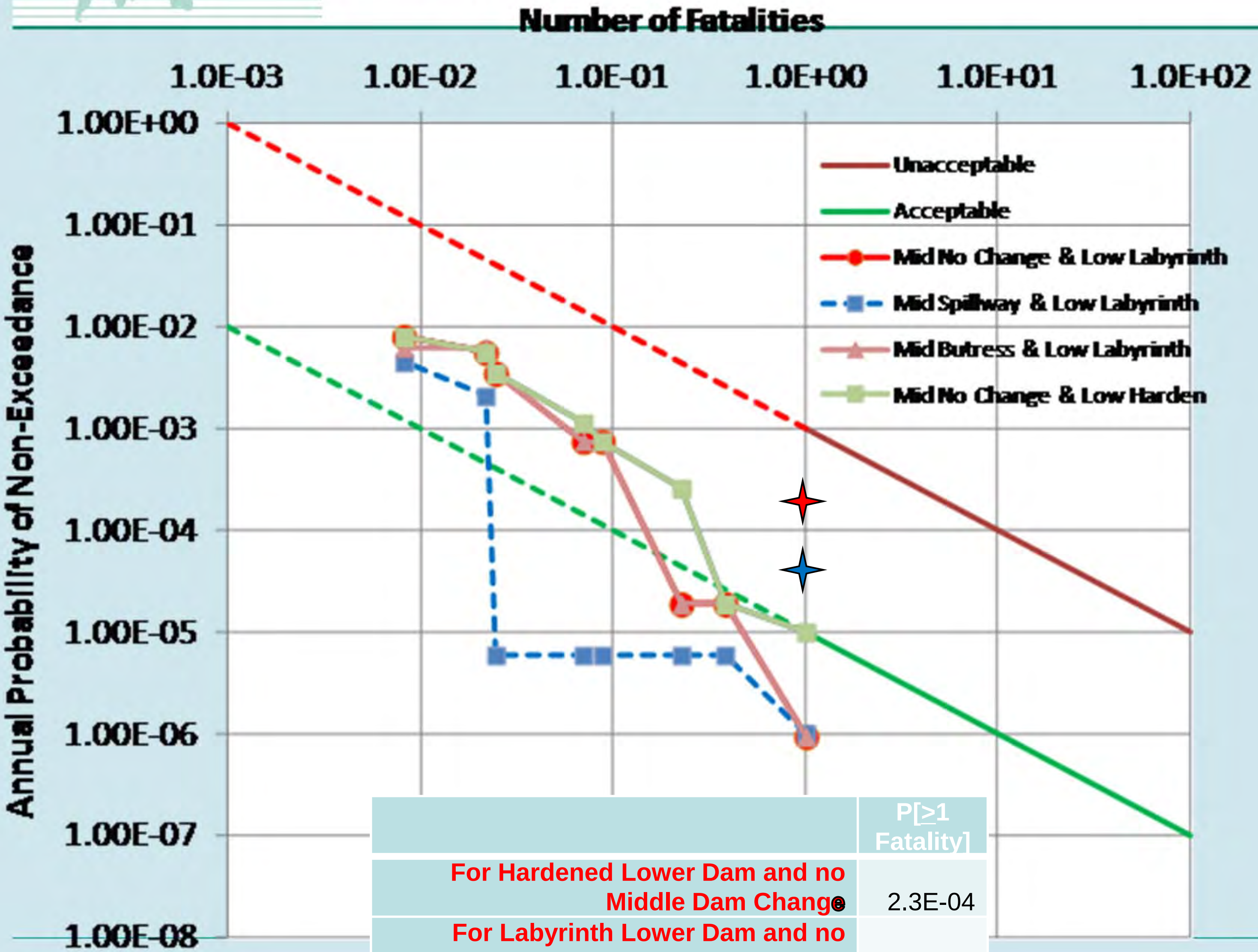
Note 3. Mean values of the estimated range in AEP levels for earthquakes should be used. The earthquake(s) with the AEP as defined in Table 6-1B is then input as the contributory earthquake(s) to develop the Earthquake Design Ground Motion (EDGM) parameters as described in Section 6.5 of these guidelines.

Note 4. Selected on basis of incremental flood analysis, exposure, and consequences of failure

Note 5. PMF and MCE have no associated AEP.

Note 6. This level has been selected for consistency with seismic design levels given in the National Building Code of Canada.

DSS Findings



	P[≥1 Fatality]
For Hardened Lower Dam and no Middle Dam Change	2.3E-04
For Labyrinth Lower Dam and no Middle Dam Change	1.8E-04
For Labyrinth Lower Dam and Middle Dam spillway	5.9E-05
For Labyrinth Lower Dam and Middle Dam buttress	1.6E-04

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Seismic Analysis

- Carried out earthquake (dynamic) analysis of Lower Dam, using FLAC software (industry practice, DSR, etc)
- Analyzed for MCE and 2475 return period earthquakes
- Based on data from current site investigations
- Supported by analysis from seismic-structural specialist – concrete core is important to the performance of the dam.
- Dealt with uncertainties, through the use of “sensitivity analyses” – eg wall embedment, wall plasticity, shaking direction, wall stiffness, etc

Summary of SSI Dynamic Analyses of Colliery Lower Dam				
Shaking Level	Wall Embedment	Wall_E	Wall_Mp	Wall x-Displ. (mm)
MCE	Bedrock	Emax	---	473
MCE	Bedrock	Emin	---	489
MCE	Rockfill	Emin	---	1104
MCE	Bedrock	Emin	600 kN.m	1826
MCE	Rockfill	Emin	600 kN.m	1785
2475-yr	Bedrock	Emin	---	309
2475-yr	Rockfill	Emin	---	442
2475-yr	Bedrock	Emin	600 kN.m	821
2475-yr	Rockfill	Emin	600 kN.m	820

Seismic Analysis

- Large deformations – particularly of downstream shell
- Walls is badly damaged by MCE or 2475 EQ
  - Severe cracking – near foundation and above foundation level
  - Less cracking higher in the dam
  - “Extremely low” likelihood of toppling of top of concrete core

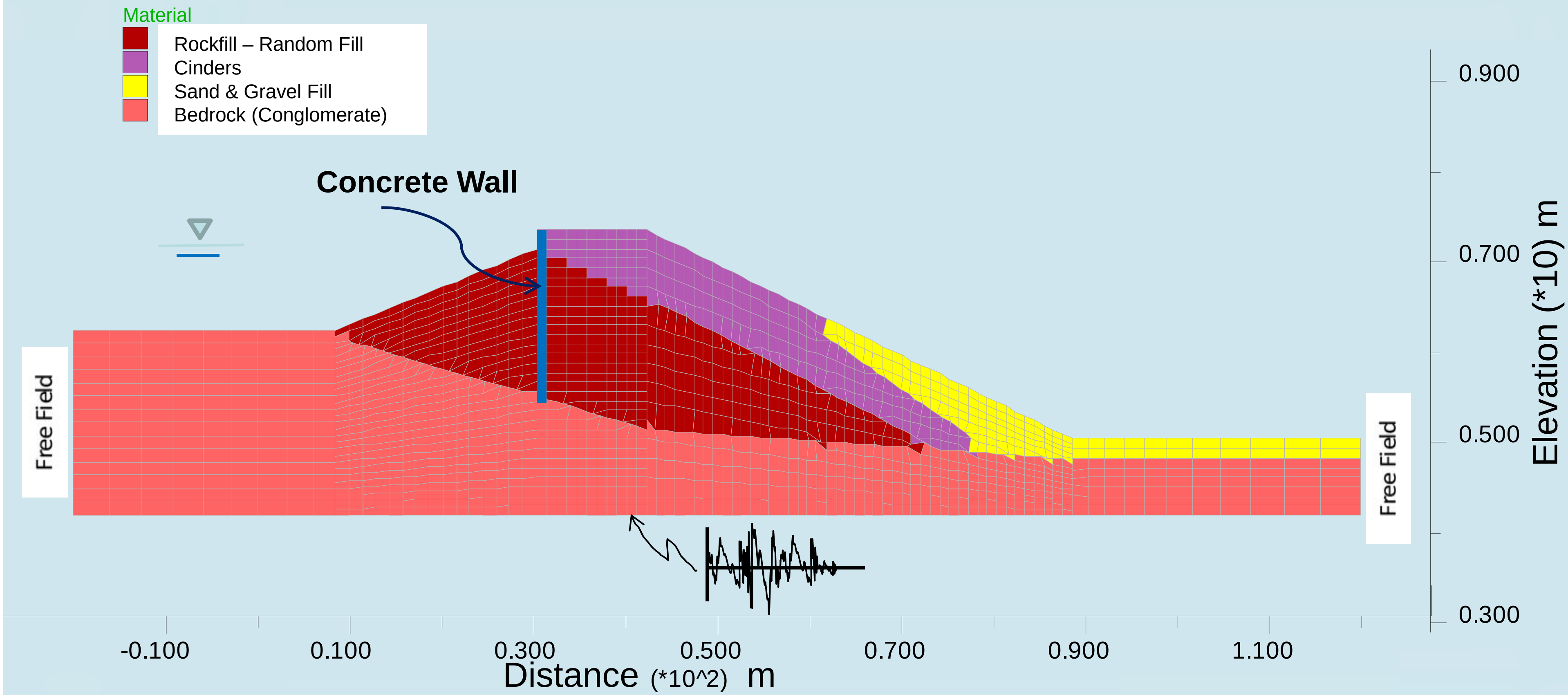
Middle Dam

- Extended preliminary structural assessment to Middle Dam
  - Using results form 2010 (EBA) modelling, and based on characteristics of concrete from 2014 investigation,
  - “Extremely low” likelihood of toppling of top of concrete core

Seismic Analysis

- Seismic Response - Middle Dam and Lower Dam
- Extremely low likelihood of toppling (which would lead to overtopping) – which was the previously understood mode of failure
- We now know that the dams will more likely fail by internal cracking – and will hence become “leaky”
- A very different mode of failure – which is much less likely to lead to a rapid breach of the dam, which is the mode of failure considered to this point.
- We are currently evaluating the post seismic condition using SEEP/W software.
- These results are likely to change the seismic risk related to the dams.
- It is important to note that the above focuses on the safety (ie ability to prevent flooding and prevent loss of life) of the dams, rather than ability to remain functional after an EQ. May need to be repaired, or removed, after a major EQ.

FD Model of the Dam – Foundation System



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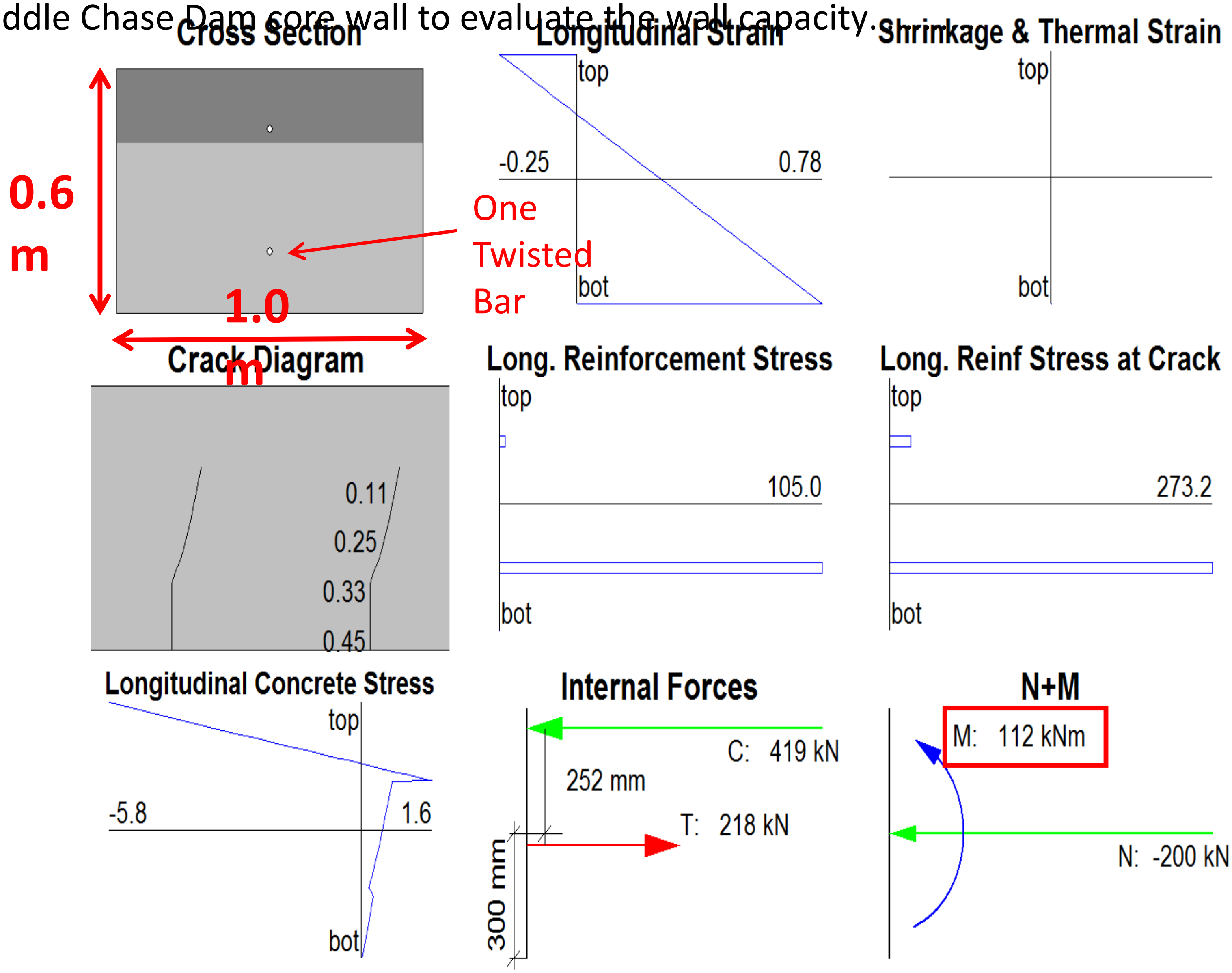
Dynamic Analysis of Dam – Foundation System

- A two-dimensional plane strain model of the dam-foundation system using FLAC F.D. computer code was analyze.
- The dam body was represented with Mohr-Coulomb Constitutive model.
- Conglomerate bedrock was treated as Elastic material.
- The concrete wall was modeled using structural elements (elastic W/WOT plastic yield).
- Earthquake motion was applied at the base of the model in terms of time history of shear forces for a compliant boundary condition.
- Free Field boundary conditions were applied at the sides of the model.
- Material properties were estimated based on limited available data from Golder 1978 and Golder 2014 investigations.

Middle Chase Dam Sectional Analysis

Based on the site investigation at Lower Chase Dam we know that there are twisted rebar placed horizontally and vertically within the core walls of the dam…………As such, we assumed a minimum one bar within a meter length of the Middle Chase Dam core wall to evaluate the wall capacity.



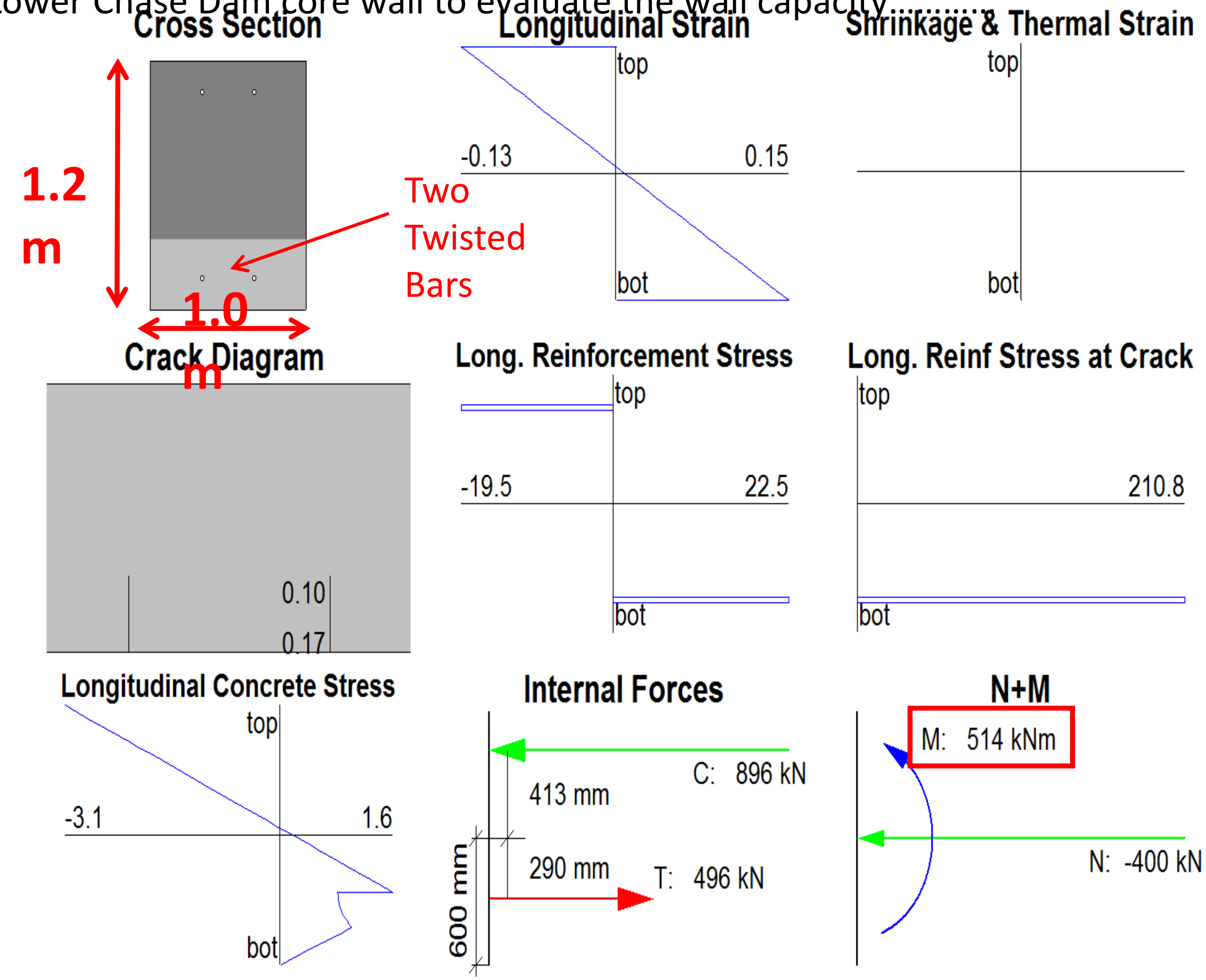
Based on our sectional analysis of the Middle Chase Dam core wall, the wall has just started to yield at a moment demand of 112 kN.m assuming one single twisted bar within a meter length………..

The crack width are quite small for the demand above; however, it is noted that, as demand increases, so, does the crack width, but the possibility of the wall toppling over is extremely low.

Further site investigation could provide more information in regard to the extent and spacing of the bars within the wall.

Lower Chase Dam Sectional Analysis

Based on the site investigation at Lower Chase Dam we know that there are twisted rebar placed horizontally and vertically within the core walls of the dam at least @ 30” on centre ………..As such, we assumed a minimum two bars within a meter length of the Lower Chase Dam core wall to evaluate the wall capacity……….

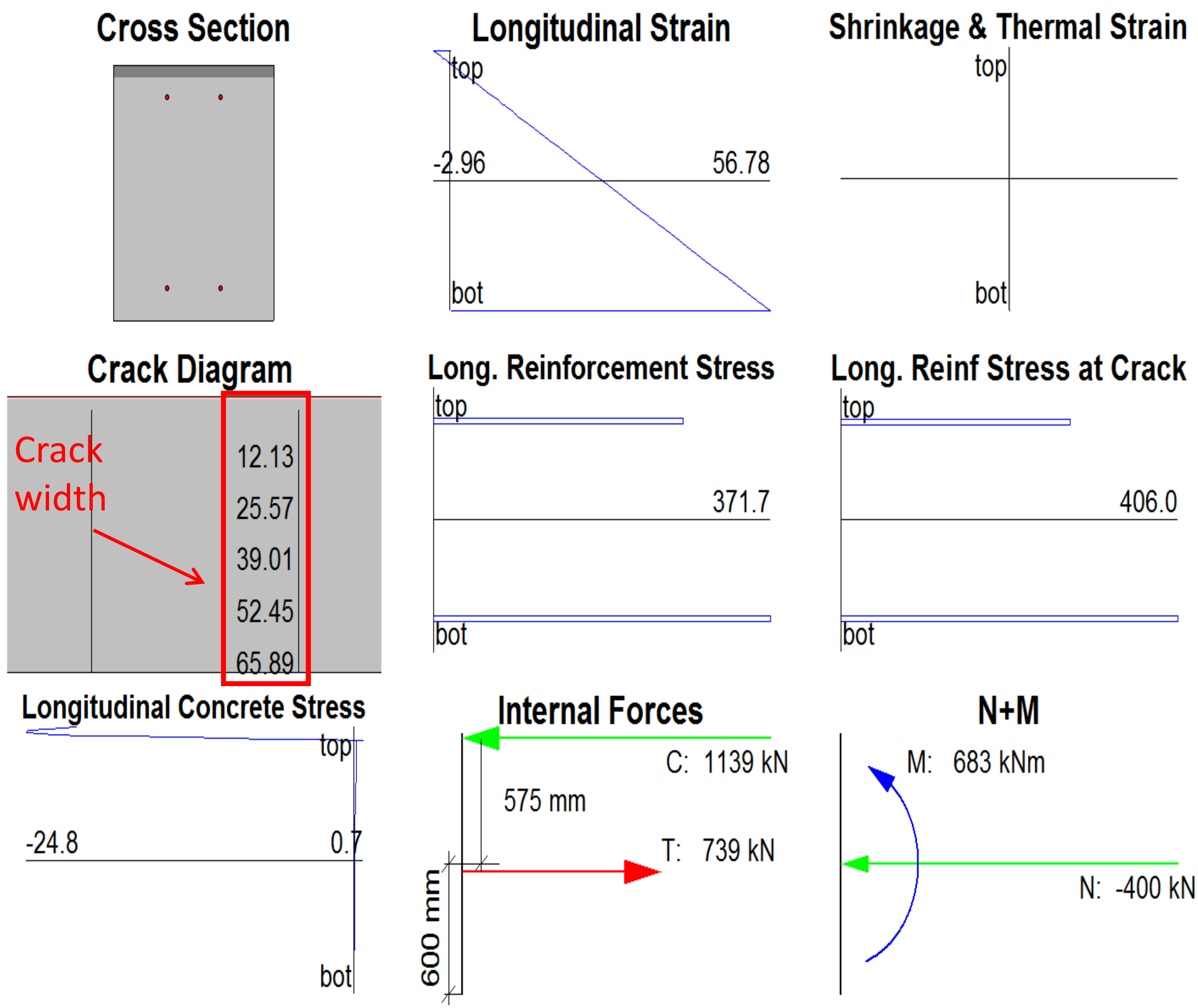


Based on our sectional analysis of the Lower Chase Dam core wall, the wall has just started to yield at a moment demand of 520 kN.m assuming two twisted bars within a meter length………..

The crack width are quite small for the demand above; however, it is noted that, as demand increases, so, does the crack width, but the possibility of the Lower Chase Dam core wall toppling over is extremely low.

Lower Chase Dam Sectional Analysis

Crack width as high as 65mm is computed, as the demand on the wall increases



JOB TITLE : Seismic Evaluatin of Colliery Dams-Lower Chase Dam, Nanaimo, Vancouver Island-B

FLAC (Version 6.00)

LEGEND

9-May-14 16:00
step 1619376
Dynamic Time 2.5000E+01
-2.792E+01 <x< 1.277E+02
-1.717E+01 <y< 1.384E+02

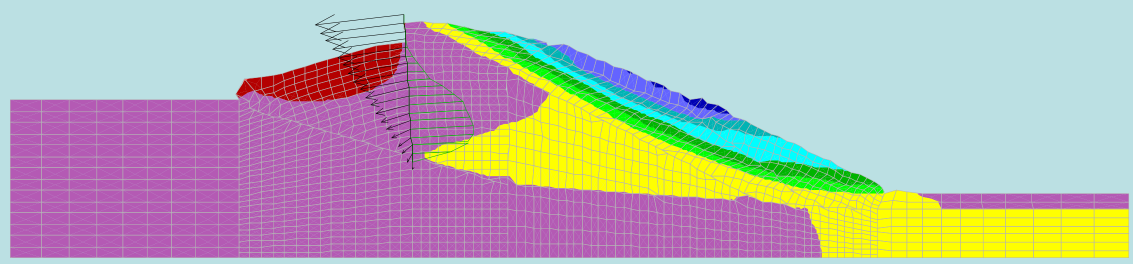
X-displacement contours
-2.00E+00
-1.00E+00
0.00E+00
1.00E+00
2.00E+00
3.00E+00
4.00E+00
5.00E+00
6.00E+00

Contour interval= 1.00E+00
Grid plot

0 2E 1

Moment on
Structure Max. Value
Wall:
Mmax = -1.656e3 kN-m
Sdis =1.112 m

Case 1: Concrete wall WoT plastic moment, subjected to MCE



Contours of lateral displacements and induced moments and displacements in the wall (end of shaking)

JOB TITLE : Seismic Evaluatin of Colliery Dams-Lower Chase Dam, Nanaimo, Vancouver Island-B

FLAC (Version 6.00)

LEGEND

9-May-14 15:35
step 1665090
Dynamic Time 2.5000E+01
-2.821E+01 <x< 1.275E+02
-1.713E+01 <y< 1.386E+02

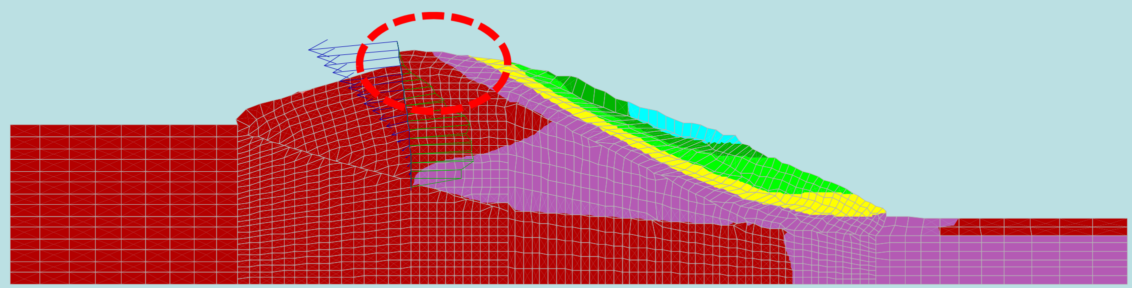
X-displacement contours
-2.00E+00
0.00E+00
2.00E+00
4.00E+00
6.00E+00
8.00E+00

Contour interval= 2.00E+00
Grid plot

0 2E 1

Moment on
Structure Max. Value
1 (Beam) -5.960E+02
Structural Displacement
Max Value = 1.785E+00

Case 2: Concrete wall with plastic moment, subjected to MCE



Contours of lateral displacements and induced moments and displacements in the wall (end of shaking)

(*10^2)
1.200
1.000
0.800
0.600
0.400
0.200
0.000

-0.100 0.100 0.300 0.500 0.700 0.900 1.100
(*10^2)

JOB TITLE : Seismic Evaluatin of Colliery Dams-Lower Chase Dam, Nanaimo, Vancouver Island-B

FLAC (Version 6.00)

Case 2: Distorted mesh at dam crest compared to original conditions

LEGEND

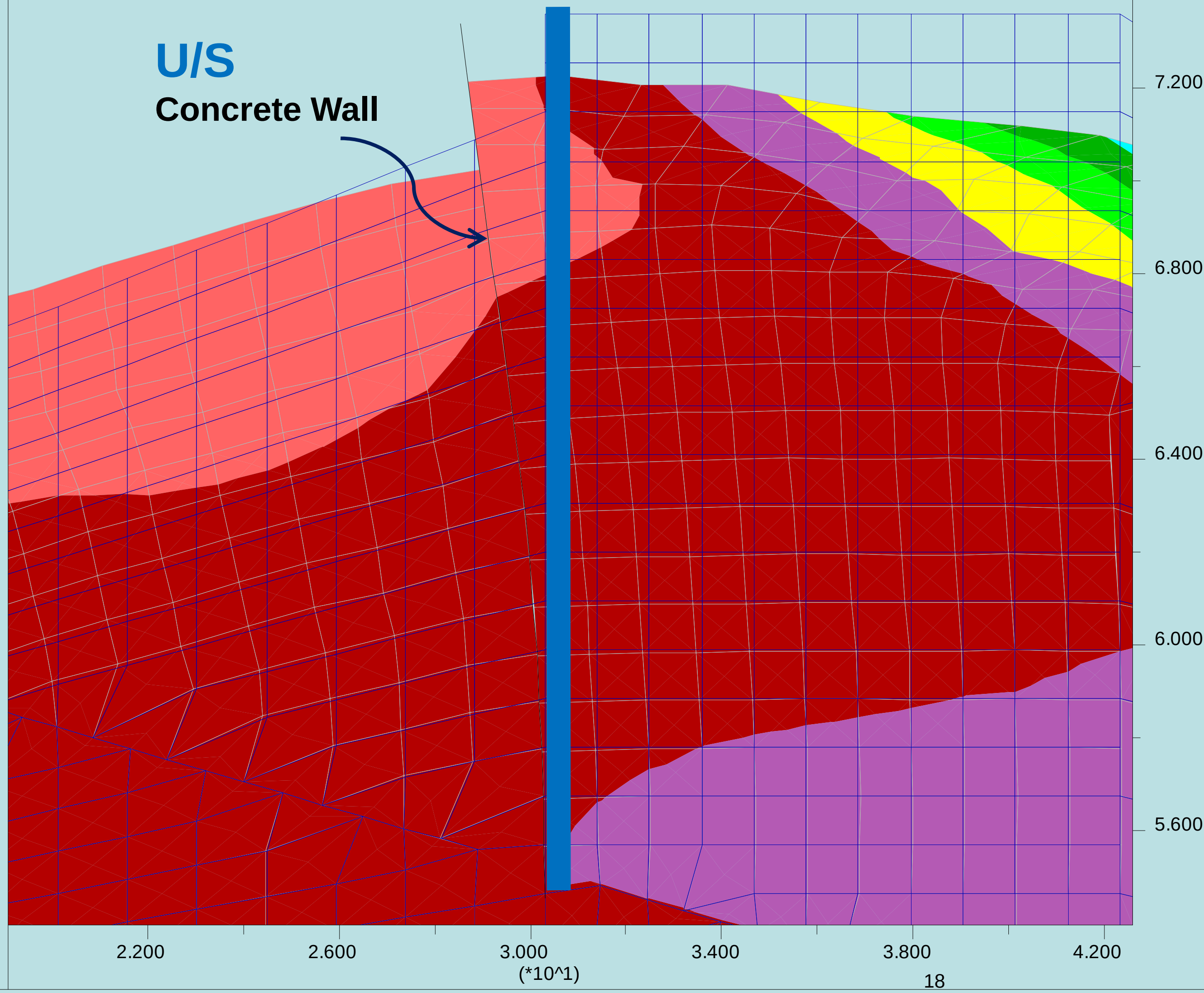
9-May-14 15:43
step 1665090
Dynamic Time 2.5000E+01
1.909E+01 <x< 4.260E+01
5.396E+01 <y< 7.747E+01

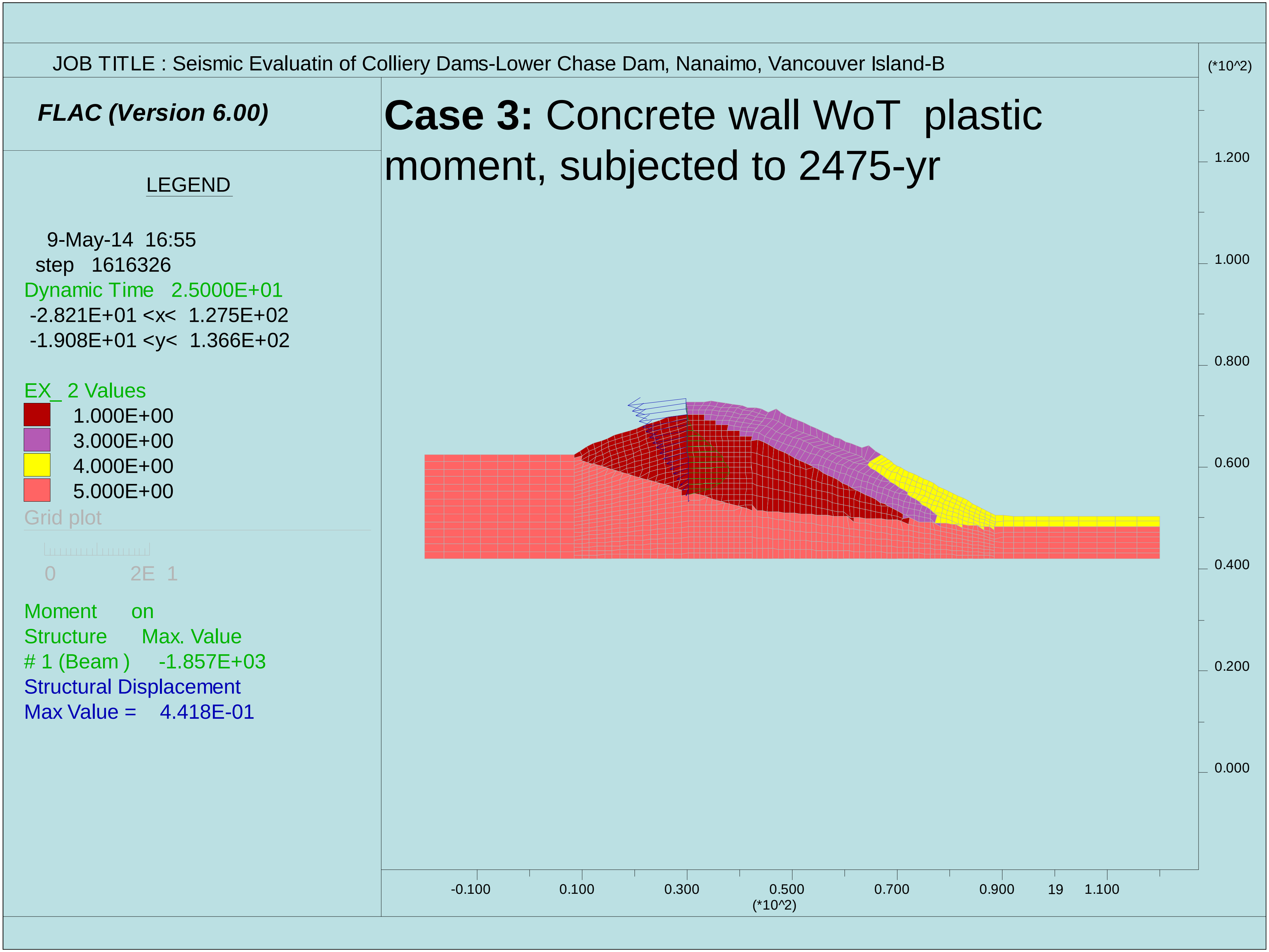
X-displacement contours
-1.00E+00
0.00E+00
1.00E+00
2.00E+00
3.00E+00
4.00E+00
5.00E+00

Contour interval= 1.00E+00
Grid plot

0 5E 0

Exaggerated Grid Distortion
Magnification = 0.000E+00
Max Disp = 4.727E+00
Beam plot




JOB TITLE : Seismic Evaluatin of Colliery Dams-Lower Chase Dam, Nanaimo, Vancouver Island-B
FLAC (Version 6.00)
Case 3: Concrete wall WoT plastic moment, subjected to 2475-yr
LEGEND
9-May-14 16:55
step 1616326
Dynamic Time 2.5000E+01
-2.821E+01 <x< 1.275E+02
-1.908E+01 <y< 1.366E+02
EX_ 2 Values
1.000E+00
3.000E+00
4.000E+00
5.000E+00
Grid plot
0 2E 1
Moment on
Structure Max. Value
1 (Beam) -1.857E+03
Structural Displacement
Max Value = 4.418E-01
(*10^2)
1.200
1.000
0.800
0.600
0.400
0.200
0.000
-0.100
0.100
0.300
0.500
0.700
0.900
1.100
(*10^2)

JOB TITLE : Seismic Evaluatin of Colliery Dams-Lower Chase Dam, Nanaimo, Vancouver Island-B

FLAC (Version 6.00)

LEGEND

9-May-14 16:47
step 1638687
Dynamic Time 2.5000E+01
-2.821E+01 <x< 1.275E+02
-1.834E+01 <y< 1.374E+02

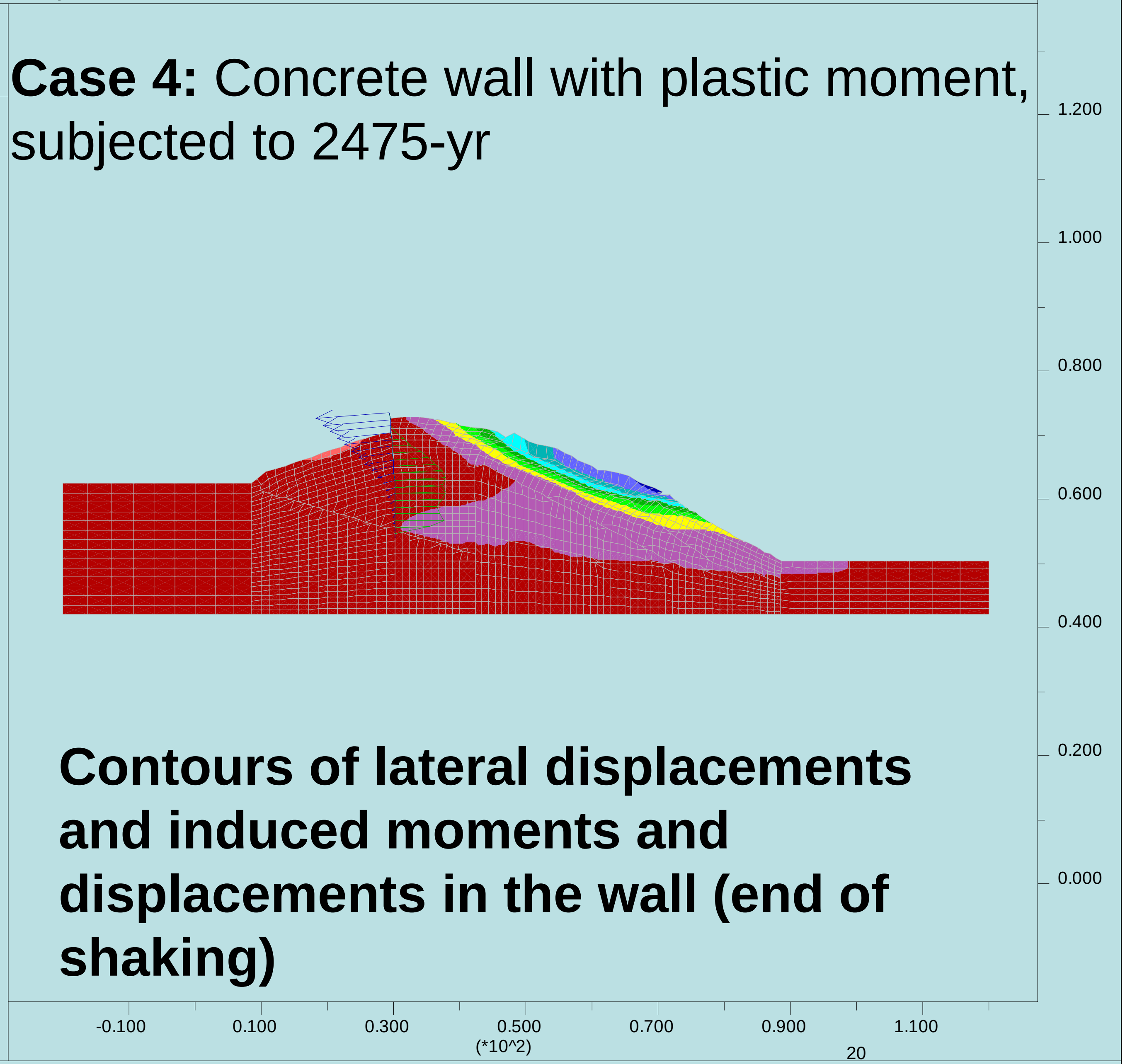
X-displacement contours
-1.00E+00
0.00E+00
1.00E+00
2.00E+00
3.00E+00
4.00E+00
5.00E+00
6.00E+00
7.00E+00

Contour interval= 1.00E+00
Grid plot

0 2E 1

Moment on
Structure Max. Value
Wall:
Mmax = -5.976e2 kN-m
Sdis = 0.819 m

Case 4: Concrete wall with plastic moment, subjected to 2475-yr

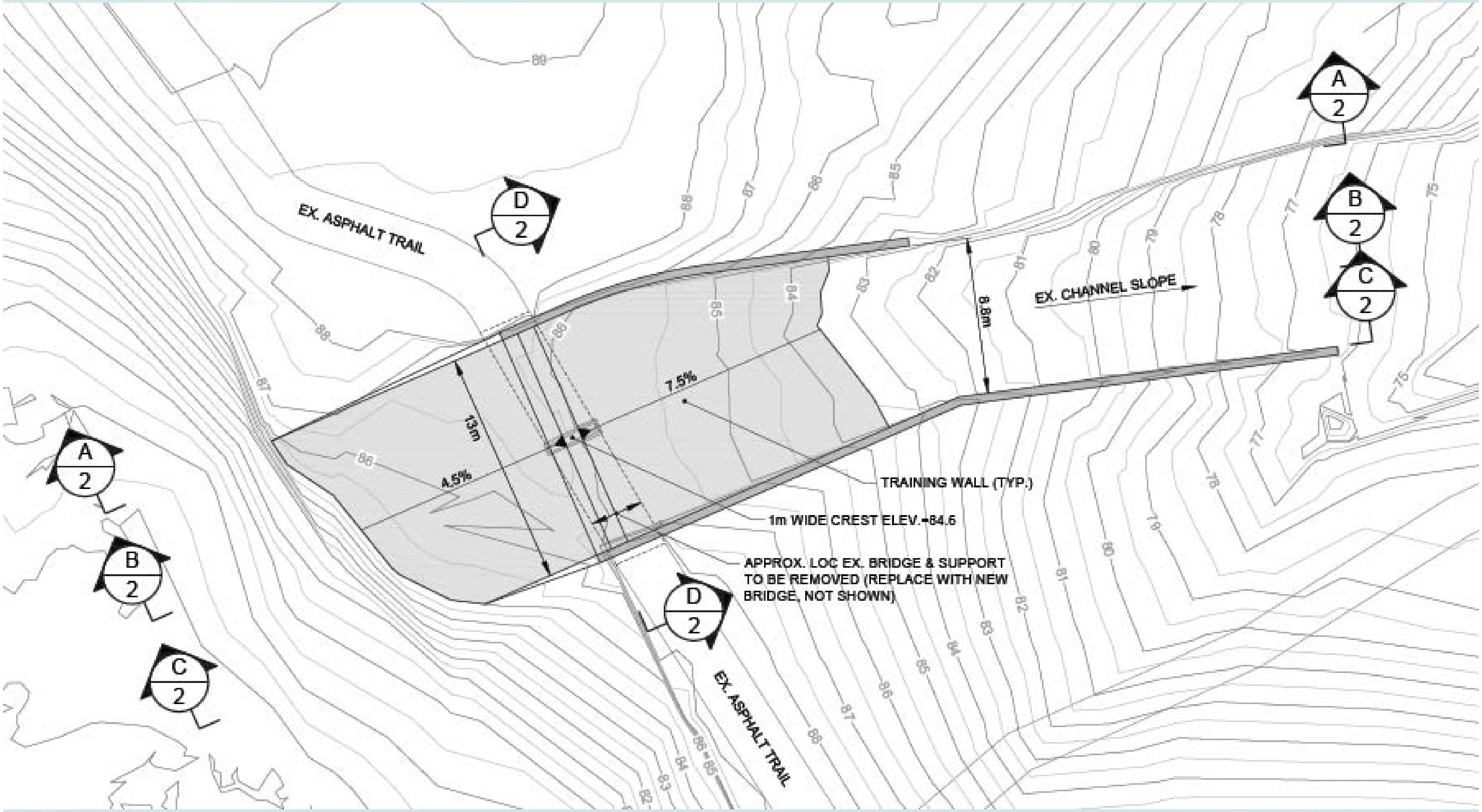


Contours of lateral displacements and induced moments and displacements in the wall (end of shaking)

Middle Dam: Deepen Spillway

- Lower crest of spillway ~1.6 m.
- Replace and raise walls.
- Remove and replace bridge.
- Further details and Cost currently being determined.

Middle Dam: Deepen Spillway Plan



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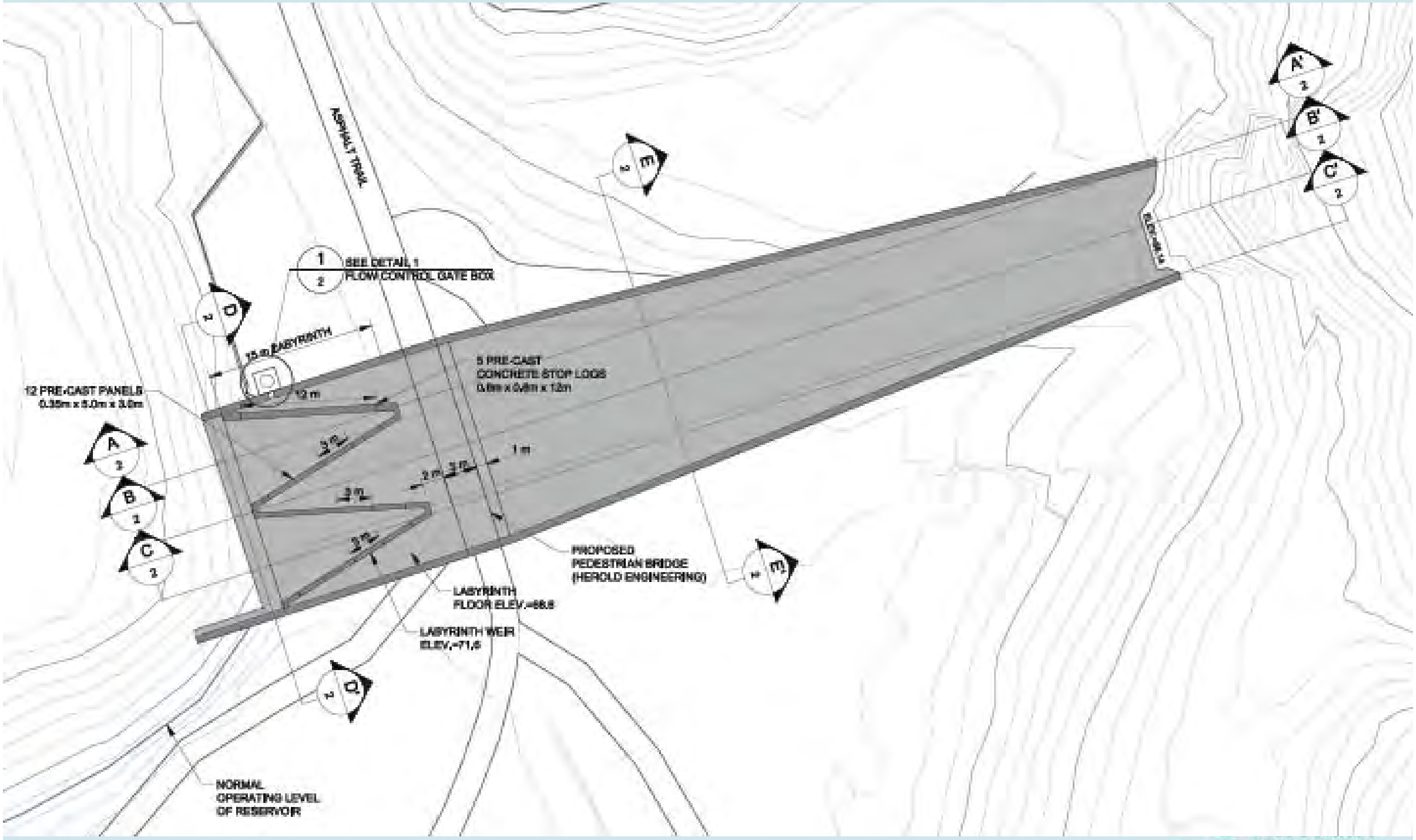
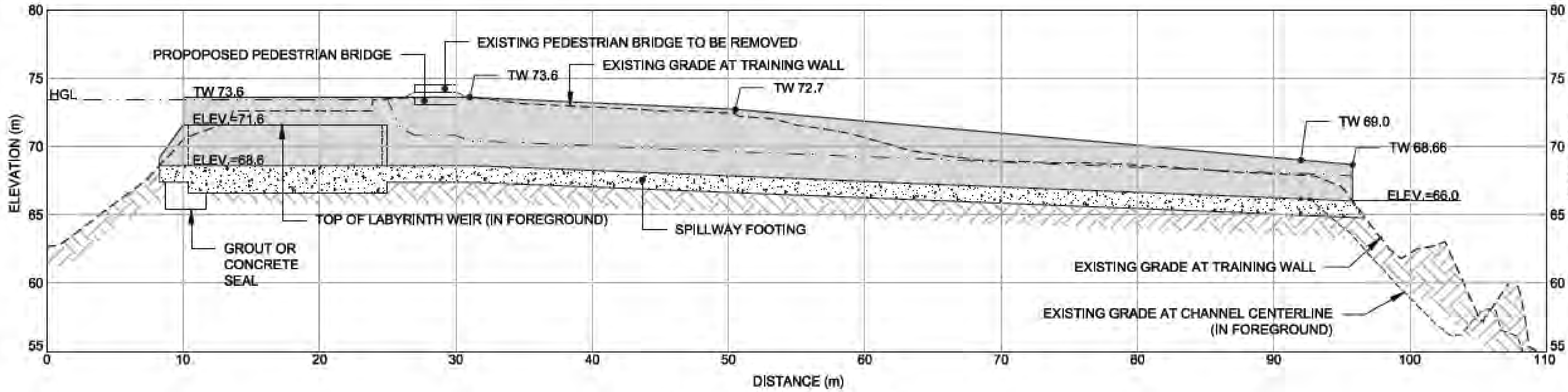
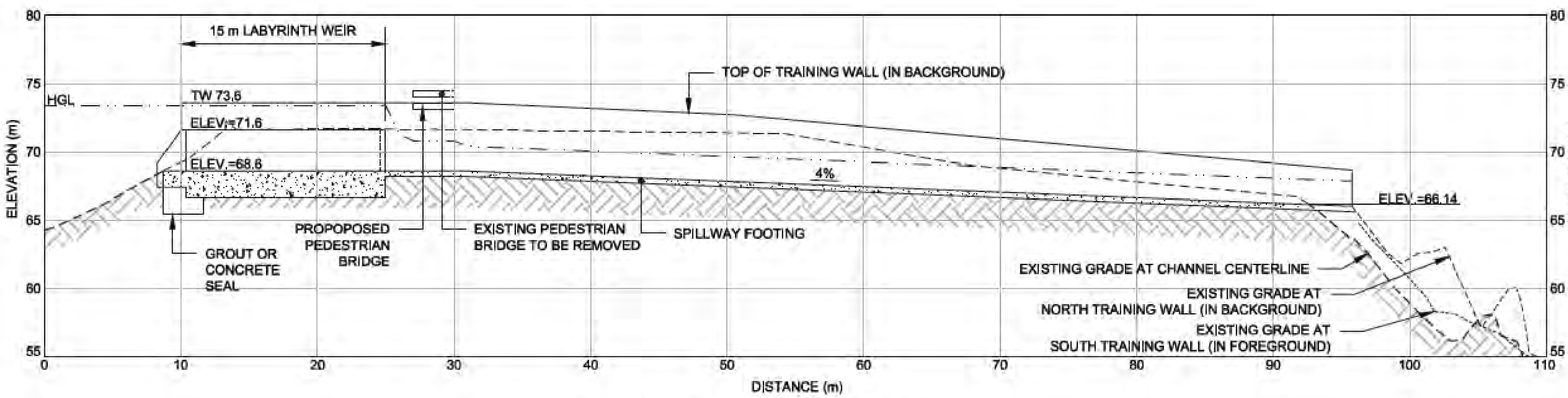
Lower Dam: Labyrinth Spillway Plan (18 m)



Lower Dam: Labyrinth Spillway Section (18 m)

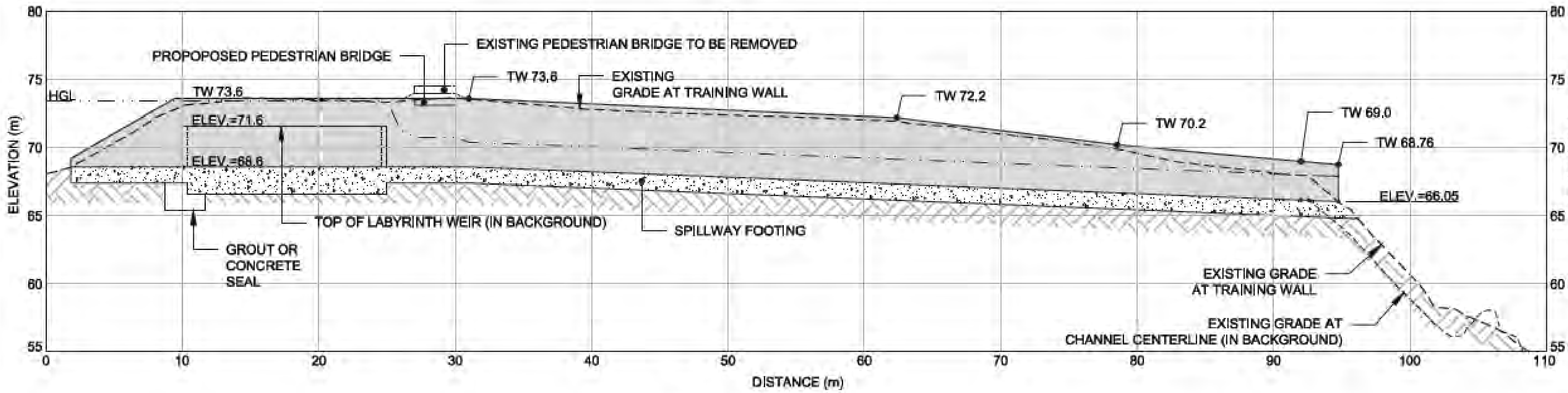


A CROSS-SECTION A-A'
1 SEE SCALE A



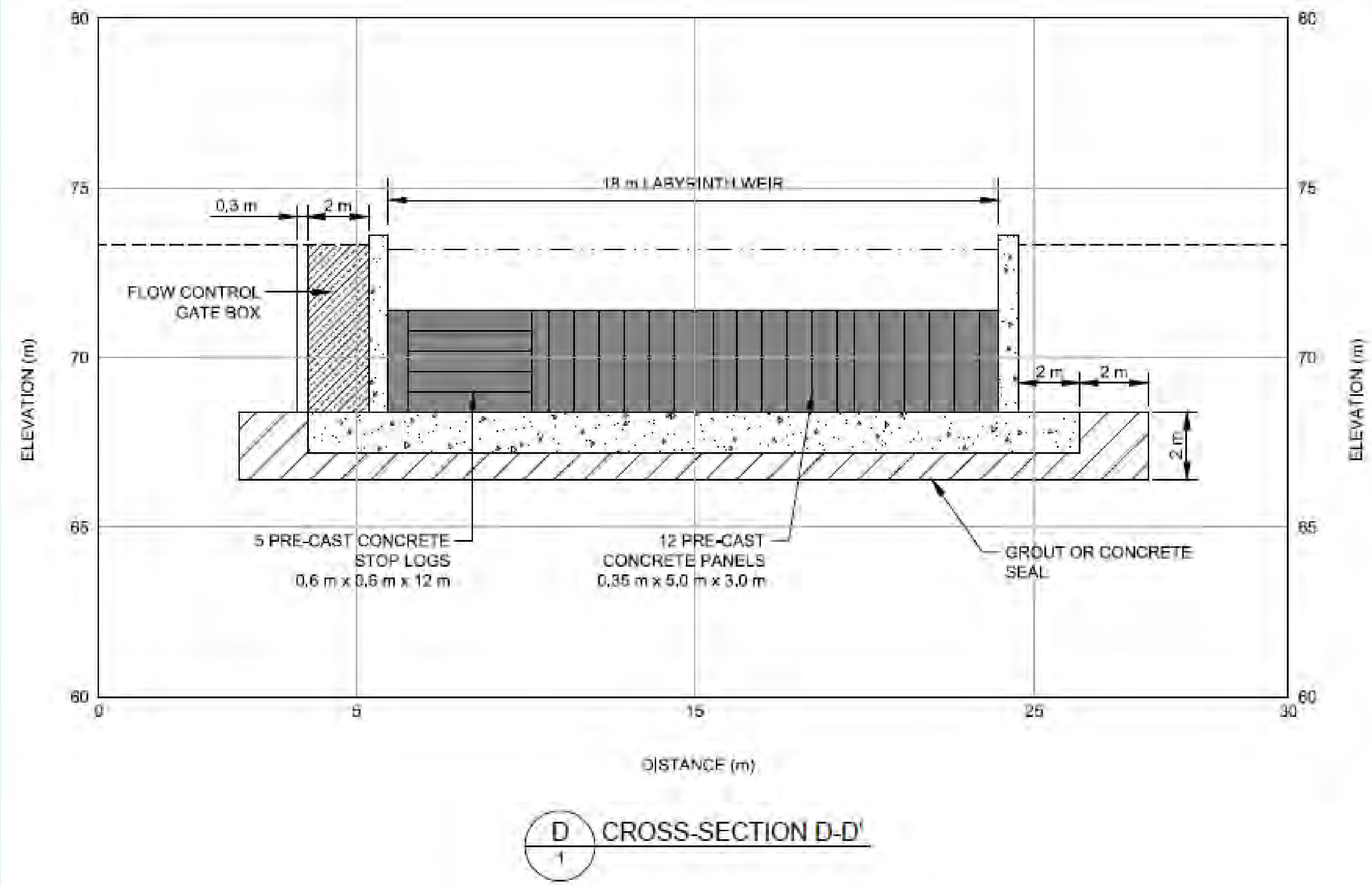
B CROSS-SECTION B-B'
1 SEE SCALE A

Lower Dam: Labyrinth Spillway Section (18 m)

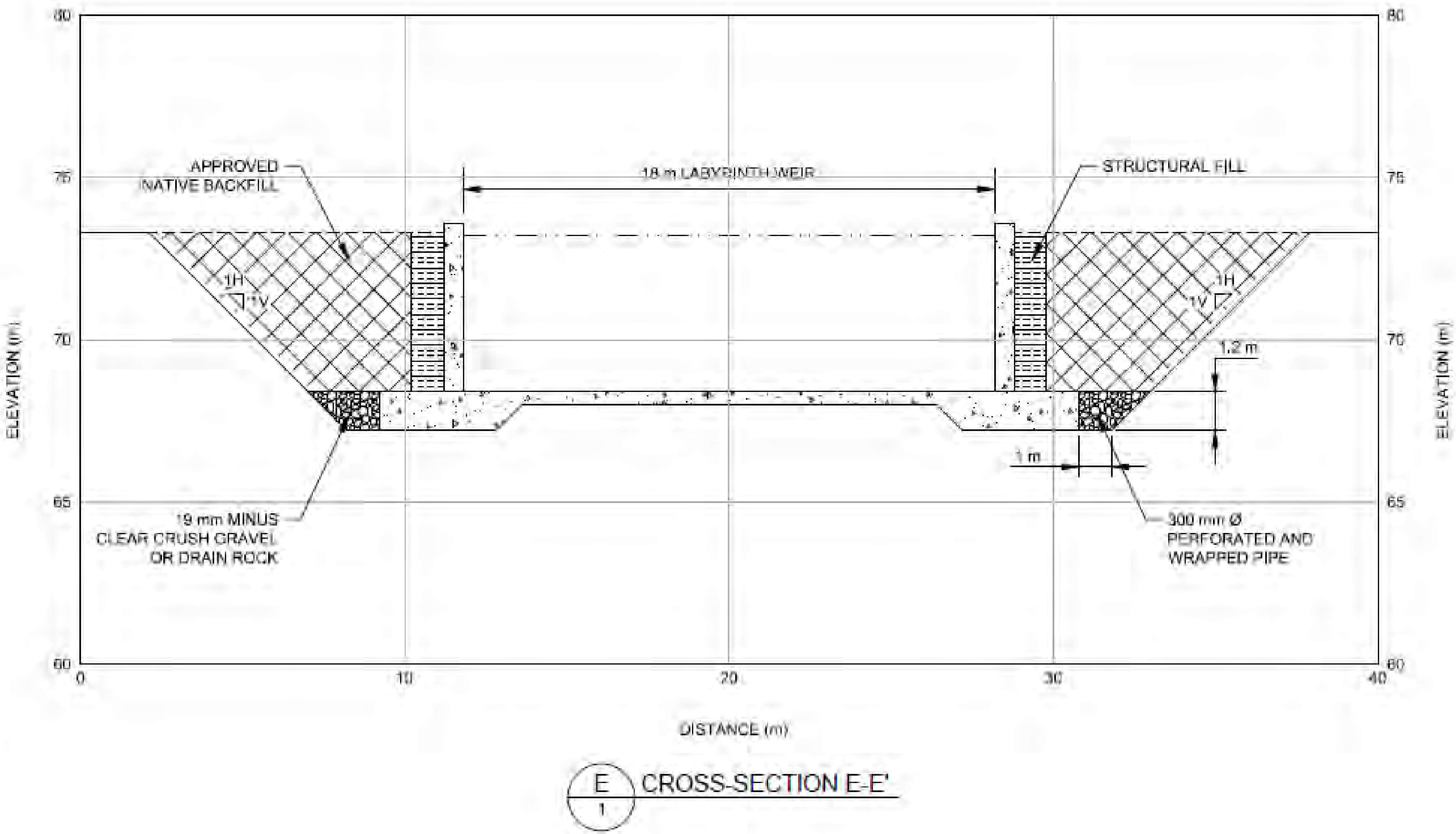


C
1
CROSS-SECTION C-C'
SEE SCALE A

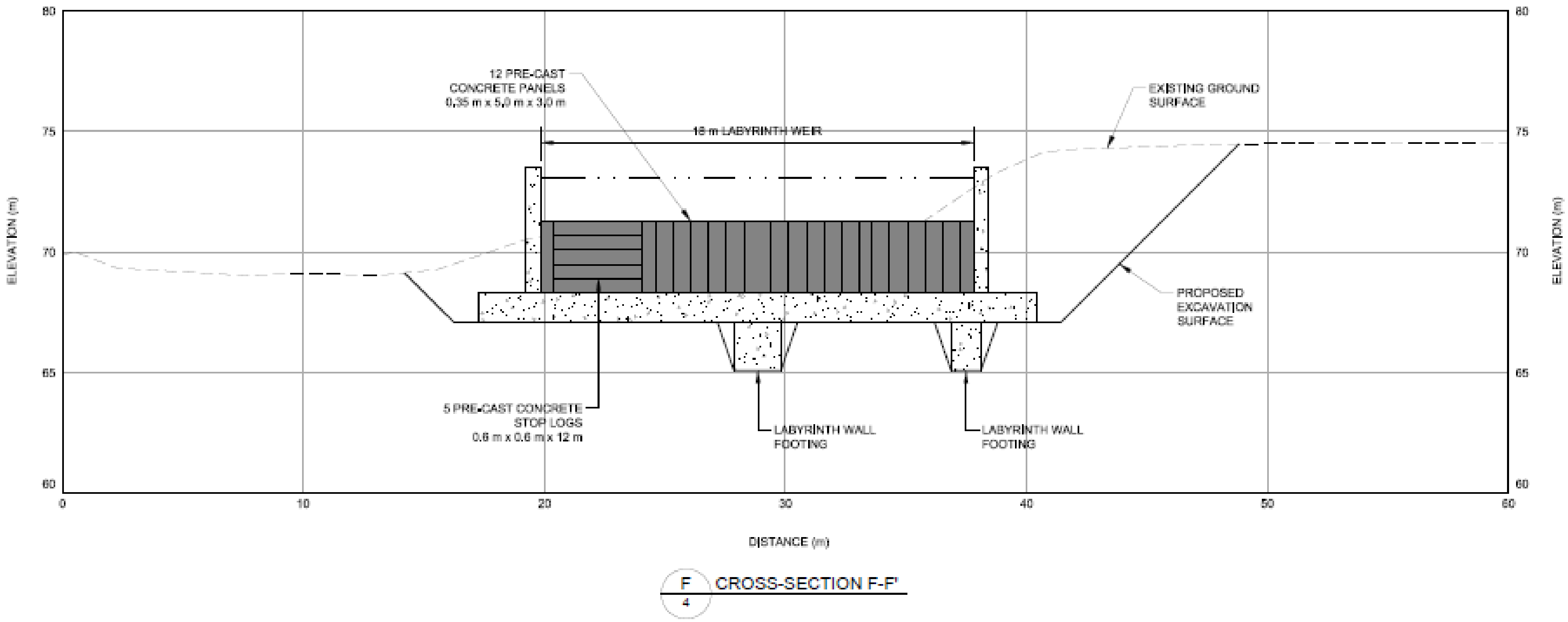
Lower Dam: Labyrinth Spillway Section (18 m)



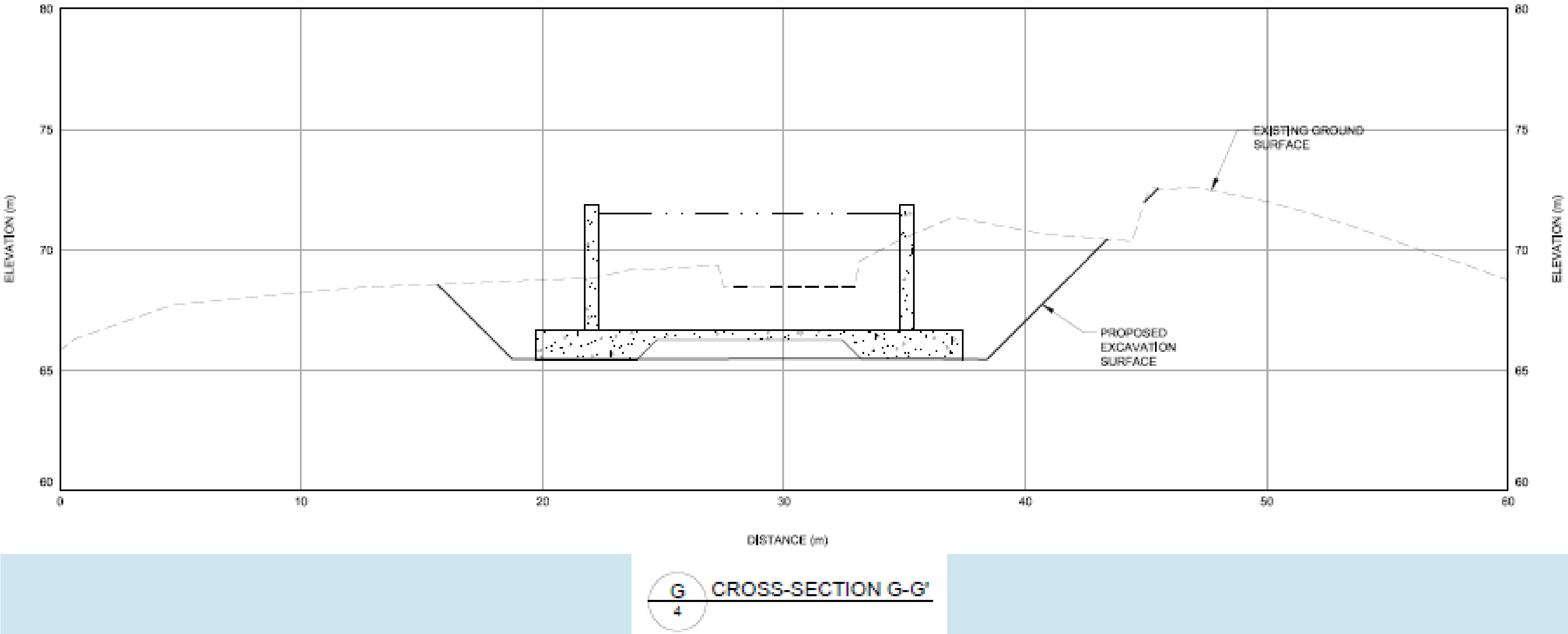
Lower Dam: Labyrinth Spillway Section (18 m)



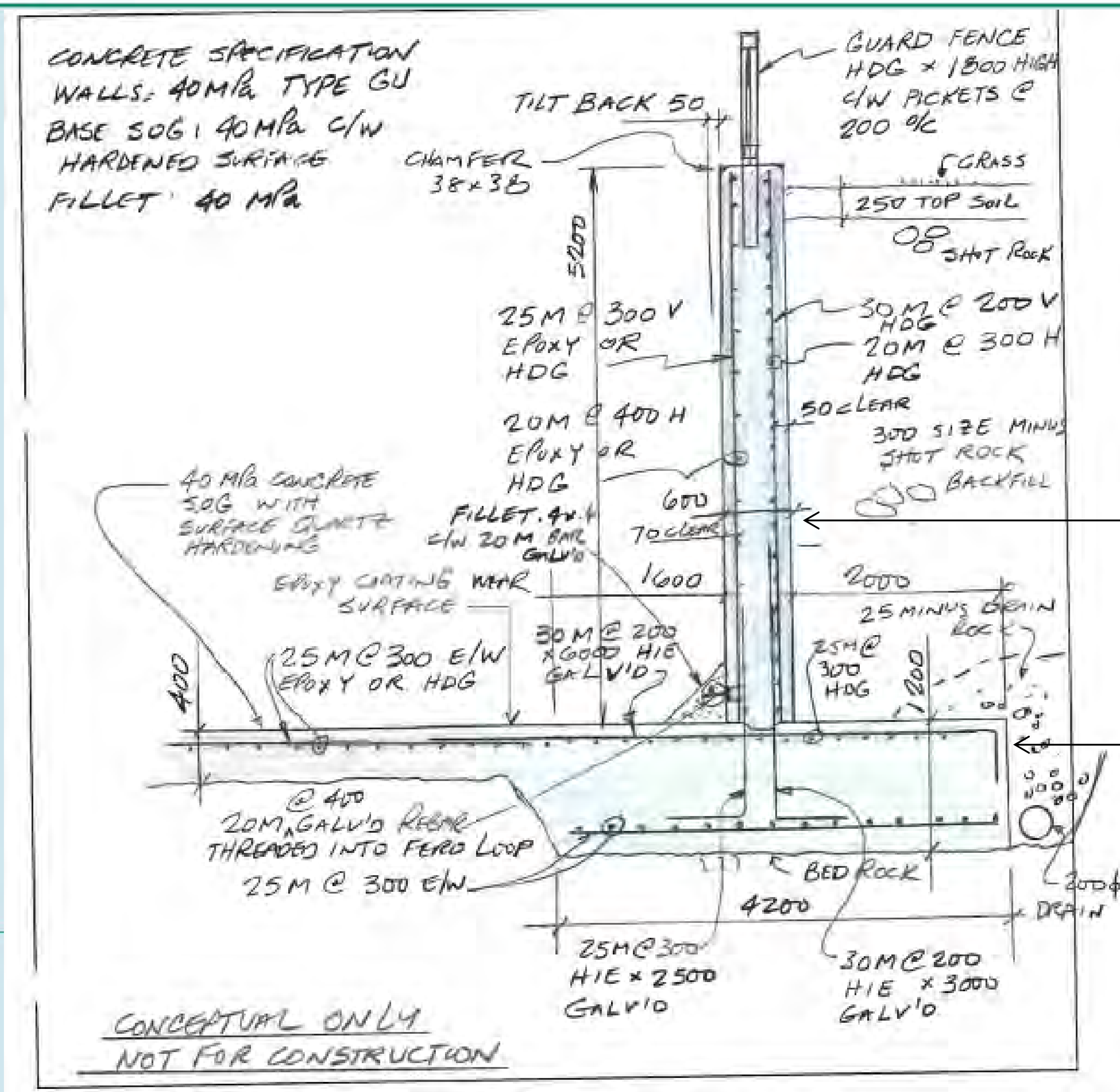
Lower Dam: Labyrinth Spillway Section (18 m)



Lower Dam: Labyrinth Spillway Section (18 m)



Lower Dam: Spillway Long Sidewall Schematic



600 mm thick wall

1200 mm thick base

Cost Exclusions

Option	Cost Exclusions
Labyrinth (12 m and 18 m)	• Bridge allowance • Detailed design • Construction management • Owners costs • Contingency • Environmental inputs and constructions related risks

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Further Work

- Lower Dam Spillway
  - Optimize
    - Alternate wall designs
    - Alternative cofferdam options
    - Alternative layout – wider and shallower?
  - Investigations
- Middle Dam Spillway – complete cost estimating
- Seismic analysis – complete
- Reporting