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February 25, 2021

Richard C. Secord, LLM, Partner
Ackroyd LLP
1500 First Edmonton Place
10665 Jasper Avenue NW
Edmonton AB, T5J 3S9

RE: Springbank Off-Stream Storage Project (SR1) – Design Review

Dear Richard Secord,

In November 2020, Austin Engineering was contacted by the President of the Springbank Community Association, Karin Hunter, to submit a proposal for completing a design review of the Springbank Off-Stream Storage Project (SR1) on behalf of the SR1 Concerned Landowners Group (SCLG), formed by members of the Springbank Community and other local landowners.

The objective of our engineering design review was to identify risks with the engineered design and operation of the SR1 Project and provide recommendations to improve the dam safety aspects of the project and prevent long-term dam safety non-conformances or deficiencies that could negatively affect downstream residents, land owners, infrastructure and have detrimental ecological impacts.

Currently across Canada, municipalities and private dam owners are investing millions of dollars to ensure their dams meet the requirements set out in the Canadian Dam Association (CDA) Dam Safety Guidelines 2007 (2013 Edition).

The SR1 Project in its current design configuration does not meet all the CDA Dam Safety Guidelines requirements, with the two main issues being:

- The Storage Dam is assigned a consequence classification of Extreme, yet the Emergency Spillway cannot safely discharge the design inflow of 600 m^3/s.
- The minimum required factor of safety against slope failure with pseudo-static loading (1.0) is not achieved for the Storage Dam.

As provincial dam safety regulators across Canada use the CDA Dam Safety Guidelines to determine whether existing dams are safe, we believe the SR1 Project, being a new dam, should at a minimum meet all of the CDA requirements.

Due to the operational complexity of the Diversion Structure, it is imperative that operational guidelines and emergency response documents be reviewed by the NRCB during Project permitting to accurately assess the Project risks, especially those associated with dam safety.

Our Design Review Report includes numerous recommendations for improving the dam safety aspects of the SR1 Project and we strongly advocate that these recommendations be addressed prior to the NRCB granting approval for construction of the SR1 Project.

I trust this letter and the attached report meet your needs, and if you have any questions or concerns, please don't hesitate to contact me at any time. Thank you.

Sincerely,

Ruth Keyes, P. Eng.
Senior Hydrotechnical Engineer
Austin Engineering Ltd.

AUSTIN ENGINEERING

Commitment to Excellence, Innovation & Client Success

SR1 Springbank Off-Stream Storage Project

Design Review

February 2021

Prepared by:

Austin Engineering Ltd.
1151 Cedar Avenue
Trail, BC V1R 4B8

LIST OF REVISIONS

Rev	Date	By	Chk	Description	Approved
2					
1	2021/02/25	RK	SH	Issued as Final	RA
0	2021/02/19	RK	SH	Issued for Review	RA

By:

Feb 25, 2021

Ruth Keyes, P.Eng. Date

Reviewed by:

Feb 25, 2021

Sara Howald Date

Reviewed and approved by:

Feb 25, 2021

Roger Austin, P.Eng. Date

EXECUTIVE SUMMARY

The Elbow River flows through southwest Calgary and is susceptible to flooding that can result in extreme damage, as experienced during the June 2013 flood event. To mitigate the impacts of a large flood flow in the Elbow River, the Government of Alberta, Alberta Transportation (AT) has developed the Springbank Off-Stream Storage Reservoir Project (SR1). The SR1 Project proposes constructing a flood mitigation system approximately 20 kilometers west of Calgary that would divert high river flows during a flood event from the Elbow River into an off-stream storage reservoir that is impounded by an earthfill embankment dam. Following the flood event, water within the reservoir would be discharged back into the Elbow River at a controlled rate, thereby reducing the effects of the flood to those experienced during a smaller event.

In November 2020, Austin Engineering was contacted by the President of the Springbank Community Association, Karin Hunter, to submit a proposal for completing a design review on behalf of the SR1 Concerned Landowners Group (SCLG), formed by members of the Springbank Community and other local landowners.

On December 10, 2020, the PHC Decision Report was issued and Austin Engineering was provided funding to complete a design review on behalf of the SCLG.

The objective of our engineering design review is to identify risks with the engineered design and operation of the Springbank Off-Stream Storage Reservoir Project and provide recommendations to improve the dam safety aspects of the project and prevent long-term dam safety non-conformances or deficiencies that could negatively affect downstream residents, landowners, and infrastructure, and have detrimental ecological impacts. Although laid out in more detail in the report a summary of our recommendations resulting from this review is provided in Table 1.

Table 1. Austin Engineering's Design Review Recommendations for the Off-Stream Storage Reservoir Project

Recommendation Number/ Identified Concern		Recommendation (Summary)
1	Diversion Inlet capacity	The bottom elevation of the access bridge across the Diversion Inlet (to the gate hoists) is shown as 1215.5 m (Ex 159 page 343). The inlet invert elevation is 1211.5 m. This gives a maximum flow depth below the access bridge of 4 m before the water surface hits the bottom of the bridge. Austin Engineering recommends the Diversion Inlet maximum discharge capacity be reviewed and modelled with the access bridge in place. We recommend that the Diversion Inlet access bridge design be reviewed to ensure that adequate freeboard (between the bridge and water surface) is achieved during passage of the design flow of 600 m^3/s.
2	Emergency Spillway discharge capacity	The Emergency Spillway maximum discharge capacity (360 m^3/s) is less than the Diversion Channel design flow or the maximum diversion intake flow. A reassessment of the Emergency Spillway should be considered to increase the discharge capacity from 360 m^3/s to 600 m^3/s (or to match the maximum capacity of the Diversion Inlet). The safety of the Storage Dam should not rely solely on the ability of operators (or electrical systems) to close the Diversion Inlet gates.
3	Diversion Structure total capacity	We recommend the following: 1. Diversion Inlet capacity be reviewed due to the access bridge breastwall and headwall causing a flow restriction. 2. Stantec should confirm the Elbow River water surface elevation that results in the fuse plug being removed down to an invert elevation of 1215.8 m. i.e. Does the WSE need to be 1217.2 m for a minimum duration of 2.76 hours to remove the entire 208 m long fuse plug, or will a WSE of 1216.9 m be sufficient based on the erosion starting at the pilot channels and progressing over the length of the fuse plug over 2.76 hours? 3. More information should be provided on the Diversion Structure rating curve with various operation combinations of the Diversion Inlet, Service Spillway, and Auxiliary Spillway. 4. It should be confirmed that the Service Spillway Obermeyer weir can operate at flow depths greater than 5.8 m (with debris flow included) in order to safely pass the IDF in combination with the Auxiliary Spillway.
4	Flood flow estimation uncertainty due to: • Climate Change • Limited historical records prior to 1934 • Snowmelt	We recommend that the Probable Maximum Precipitation (PMP) analysis be reviewed as part of the final design to confirm rain-on-snow has been included in the PMP. We recommend that consideration for forest fire and climate change be made as an allowance in the flood flow determination. We recommend an allowance to account for these uncertainties be included within the design flood prior to completing final design of the diversion structure components and sizing of the Diversion Inlet gates and final sizing of the emergency spillway.

Recommendation Number/ Identified Concern		Recommendation (Summary)
5	Stoplog slots and gate guide heaters	Austin Engineering recommends the inclusion of stoplog slots, at a minimum, preferably with at least enough stoplogs to isolate one intake gate, upstream of the Diversion Inlet gates to facilitate annual testing, reduce the requirements for fish salvage during testing and allow for future maintenance of the gates. In addition, due to the cold climate in the region for portions of the year and the necessity to keep the system functional, we recommend the inclusion of gate guide heaters.
6	Emergency Spillway flow conveyance	We recommend that the outlet of the Emergency Spillway be channelized with riprap or other erosion protection between the downstream extent of the Emergency Spillway and the return to the Elbow River to prevent embankment scour on the downstream side.
7	Auxiliary Spillway	We recommend the Diversion Inlet gate operation between WSEs of 1216.9 m and 1217.2 m be documented, as well as contingencies for the following conditions: • The fuse plug does not operate as expected; or • Activation of the fuse plug causes water quality (sedimentation and turbidity) issues downstream.
8	Flood protection between Service Spillway and Glenmore Dam	We recommend flood maps be produced, showing the flood extents within the Elbow River between the Service Spillway and the Glenmore Dam, for Service Spillway discharge flows of 160 m^3/s, 760 m^3/s and 1600 m^3/s. The three flood maps should be used to determine impacts and identify if flood protection works are required along this stretch of the Elbow River.
9	Control Building location	We recommend that the Control Building be located in an area that would not be subject to flooding, or where access to the building will not be impeded by flooding, permitting the SR1 reservoir to continue to be of benefit during a flood event and reduce operational risks during a large flood event. Consideration should be given to helicopter access near the Control Building in the case of damage occurring to the access road along the Diversion Channel between Township Road 242 and the Diversion Inlet and we recommend a clear landing area be included in the final design.
10	Factor of Safety of the Storage Dam and Floodplain Berm under pseudo-static loading	The minimum factor of safety for the Storage Dam under pseudo-static loading is 0.7 (at Section 22+500). The minimum factor of safety for the Floodplain Berm under pseudo-static loading is 1.0 (at Section 1+600). It would be imprudent to construct a new dam with a safety factor at or below the minimum CDA Dam Safety Guidelines (CDA, 2013) safety factor thresholds. We recommend that the design of the Storage Dam be modified to ensure the minimum required factor of safety of 1.0 be achieved for the pseudo-static scenario under seismic loading. Consideration should also be given to increasing the Floodplain Berm factor of safety under this load case.

Recommendation Number/ Identified Concern		Recommendation (Summary)
11	Fracking exclusion zone	During a review of the available documentation on the National Resources Conservation Board (NRCB) website, Austin Engineering did not encounter any reference to fracking induced seismic events. As a significant amount of fracking has been undertaken within Alberta, the approval to commence construction of the SR1 reservoir needs to be undertaken with a dedicated fracking exclusion zone surrounding the project extents. This zone is to be established by the design engineers to ensure that the SR1 structure is not damaged due to fracking within proximity of the structure.
12	Emergency operation of the Diversion Inlet gates	As the mechanical and electrical details for the project have not been provided at this time, we believe that it is imperative to the safety of the overall structure that the Diversion Inlet gates fail closed under their own weight. Table 5-2 on Page 106 of Ex 20 indicates that in the case of mechanical and electrical failure preventing typical gate operation, the gate hoists (wire rope) will have hoist brakes that can be released allowing the gates to be lowered. If this is implemented in the final design, we recommend that the hoist brakes be capable of manual release. It is unclear how operators will access the hoist breaks in the event of an emergency. As such, we recommend that the final design consider access to this critical location for operation during a high flood flow event, should loss of power occur at the structure.
13	Emergency backup power and automatic switching	As the SR1 project is to function during a large flood event of an emergency nature, we recommend that emergency backup power be included as part of the overall project scope, with emergency power being capable of powering all monitoring instrumentation, the intake gates, and the service spillway weir. The emergency power generator should be set to automatically start with an automatic transfer switch to provide real-time backup power in the event of an emergency. This backup generator should not be located in an area where flood flows could impede the safe operation of the generator or operator access for re-fueling should an electrical outage extend over a long period of time.
14	Springbank Road acting as a dam	We recommend that, if not already considered, drainage upgrades and stability assessments for Springbank Road be included in the final project design.
15	Emergency (secondary) low level outlet through Storage Dam	We recommend consideration be given for the addition of a secondary low level outlet (or enlargement of the current low level outlet) through the Storage Dam to be utilized if an emergency drawdown of the reservoir is needed and requiring dewatering much faster than the current low level outlet would allow. A secondary outlet would be preferable, as this would allow for draw down in the event the primary low level outlet were to fail or become blocked.
16	Intake screen design on low level outlet	The intake screen on the low level outlet (through the Storage Dam) needs to be able to accommodate silt deposits anticipated within the reservoir and be able to drawdown water to the top of the anticipated silt deposit. We recommend that the screens be designed with sufficient height to accommodate (at a minimum) a 1.0 m silt layer at the bottom of the reservoir (or the maximum height of the silt anticipated).
17	Riprap on upstream face of Storage Dam (wave runup)	The preliminary design does not indicate riprap on the upstream face of the Storage Dam. While the structure is not continuously operated, it will be subject to the design cases and loads associated with wind setup and wave runup over its lifespan. Austin Engineering recommends that riprap be included for armouring along the upstream face of the Storage Dam.

Recommendation Number/ Identified Concern		Recommendation (Summary)
18	Differential settlement of the Storage Dam	Differential settlement of the Storage Dam needs to be considered during the design of the low level outlet and associated concrete piping/conduit based on the anticipated settlement within this portion of the dam. Stresses are likely to be quite significant due to the settlement over time. If differential settlement along the crest of the Storage Dam occurs and results in a lowering of the overall crest elevation, instrumentation set points will need to be adjusted to maintain adequate freeboard during diversion of the design flood event.
19	Silt removal within the Off-Stream Storage Reservoir	We recommend that a thorough plan be developed prior to completion of final design to allow for the introduction of access roads, drainage, and drainage ditches within the reservoir, sloped towards the low level outlet (conduit), to facilitate maximum dewatering and provide good access for removal of the silt deposit. Knowing the locations of these access roads, along with potential stockpile locations, in advance will allow for crews and equipment to work logically and methodically with a pre-established plan for removal of the silt from the reservoir. These pre-established access roads will also provide better access for fish rescue and minimize the amount of time required to salvage fish and remove the silt.
20	Dam commissioning	Due to the high-risk and higher probability of failure during first fill, we recommend instrumentation be carefully considered. Instrumentation for the structure should include settlement monitoring, slope inclinometers, piezometers (vibrating wire), in addition to water level monitoring within both the reservoir and the upstream reaches of the river. Each piece of instrumentation should have trigger levels determined in advance by the design engineers. Should the first fill condition then happen without adequate presence of design engineers, the instrumentation could be interlocked with the Diversion Inlet gates to stop flow into the reservoir should any of the instrumentation trigger levels set by the designers be reached during filling. Austin Engineering has concerns over the first fill of the SR1 reservoir occurring during a flood event, as a high percentage of reservoir failures occur during the first fill. It would be prudent to include first fill and commissioning requirements within the SR1 Approval to Construct. Should this not be included, an instrumentation and monitoring plan needs to be clearly outlined, indicating cut-off levels with reliable logic, piezometers, slope inclinometers, and settlement monitors designed to close the intake gates and commence immediate emergency discharge from the low level outlet should any of those trigger levels be met. However, it would be much more prudent to have the first fill and commissioning undertaken outside of a flood event to reduce the risk to downstream occupants, infrastructure, and environmental habitat. A plan for the first fill and commissioning is critical to the operation of the structure and should address the higher risk in early operations of the structure that would occur on a repetitive basis during flood events.
21	Safety Management Plan	We recommend that a draft Safety Management Plan be developed and submitted to the NRCB prior to construction approval being granted.
22	Emergency plans and response	There is a large travel distance from Calgary to the dam. Although we are unsure where the operators will be located when a flood event occurs, this needs to be taken into consideration to ensure that flood forecasting is adequately undertaken to provide operators with an adequate response time to reach the SR1 reservoir in time to divert water during a major flood event. Austin Engineering is recommending that approval of this project does not go forward without submission of a draft dam emergency plan and emergency response plan.

Recommendation Number/ Identified Concern		Recommendation (Summary)
23	Dam break inundation mapping	We recommend that the Storage Dam break inundation mapping be updated to show velocity and flow depths. We recommend that a separate dam break analysis and inundation mapping be produced for the Floodplain Berm for inclusion in the emergency plan.
24	Operation, Maintenance and Surveillance documentation	We recommend that the following be documented prior to project approval: • Elbow River flows that trigger Diversion Inlet gate opening and closing • Glenmore Reservoir levels that trigger the Diversion Inlet gate opening • SR1 Reservoir levels that trigger Diversion Inlet gate closing • All aspects of weir and gate operation including the use of manual versus electrical systems • All aspects of Low Level Outlet operation and Storage Reservoir draining • How forecasting systems be used to predict trends for operation • The overall training and operation plan, including operational accountability for the structures • Roles and responsibilities, particularly in regard to dam safety management • Inspection frequencies and requirements (including monitoring for erosion on the upstream side of the Floodplain Berm) • Maintenance schedules • Instrumentation details and monitoring requirements • All weir flow rating curves (Diversion Inlet, Service Spillway, and Auxiliary Spillway) • Auxiliary Spillway fuse plug operation (and emergency operation) • Floodplain Berm Stage-Storage Curve • Off-Stream Storage Reservoir Stage-Storage Curve • Conditions or events requiring the closure of Springbank Road • Fish salvage requirements prior to Storage Reservoir draining • Storage Reservoir dewatering and sediment removal plan

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LIMITATIONS

This report has been prepared for the SR1 Concerned Landowners Group (SCLG) for the objectives and to the scope set out in the report. This report presents the findings of Austin Engineering's independent and professional assessment of the proposed design for the Off-Stream Storage Reservoir (SR1) Project. We believe our findings are objective and are not influenced by any potential motivations of our client or other stakeholders.

Austin Engineering's aim was to review the proposed structures based on the available preliminary design reports, and to provide an unbiased, peer evaluation of the safety and functionality of the SR1 Project, as proposed by Alberta Transportation (AT).

Over 300 documents have been submitted as evidence as part of the SR1 Project application with the Natural Resources Conservation Board (NRCB). Our office has had approximately 10 weeks to review as many of these documents as possible and prepare our assessment. While Austin Engineering has endeavored to review the most relevant documents within the timeframe available to us, we acknowledge that we were unable to review all documentation pertaining to the SR1 Project that was available on the NRCB website.

Austin Engineering focused the design review and assessment on design documents for the proposed SR1 structures, hydrological and hydrotechnical studies and data, and stability and geotechnical analysis reports. By prioritizing these documents for review, we were able to achieve the best possible job of defining the major dam safety issues for the Project given the limited timeframe available.

In the report, Austin Engineering has identified areas of missing information that should be requested from the design engineer and we recommended that several additional studies or assessments be conducted to verify or support specific Project designs and assumptions. In such cases, we made attempts to locate potentially existing reports or other documentation that could provide the missing information or verify design assumptions. However, we acknowledge that the missing information or supporting documentation may exist in reports that we either did not have access to during our review or that were not reviewed due to project time constraints.

DISCLAIMER

This report has been prepared by Austin Engineering Ltd. (AEL) for the benefit of the client to whom it is addressed (Client) and for the express purpose described herein. In some circumstances, the scope of services may have been limited by a range of factors, including, without limitation, time, budget and other constraints. This report pertains to a specific site, a specific development and a specific scope of work. This report is not applicable to any other site, nor should it be relied upon for types of development other than the specific one to which it refers. Any variation from the site or proposed development would necessitate a supplementary investigation and assessment. Unless expressly stated otherwise, assumptions, data and information supplied by, or gathered from other sources (including the Client, other consultants, testing laboratories and equipment suppliers, etc.) (Third Party Data) upon which AEL's design and/or opinion as set out herein is based, has not been verified by AEL and may be incomplete. AEL makes no representation as to the Third Party Data's accuracy and disclaims all liability with respect thereto.

Designs, plans and recommendations are provided for the specific purpose indicated herein and may need to be modified depending on new operating conditions and actual field conditions that may be discovered during subsequent investigations and construction. AEL expressly denies any responsibility for constructed works that are subject to new operating conditions that affect the integrity of the design. Sufficient monitoring, testing and consultation should be provided by AEL during construction to confirm that the conditions encountered are consistent with those anticipated, to provide recommendations for design changes should the conditions revealed differ from those anticipated, and to evaluate whether or not earthwork activities are completed in accordance with AEL's recommendations. The development of suitable options and final design modifications based on encountered conditions requires that AEL be commissioned for construction quality assurance and design review during construction when actual soil, hydrogeological and other conditions can be identified with certainty. Accordingly, AEL disclaims all responsibility for constructed works where AEL is not commissioned to provide site inspection, construction quality assurance and design review services during construction of works that have been designed by AEL.

Except as required by law, this report and the information and data contained herein are to be treated as confidential and may be used and relied upon only by the Client, its officers, directors, employees and those parties who has been expressly authorized to do so by AEL in writing, subject at all times to the terms and conditions of AEL's contract with Client. AEL denies any liability whatsoever to other parties, who may obtain access to this report, for any injury, loss or damage suffered by such parties arising from their use of, or reliance upon, this report or any of its contents without the express written consent of AEL and the Client.

1.0 OVERVIEW

1.1 Introduction

The Elbow River flows through southwest Calgary and is susceptible to flooding that can result in extreme damage, as experienced during the June 2013 flood event. To mitigate the impacts of a large flood flow in the Elbow River, the Government of Alberta, Alberta Transportation (AT) has developed the Springbank Off-Stream Reservoir Project (SR1). The SR1 Project proposes constructing a flood mitigation system approximately 20 kilometers west of Calgary's outer limits that would divert high river flows during a flood event from the Elbow River into an off-stream storage reservoir that is impounded by an earthfill embankment dam. Following the flood event, water within the reservoir would be discharged back into the Elbow River at a controlled rate. The design (to date) for the SR1 Project has been completed by Stantec, an engineering consulting company.

1.2 Background

In October 2017, AT filed its original application for the SR1 Project to with the National Resource Conservation Board (NRCB) and Alberta Environmental and Parks (AEP), requesting approval to construct and operate an off-stream reservoir at Springbank, Alberta, in Rocky View County. AT submitted an updated application on March 26, 2018.

The NRCB issued a letter on September 23, 2020, advising interested parties that the review of the application would include a virtual oral Pre-hearing Conference and invited submissions from parties wishing to make presentations at the pre-hearing.

In November 2020, Austin Engineering was contacted by the President of the Springbank Community Association, Karin Hunter, to submit a proposal for completing a design review on behalf of the SR1 Concerned Landowners Group (SCLG), formed by members of the Springbank Community and other local landowners.

On December 2, 2020, the Pre-Hearing Conference (PHC) was conducted by the NRCB, with Austin Engineering's proposal submitted as an Exhibit.

On December 10, 2020, the PHC Decision Report (Ex 156) was issued and Austin Engineering was provided funding to complete a design review on behalf of the SCLG. Note that a portion of the proposed scope was not awarded by the NRCB due to it being new work.

The SR1 Project documentation has been developed over several years starting in 2015 (Ex. 1). In total, 189 documents (Exhibits) have been submitted between 2015 and February 2021 to the National Resource Conservation Board (NRCB) for review and inclusion in the Exhibit List.

The latest design documentation: Final Preliminary Design Report (Ex 159), by Stantec, dated December 8, 2020, was uploaded to the NRCB website on December 18, 2020.

1.3 Objective

The objective of our engineering design review is to identify risks with the engineered design and operation of the Off-Stream Storage Reservoir Project and provide recommendations to improve the dam safety aspects of the project and prevent long-term dam safety non-conformances or deficiencies that may impact downstream residents, landowners, infrastructure, and cultural or ecological zones.

Austin Engineering has completed an independent, professional assessment of the SR1 Project. Our findings are objective and not influenced by any potential motivations of our client or other stakeholders. Our aim was to review the proposed structures based on the preliminary design reports available, and to provide an unbiased, engineering evaluation of the safety and functionality of the Off-Stream Storage Reservoir Project, as proposed by Alberta Transportation.

1.4 Scope of Work

Our proposed scope of work presented at the PCH is summarized as follows:

- Item 1: Review of Existing Information
- Item 2: Design Assessment
- Item 3: Risk Assessment
- Item 4: Inundation Mapping for Springbank
- Item 5: Final Report and Submissions

The NRCB PHC Decision Report (Ex 156) excluded the following scope items from Austin Engineering's proposed scope of works:

- Item 2.05: Independent Geotechnical Stability and Seepage Analysis
- Item 2.06: Structural Analysis on Outlet Works
- Item 3.02: Develop Hazard and Failure Modes Matrix
- All of Item 4.0: Inundation Mapping for Springbank

Note that Ex 156 excluded items 2.05, 2.06, 3.02 and 4.0 as they were perceived as new work; however, only items 3.02 and 4.0 would have been new work and items 2.05 and 2.06 would be a review of existing design.

Although Item 2.05 was excluded from our scope by the NRCB, we did complete a design review of geotechnical considerations on behalf of the SCLG and have included the results in Section 2.2 of this report.

1.5 Reviewed Project Documents

Numerous documents have been compiled throughout the development of the project and are provided on the NRCB website. New design documentation is continuing to be developed and uploaded to the NRCB website as the design evolves and documentation progresses.

Austin Engineering has reviewed many relevant project documents. Given the limited timeframe that Austin Engineering had to review the overall project, not every document could be considered. However, we focused on the most relevant documents based on our experience as a dam safety engineering company and our understanding of the goals and risks associated with the project. A list summarizing the documents we have reviewed thoroughly, among others, as part of our assessment to date can be found in Table 2.

Table 2. Documents reviewed during Design Assessment

NRCB Exhibit Number	Date	Document Title
N/A	20171114	AT EIA-R to NRCB re Draft Preliminary Design Report Dated 20170331 (Stantec, 2017)
11	20171114	AT EIA-R to NRCB re Draft Probable Maximum Flood Analysis 20150807
12	20171114	AT EIA-R to NRCB re Draft Hydrology Flood Frequency Analysis Dated 20151214
14	20171114	AT EIA-R to NRCB re Breach Analysis and Inundation Mapping Dated 20170308
15	20171114	AT EIA-R to NRCB re AMEC Flood Mitigation Measures to SAFRTF Dated 201406
20	20180326	AT EIA to NRCB re Vol 1 Project Description
27	20180326	AT EIA to NRCB re Vol 3A S06 Hydrology
45	20180326	AT EIA to NRCB re Vol 3B S06 Hydrology
60	20180326	AT EIA to NRCB re Vol 3D S01 Accidents and Malfunctions
156	20201210	NRCB Springbank PHC Decision Report
159	20201218	AT SIR to NRCB re Preliminary Design Report

NRCB Exhibit Number	Date	Document Title
160	20201218	AT SIR to NRCB re Preliminary Design Change Summary Memo
173	20210201	AT EIA to NRCB re PDR Appendix B Hydrology
174	20210201	AT EIA to NRCB re PDR Appendix C Hydraulics
175	20210201	AT EIA to NRCB re PDR Appendix D Geotechnical Volume 1
176	20210201	AT EIA to NRCB re PDR Appendix D Geotechnical Volume 2
177	20210201	AT EIA to NRCB re PDR Appendix D Geotechnical Volume 3
178	20210201	AT EIA to NRCB re PDR Appendix D Geotechnical Volume 4
180	20210201	AT EIA to NRCB re PDR Appendix F Civil
187	20210203	AEP EIA to NRCB re EIA Complete Letter

1.6 SR1 Project Summary

Based on our review of the most recent design documents, Austin Engineering understands that the Off-Stream Storage Reservoir Project includes a new gated weir (Diversion Inlet) that will intersect the Elbow River west of Calgary, and divert flood flows via a diversion channel to a new off-stream storage reservoir. The reservoir will be impounded by a new earthfill embankment dam (the Off-Stream Storage Dam).

Flows in the Elbow River will be backed up via another new earthfill embankment dam (Floodplain Berm with an Auxiliary Spillway) near the diversion location. A new gated weir (Service Spillway) within the Elbow River and adjacent to the Diversion Inlet will control how much flow continues along the Elbow River towards Calgary.

The Diversion Structure is comprised of the following sub-components:

- Diversion Inlet
- Service Spillway
- Auxiliary Spillway
- Floodplain Berm
- Debris Deflector Barrier

See Figure 1 and Figure 2 for the locations and schematics of the project components, respectively. The SR1 Project has been designed to work in conjunction with the downstream Glenmore Reservoir to accommodate the 2013 flood event, which is estimated to be the 1:200 year flood event. The design discharge rate is approximately 160 m^3/s downstream of the Glenmore Reservoir.

Figure 1. Springbank Off-stream Storage Reservoir Project (SR1) component locations (Source: Government of Alberta)

Figure 2. Schematic of Diversion Inlet, Debris Barrier, and Service Spillway along Elbow River, looking north (Source: Government of Alberta)

1.6.1 Consequence Classification

The Dam Safety Hazard Classification for the Diversion Structure and Storage Dam have been assigned based on the Canadian Dam Association (CDA) Dam Safety Guidelines 2007 (2013 Edition) and the Alberta Dam and Canal Safety Directive (GoA, 2018). The Hazard Classification is selected based on the consequences associated with a hypothetical failure of the Dam. The results of the inundation study (Ex 14 and Ex 174) were used to support the hazard classification designation.

The dam failure hazard (consequence) classification of the Diversion Structure and the Off-Stream Storage Dam are summarized in Table 3 (Ex 159 page 26 and 27).

Table 3. Consequence classification of project components

Project Component	Consequence Classification
Diversion Structure	High
Off-Stream Storage Dam	Extreme

1.7 Organization and Methodology

The engineering design review has focused on the following project features in order to identify potential dam safety improvements for the SR1 Project:

- Floodplain Berm
- Auxiliary Spillway
- Debris Deflector
- Service Spillway
- Diversion Inlet
- Diversion Channel
- Emergency Spillway
- Off-Stream Storage Dam
- Low Level Outlet
- Off-Stream Storage Reservoir

Austin Engineered has organized the results of the engineering design review into the following four sections:

- Hydrotechnical Considerations
- Geotechnical Considerations
- Operational Considerations
- Environmental Considerations

Structural analysis of the outlet works was excluded in the PHC Decision Report (Ex 156), so Austin Engineering did not undertake structural analysis of the outlet works.

However, we did complete a tabletop risk assessment for risks associated with the outlet works for consideration in permitting and approval.

1.7.1 Hazard and Failure Modes Identification

Although development of the hazard and failure modes matrix was removed from the review (as per the PHC Decision Report), Austin Engineering undertook a tabletop review and created a list of hazards and failure modes. A risk level of High (H), Medium (M), or Low (L) was then assigned based on the likelihood and consequence. The hazards and assigned risk levels for each of the project components are summarized in Table 4. Our objective was to identify the critical areas in which to focus our engineering effort for evaluation of the Off-Stream Storage Reservoir components given the time constraints for our evaluation.

The primary risks that we identified for the Off-Stream Storage Reservoir Project are fundamentally driven by hydrotechnical inflows and outflows and geotechnical stability of the structure.

As such, Austin Engineering could not develop a thorough assessment report outlining the risks of the project without undertaking some geotechnical stability and seepage analysis modelling, despite independent analyses of this nature being excluded from our scope. Therefore, we conducted our geotechnical review on a high-level basis, utilizing data obtained and available on the NRCB website, such as the geotechnical investigation program.

Table 4. Failure and Hazard Modes and Assigned Risk Levels

Project Component	Hazard	Assigned Risk
Service Spillway	Blockage due to ice/debris	M
	Weir stuck open due to ice/debris	M
	Weir plates loss due to damage.	L
	Sabotage	M
	Mechanical failure	M
	Instrumentation failure	M
	Operator error	M
	Delay in response time	H
	Larger flood than system can handle	M

Project Component	Hazard	Assigned Risk
	Construction or design defect	M
	Structural or foundation failure	L
	Erosion downstream (undermined)	L
	Improper maintenance	L
	Loss of power	M
Trash Screen/ Debris Diffuser	Plugged by ice (debris)	M
	Damage	M
	Improper cleaning due to maintenance access	M
	Overtopping	L
	Flow restriction preventing intake reaching design flow	M
	Concrete plinth below deflector acting as broad crested weir	M
	Erosion	M
Diversion Inlet	Erosion downstream	M
	Mechanical gate failure	M
	Lack of maintenance provisions (access)	M
	Electrical failure	M
	Instrumentation failure	M
	Delay in response	H
	Blockage due to ice	H
	Operator error	M
	Debris stuck below gate	M
	Overtopping of gates, causing damage to the control building	M
	Gates frozen/stuck open or closed	L

Project Component	Hazard	Assigned Risk
	Sabotage	M
	Operational error	M
	Construction/design error	M
Diversion Channel	Erosion	M
	Geotechnical stability	L
	Silt at reservoir inlet restricting flow	H
	Reduced hydraulic capacity	L
	Rapid drawdown stability	L
	Settlement	M/H
	Aquifer eroding dams/berms	L
	Overtopping	M
	Ground water flow – aquifer surcharge	L
	Sliding failure on fluvial deposit	L
	Rotational failure	L
	Construction or design defect	L
	Seismic event	L
	Winter fill placement	M
	Piping failure	L
Emergency Spillway	Scour downstream	H
	Sliding failure	M
	Discharge capacity exceeded	L
	Blockage	L
	Foundation/structural failure	L
	Rotational failure	L
	Construction or design defect	L

Project Component	Hazard	Assigned Risk
	Seismic event	L
	Winter fill placement	M
	Piping failure	L
Off-Stream Storage Dam	No ability to rapidly draw down below Emergency Spillway	H
	Sediment buildup	H
	Erosion	L
	First fill issues	H
	Seismic	L
	Settlement	M/H
	Instrumentation failure	M
	Lack of instrumentation (seepage weirs, settlement monitors, piezometers)	Risk level has not been assigned due to unknowns
	Frost penetration/settlement at existing utilities	M
	Extended period of turbidity	H
	Low level outlet blockage	M
	Sliding failure	L
	Rotational failure	L
	Overtopping	L
	Wave action	H
	Fish entrapment	H
	Piping failure	L
	Pipeline rupture below dam (differential settlement)	M
Low Level Outlet	Blockage	M

Project Component	Hazard	Assigned Risk
	Gate mechanical failure	L
	Seepage around conduit	L
	Conduit failure	M
	Intake screen plugged	M
	Differential settlement	M
	Sediment above intake level	M
	Electrical failure	M
	Instrumentation failure	M
	Jammed gate	M
	Sabotage	M
	Frozen shut	M

2.0 DESIGN REVIEW RESULTS

2.1 Hydrotechnical Considerations

Our hydrotechnical analysis focused on a high-level review of discharge capacities and the ability of the structures to pass the design flows while maintaining the minimum required freeboards for wind setup and wave runup, as well as identifying areas of concern with regards to erosion.

2.1.1 Inflow Design Flood

The Inflow Design Floods (IDFs) for the Diversion Structure and Off-Stream Storage Dam are provided in Table 5. The IDF is determined from hydrological modelling for the applicable Annual Exceedance Probability (AEP). The applicable AEP is based on the failure consequence classification (CDA, 2013).

However, the Diversion Inlet controls or limits the maximum flow into the Storage Reservoir and the remaining Elbow River flow discharges through the Service Spillway and Auxiliary Spillway on the Floodplain Berm.

The 1:1000 year flood in the Elbow River was determined as 1,930 m^3/s. (Ex 159 Section 3.4.3 pg. 33-34).

The Probable Maximum Flood (PMF) in the Elbow River was determined to be 2,770 m^3/s (Ex 159 Section 3.4.2 page 31 to 32).

Table 5. IDF summary for project components

Project Component	IDF (CDA, 2013)
Diversion Structure	High consequence AEP = one-third of the way between 1:1000 year flood and PMF = 2,210 m^3/s
Off-Stream Storage Dam	Extreme consequence PMF = 2,770 m^3/s

2.1.2 Diversion Inlet Capacity

The Diversion Inlet is designed as a gated, rectangular broad-crested weir with two bays. Each inlet bay width is 20 m, to give a total width of 40 m.

Figure 3 shows Section B taken from Drawing 73396S-331 in the Final Preliminary Design Report (Ex 159 page 343). The bottom elevation of the access bridge across the diversion inlet (to the gate hoists) is shown as 1215.5 m. The inlet invert elevation is 1211.5 m. This gives a maximum flow depth below the access bridge of 4.0 m before the water surface hits the bottom of the bridge and the curvature on the bottom of the bridge girder indicates water levels higher than this are anticipated.

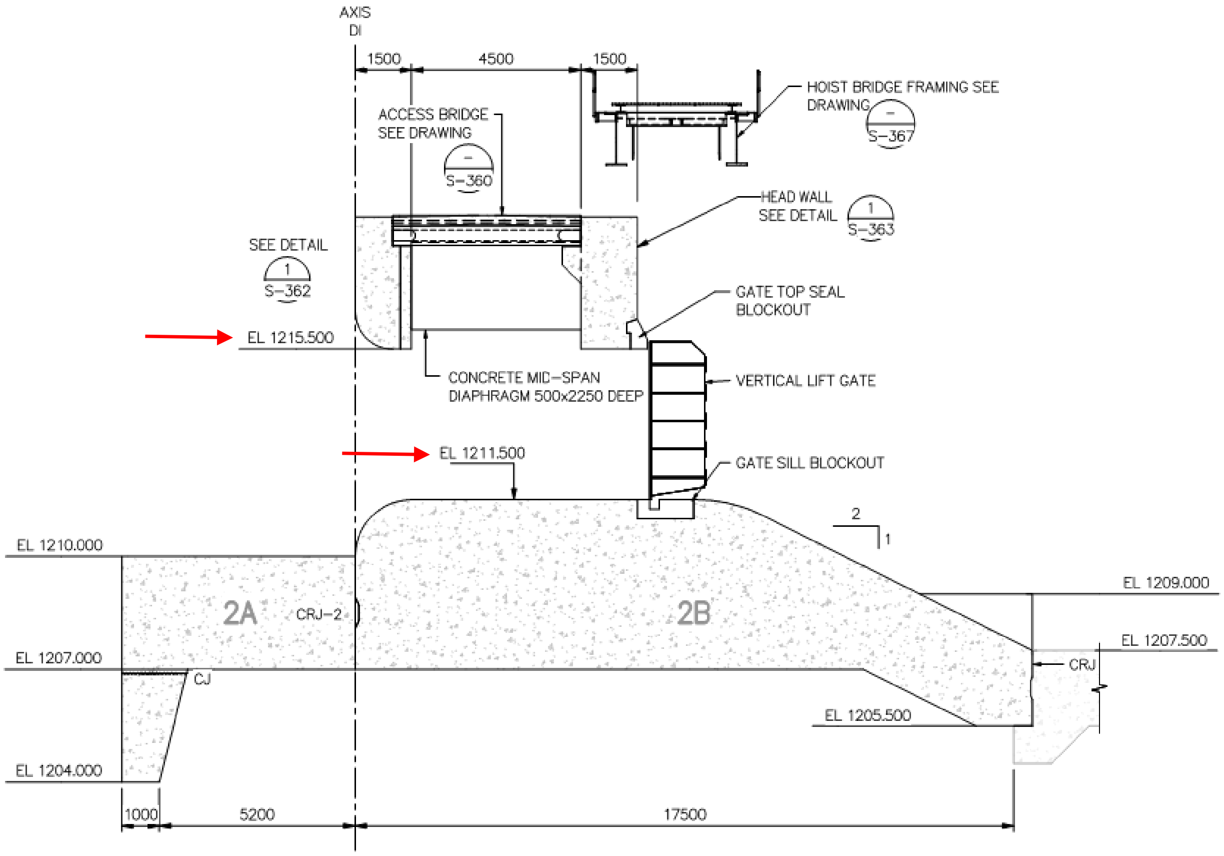

Figure 3. Diversion Inlet cross section from Final Preliminary Design Report (Ex 159 page 343)

Utilizing the rectangular broad-crested weir equation, Equation 1 (Smith 1978), with a coefficient of discharge (C) of 1.7, a total width (L) of 40 m, and a flow depth of 4 m gives an approximate weir discharge capacity of 544 m³/s.

Equation 1. Rectangular broad-crested weir equation

$$Q = CLH^{3/2}$$

$$C = (\frac{2}{3})^{3/2} g^{1/2}$$

where

Q = Discharge (m³/s)

L = Width of weir perpendicular to flow direction (m)

H = Head above weir crest (m)

C = Coefficient of discharge

The Diversion Inlet rating curve given in Section 8.2.4.2 of the Final Preliminary Design Report (Ex 159 page 100, Figure 19) shows water surface elevations higher than 1215.5 m, up to 1217 m. We recommend that the access bridge design be reviewed to ensure that adequate freeboard (between the bridge and water surface) is achieved during passage of the design flow of 600 m^3/s and that the bridge will not suffer damage due to ice, and high water levels during a flood event.

2.1.3 Freeboard

Section 10.1.3 of the Final Preliminary Design Report (Ex 159 page 177 to 178) summarizes the freeboard requirements for the Off-Stream Storage Dam as follows:

- Normal freeboard: 2.25 m
- Minimum freeboard: 1.46 m

The maximum reservoir level to maintain the minimum freeboard is 1212 m.

Maintaining the minimum freeboard requires the operator to close the Diversion Inlet gates once the reservoir reaches a level of 1212 m. Although no operation guidelines have been provided for review, it is assumed the operator of the Diversion Inlet will be quite a distance from the reservoir during gate operation. Thus, there is a need for adequate procedures and properly selected reliable instrumentation and backup power to ensure the Diversion Inlet gate operator has the information required to make the decision to close the gates. See our recommendations in Section 2.3.10.

2.1.4 Off-Stream Storage Dam

The design flow for the Diversion Channel is 600 m^3/s.

The Off-Stream Storage Dam (Storage Dam) has two discharge facilities:

1) Low Level Outlet (LLO): max discharge = 27 m^3/s (Ex 159 page 25)
2) Emergency Spillway: max discharge = 360 m^3/s (Ex 159 page 25)

Based on these flow values, the Emergency Spillway is undersized compared to the Diversion Channel, which in this case controls the inflow into the reservoir and is noted to be 600 m^3/s. The CDA Dam Safety Guidelines (CDA, 2013) call for the spillway of the structure to be rated for the Inflow Design Flood (IDF). As the maximum inflow, although controlled, is 600 m^3/s, the typical required spillway discharge should also be 600 m^3/s.

Additionally, the Emergency Spillway is positioned at such a high elevation within the Diversion Channel that it cannot prevent the Storage Dam from overtopping if the Diversion Inlet gates are left open during a large flood event. Refer to Figure 4 below for the Diversion Channel cross section at the Emergency Spillway location (station 13+400).

Based on the CDA Dam Safety Guidelines (CDA, 2013), the spillway of a dam must be able to discharge the IDF while maintaining the minimum required freeboard.

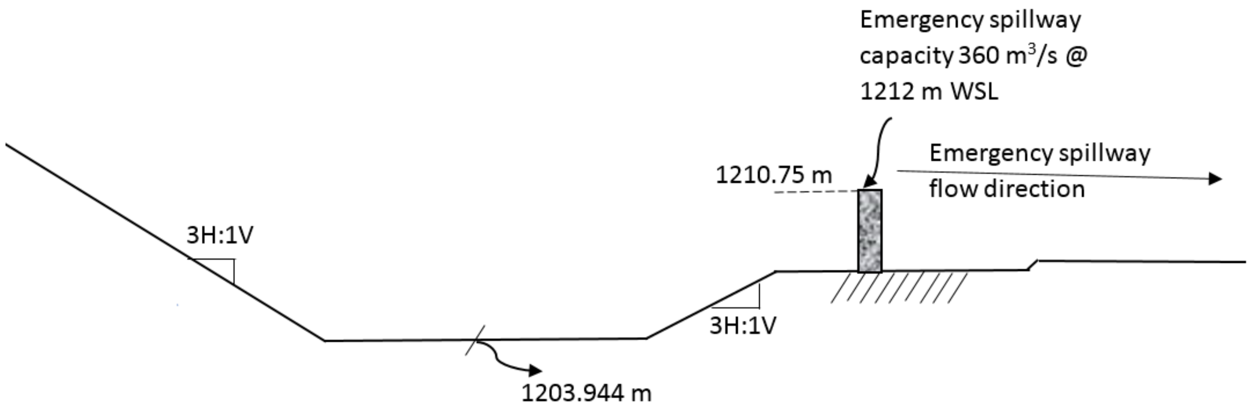

Figure 4. Diversion Channel cross section at station 13+400 looking downstream towards the Storage Dam (not drawn to scale)

2.1.4.1 Emergency Spillway

The Emergency Spillway maximum discharge capacity (360 m^3/s) is less than the IDF and less than the Diversion Channel design flow.

The Emergency Spillway requires the Off-Stream Storage Reservoir to fill to an elevation of 1210.75 m, which creates a back-water effect within the Diversion Channel all the way to station 11+100 (approximately), before the Emergency Spillway can start spilling. Unless the Diversion Inlet gates are closed, the Diversion Channel will continue to discharge. Should the gates remain open, it will take only 12 hours to overtop the Storage Dam with an inflow of 600 m^3/s (reservoir fills from 1210.75 m to 1213.5 m). Service Spillway discharging will also not prevent flow from entering the Diversion Channel with the Diversion Inlet gates open (unless the flow depth in the Elbow River is less than 1.5 m, which is unlikely directly following such a flood event).

The design relies on the Diversion Inlet gates being functional or an operator being able to close the gates to prevent overtopping the Storage Dam. It is not ideal that the Off-Stream Storage Dam's ability to safely discharge inflows completely relies on the operation of gates at the Diversion Inlet. If the gates cannot close, the Emergency Spillway should be able to safely pass design inflows to prevent overtopping.

There are several scenarios that could lead to the Diversion Channel conveying more water than the Emergency Spillway could pass, including one or both Diversion Inlet gates getting stuck in the open position during a flood event.

A redesign of the Emergency Spillway should be considered to increase the discharge capacity from 360 m^3/s to 600 m^3/s (or to match the maximum capacity of the Diversion Inlet).

Possible design options include the following:

- Keeping the Emergency Spillway at the current location in the Diversion Channel but lowering the invert elevation during a large event by using a fuse plug design; or
- Changing the location of the Emergency Spillway to the Storage Dam and using an ogee style weir. The discharge flow path would be similar to the Low Level Outlet flow path in the existing design.

2.1.4.2 Emergency Spillway Armouring

The safe operation of the Storage Dam relies on the Emergency Spillway. Review of the design for the Emergency Spillway does not show any downstream armouring or erosion protection. Should the Diversion Inlet gate(s) jam in the open position, the Emergency Spillway may be required to discharge for a long period of time. As such, we recommend that the outlet of the Emergency Spillway be channelized with riprap or other erosion protection between the downstream extent of the Emergency Spillway and the return to the Elbow River.

2.1.5 Dam Breach Analysis and Inundation Mapping

The Storage Dam breach analysis and inundation mapping produced by Stantec (Ex. 14) were reviewed during our assessment, in particular the flooding extents from the Dam breach (Ex 14 pages 30 to 41/Ex 174 pages 364 to 375). Based on our review of the Storage Dam break inundation maps we agree with Stantec's assigned consequence classification of 'extreme' for the Storage Dam.

We recommend the following updates to the Storage Dam break analysis and inundation mapping:

- Inundation maps should be updated to show the flood flow depths and velocities.
- Storage Dam break analysis should include an estimation for the loss of life.
- The Diversion Structure/Floodplain Berm dam break analysis should be separated from the Storage Dam break analysis and two sets of inundation maps developed (one set for the Storage Dam break and the other set for the Floodplain Berm dam break). The Floodplain Berm (as part of the Diversion Structure) and the Storage Dam are classified as separate structures, and would therefore have different emergency response procedures based on which structure were to fail.

2.1.6 Service Spillway

The rating curve for the Service Spillway has been provided in Ex 174 (page 391). The maximum possible flow through the Service Spillway occurs when the Obermeyer weir is at an elevation setting of 1210.0 m and the water surface is at 1215.7 m. The rating curve shows a maximum discharge of 585 m^3/s (approximately) for a single 24 m wide bay. This flow has been multiplied by 2 to give the maximum discharge of the Service Spillway of 1170 m^3/s, which is in the same order of magnitude as results achieved using Equation 1 (see Section 2.1.2).

2.1.7 Floodplain Berm

The stage-storage curve has not been provided for the Floodplain Berm in the Final Preliminary Design Report (Ex 159), presenting challenges when reviewing the Floodplain Berm. Although this does not contribute a large area to the overall storage of the structure, should the Floodplain Berm be utilized to impound water due to meandering of the Elbow River, the storage behind the Floodplain Berm could potentially be utilized to mitigate floods in the future. As such, it may be beneficial that a stage-storage curve be developed and provided to the NRCB.

During review of the hazards and risks associated with the dam, Austin Engineering noted that a debris jam has the potential to reduce the overall capacity of the Service Spillway at the diversion structure. Such a jam would be the result of debris collecting on the debris deflector, becoming dislodged, and accumulating either at the Service Spillway weir or directly downstream of the weir. A reduction in capacity of the Service Spillway weir could potentially lead to a back-water effect upstream of the Floodplain Berm, and potentially result in the Auxiliary Spillway fuse plug being removed.

2.1.8 Auxiliary Spillway

The Auxiliary Spillway does not start to flow until the water surface in the reservoir impounded by the Floodplain Berm exceeds an elevation of 1216.5 m (pilot channel crest) and requires the fuse plug to be removed from the crest down to an elevation of 1215.8 m. The maximum flow for the Auxiliary Spillway is provided in Ex 159 (page 25) as 620 m^3/s at a water surface elevation of 1217.3 m.

Appendix F, F.3.1 (Ex 180 page 52), Section 4.4 indicates an overtopping depth of 0.4 m is required to initiate erosion of the fuse plug. This translates to a water surface elevation of 1216.9 m and 1217.2 m at the fuse plug pilot channels and full sections, respectively.

Section 4.4 (Ex 180 page 52), also states:

The entire fuse plug needs to erode during the IDF event prior to the water surface elevation (WSE) reaching the peak WSE of the IDF event.

This may require the operator to close the Diversion Inlet gates between WSEs of 1216.9 m and 1217.2 m to provide sufficient fuse plug erosion time leading up the peak IDF WSE. If the operator keeps the Diversion Inlet open during the IDF peak, the fuse plug may not erode sufficiently and safe discharge of the IDF might not be achieved.

We recommend the Diversion Inlet gate operation between WSEs of 1216.9 m and 1217.2 m be documented, as well as contingencies for the following conditions:

- The fuse plug does not operate (erode) as expected.
- Activation of the fuse plug causes water quality (sedimentation and turbidity) issues downstream.

2.1.9 Total Diversion Structure Discharge

The total Diversion Structure Discharge capacity will vary depending on the operational setting of the Diversion Inlet gates and the Service Spillway weir. The operational setting of these systems at any time depends on the Elbow River flows as described in Section 8.1.3 of Ex 159 (pages 84 to 85) and summarized in Table 6.

Table 6. Diversion Inlet Gate and Service Spillway Weir Operation Based on Elbow River Flow

Flow in Elbow River	Operation
0 – 160 m^3/s	No Diversion Service Spillway weir fully open
160 – 760 m^3/s	Diversion Inlet gates opened incrementally with discharge flow between 0 - 600 m^3/s Service Spillway weir raised incrementally to maintain a flow rate downstream of 160 m^3/s
760 – 1600 m^3/s	Diversion Inlet gates open Service Spillway weir incrementally lowered
1600 m^3/s to IDF	Diversion Inlet gates closed to limit diversion flows to no more than 600 m^3/s Service Spillway weir fully lowered

The corresponding water surface elevations for the above operation scenarios and total Diversion Structure flow has been determined (using a combination of Equation 1 and rating curves as summarized in Table 7.

Once flows in the Elbow River increase from 160 to 760 m^3/s, it will be challenging for operators to maintain a flow of 160 m^3/s in the Elbow River downstream of the Service Spillway, as they will have to change the setting on the Obermeyer weir based on 6 rating curves (Ex 174 page 391). Also, it is unlikely that operators will be able to develop a comfort level with the system, as they will only have the opportunity to operate the Obermeyer weir at all 6 settings under full head, when a flood event is underway. This increases the probability of erroneous operation.

Although Section 8.1.3 of Ex 159 (pages 84 to 85) indicates that operation of the Diversion Inlet gates and Service Spillway weir will be based on Elbow River flows, in reality the operation of these systems will also be governed by available remaining storage volume at both the SR1 and Glenmore reservoirs. This additional complexity means the operators will need to use sophisticated tools (such as software performing calculations based on real-time and forecasted data) in order to manage the system effectively and safely.

The Diversion Inlet gates are assumed to be closed once the Elbow River water surface elevation exceeds an elevation of 1216.9 m, based on the information provided in Appendix F, F.3.1, Section 4.4 (Ex 180 page 52 to 54). This is also the WSE elevation at which the fuse plug in the two pilot channels starts to erode. It is implied that the Diversion Inlet gates should be closed to ensure sufficient head (0.4 m) occurs for a long enough duration (2.76 hours) for the fuse plug to become completely eroded, immediately before the peak IDF WSE is reached. It is assumed, that once the Auxiliary Spillway fuse plug is eroded (or activated), that if the river flows exceed the IDF, the Diversion Inlet gate can be opened so that the Diversion Structure can discharge up to the total flood. In the event this exceeds the IDF of the Diversion Structure, the emergency response documents should include additional instruction for the operators under this scenario.

Table 7. Total Diversion Structure Flow

Water Surface Elevation in Elbow River (m)	Flow (m^3/s)			
	Diversion Inlet	Service Spillway	Auxiliary Spillway	Diversion Structure
1211.7	Closed	150.0	0	150.0
1212.3	48.7*	160.0	0	208.7
1213.15	144.1*	160.0	0	304.1
1214.2	301.7*	160.0	0	461.7
1215.05	454.8*	160.0	0	614.8
1215.2	484.0*	190.0	0	674.0
1215.3	503.7*	376.0	0	879.7
1215.4	523.7*	646.0	0	1169.7
1215.5	544.0*	920.0	0	1464.0
1215.7	544.0*	1170.0	0	1714.0

Water Surface Elevation in Elbow River (m)	Flow (m^3/s)			
	Diversion Inlet	Service Spillway	Auxiliary Spillway	Diversion Structure
1216.9	544.0*	1352.3*	11.2*	1907.5
1217.3	Closed	1609.0*	620.0**	2229.0
1217.3	544.0*	1609.0*	620.0**	2773.0

*Calculated using Equation 1

**Assumes that entire fuse plug is removed down to 1215.8 m

To address these concerns, Austin Engineering recommends the following:

- Diversion Inlet capacity should be reviewed due to the access bridge breastwall and headwall causing a flow restriction.
- Stantec should confirm the Elbow River water surface elevation that results in the fuse plug being removed down to an invert elevation of 1215.8 m. i.e. Does the WSE need to be 1217.2 m for a minimum duration of 2.76 hours to remove the entire 208 m long fuse plug, or will a WSE of 1216.9 m be sufficient based on the erosion starting at the pilot channels and progressing over the length of the fuse plug over 2.76 hours?
- More information should be provided on the Diversion Structure rating curve with various operation combinations of the Diversion Inlet, Service Spillway, and Auxiliary Spillway.
- It should be confirmed that the Service Spillway Obermeyer weir can operate at flow depths greater than 5.8 m (with debris flow included) in order to safely pass the IDF in combination with the Auxiliary Spillway.

2.1.10 Flood Protection

The maximum discharge capacity of the Glenmore Dam low level outlet is 160 m^3/s (Ex159 page 84). One of the main objectives of the SR1 Project is to maintain a flow of 160 m^3/s downstream of the Service Spillway when flows in the Elbow River are between 160 and 760 m^3/s. The degree of flood protection provided between the SR1 Project and the Glenmore Dam is difficult to determine during this design review as flood maps showing the flood extents within the Elbow River between the Service Spillway and the Glenmore Dam, based on operation of the Diversion Structure, have not been made available.

We recommend flood maps be produced, showing the flood extents within the Elbow River between the Service Spillway and the Glenmore Dam, for Service Spillway discharge flows of 160 m^3/s, 760 m^3/s and 1600 m^3/s. The three flood maps should be used to determine impacts and identify if flood protection works are required along this stretch of the Elbow River.

In addition, we recommend that operational guidelines for the following conditions be developed prior to project approval:

- Glenmore Reservoir levels that trigger the Diversion Inlet gate opening independent of Elbow River flows.
- How forecasting systems will be used to predict trends for operation.

The degree of flood protection provided by the SR1 Project to both the City of Calgary and Springbank communities will depend heavily on the operation guidelines and systems developed and implemented.

2.1.11 Flood Flow Estimation Uncertainty

2.1.11.1 Climate Change

Many events can affect the overall flood flows, including forest fire, future development upstream of the Project, upstream logging, and changes in temperature affecting frost penetration depth (climate change). These unpredictable events will likely alter the runoff coefficients used to determine the flood flow estimations.

After a review of the development of the design flood case (Ex 173), it is unclear what factors were associated with future climate change, whether allowances for future development upstream have been included, and whether there are any allowances for factors affecting the overall magnitude of a flood or affecting the distribution of the flood curve. For example, a change in runoff coefficients may not significantly alter flood volumes but can change the overall peak of the flood. While the overall volume of the flood may end up being similar, the maximum flow could be compressed into the early stages and heighten the overall peak of the flood flow.

Due to the uncertainty of these variables, Austin Engineering recommends that the design flood case include allowances for forest fire and climate change in determination of the overall peak of the flood flow curve, if not already included. If these allowances have already been considered, the design flood case should be clarified to state what allowances were made during the flood flow determination.

2.1.11.2 Limited Historical Records Prior to 1934

While we understand that the structure has been designed based on the 2013 flood flow event, the design of a dam of this nature must include a thorough review of the flood flow events and the determination of the design flood flow is particularly critical with regard to the intake elevations, gate sizing, and spillway weir sizing.

We note that the design flood event for design of the structure was based on data that included a near real-time data set from monitoring stations at Bragg Creek and Sarcee Bridge. The data from these stations was collected between 1934 to 2013, with some sporadic gaps, as is typical of monitoring stations.

We also note that several large flood events that occurred prior to 1934 have been excluded from the data set, including very large flood events that occurred in 1879, 1897, and 1902. The reason for exclusion from the data set is that continuous monitoring data was not available for these three isolated, large events, and thus the data from these events would be challenging to analyze reliably.

However, as these floods were significant, it brings into question the level of confidence for the 1:200 year flood event established for the design levels if these three significant events are not included in the data. If these three large flood events cannot be reliably included in the data analysis, we recommend the IDF include an allowance for uncertainty of the design flood to better represent the likelihood of these three large events, which did occur within the 1:200 year recurrence interval, prior to completing final design of the diversion structure, spillways, and gates.

2.1.11.3 Rain-on-Snow

Rain-on-snow events have a significant contribution to overall flood conditions. The 2014 AMEC Flood Mitigation Measures report (Ex 15 Section 3.2 page 60) noted the following:

Flood discharges along the Elbow River result from three primary causes: snowmelt, rainfall with little or no snowmelt, or rain-on-snow. The latter characteristically produces the largest floods. Given the range of potential flood runoff inputs depending on the timing, rate and location of rainfall and snowmelt inputs, a wide range of runoff hydrographs can result.

The design considered snowmelt for model calibration purposes (Ex 11 Section 3.3.1 page 20/Ex 173 page 538) based on the contribution of snowmelt to the 2005 and 2013 flood events, with the volume of snowmelt for each event estimated.

Snowmelt for the PMF model was calculated external from the HEC-HMS model and entered as a baseflow hydrograph. (Ex 11 Section 3.3.1 page 21/Ex 173 page 539).

We recommend that the impact from the rain-on-snow scenario be reviewed as part of the Probable Maximum Precipitation analysis (Ex 173 page 60) to ensure that prior to the final design, if required, the Diversion Structure IDF be updated along with any associated design changes to the structures.

2.1.12 Upstream Erosion Bypassing Diversion Inlet

The location of the diversion inlet has been well chosen as the high ground southwest of the inlet, which significantly reduces the likelihood of erosion causing bypassing on the left side of the River channel (looking downstream). The field immediately west of the diversion inlet is at an elevation of 1236 m.

However, Section 8.1.6.3 “Channel Switch” in the final preliminary design report (Exhibit 159 page 93) acknowledges that channel migration or switch is possible on the right side of the River channel (looking downstream) and the design appears to be relying on the Floodplain Berm to mitigate the risks. The design includes erosion protection on sections of the Floodplain Berm where overland flow is expected to connect with the upstream slope. We recommend operators closely monitor the Floodplain Berm for erosion on the upstream slope during and after a flood event and ensure this direction is included in the Operation, Surveillance and Maintenance Manual for the SR1 Project.

In addition, Highway 22 would act as a barrier to large scale migration on the east side. Ultimately, the Floodplain Berm appears to be designed to intercept any overland flow and direct flow towards the Diversion Inlet and Service Spillway.

2.1.13 Isolation of Diversion Inlet Gates

The design does not currently allow for isolation for the Diversion Inlet gates for maintenance activities. Regular maintenance of the Diversion Inlet gates is important to the reliable functioning of these critical components of the diversion system. Austin Engineering assumes that the current plan is to lower the Service Spillway weir to bypass water over top of the weir during maintenance of the Diversion Inlet gates.

The inclusion of stoplog gate guides (slots) and one set of stoplogs within the design would provide more flexibility for maintenance and testing of the gates should the weir operation prove insufficient to allow maintenance activities. In addition, stoplogs can be utilized to conduct gate testing while restricting flows into the structure, thereby minimizing requirements for fish salvage during gate flow testing. As such, Austin Engineering recommends the inclusion of stoplog slots, at a minimum, upstream of the Diversion Inlet gates.

2.1.14 Emergency (Secondary) Low Level Outlet

The final preliminary design (Ex 159) does not include a means to rapidly drawdown the Off-Stream Storage Reservoir in the event of a dam safety incidents or related emergency. Should any leading indicator occur during filling of the reservoir, such as sloughing, saturation of the downstream toe, sliding, or rotational failures, the current available operating mechanisms are to:

1) Shut the Diversion Inlet gates;
2) Allow for water to discharge over the Emergency Spillway (between reservoir water levels of 1210.75 m and 1212 m); and
3) Open the Low Level Outlet to draw the water down.

This drawdown can reportedly take up to 30 days, leaving the structure at risk for a prolonged period of time.

Ongoing monitoring and typical practices that would become routine through the continuous operation and maintenance of a reservoir, along with steady state conditions that typically stabilize over time within the reservoir environment, will not likely be achieved with this style of reservoir. As such, a major risk reduction would be to allow for rapid dewatering of the reservoir, if required during a dam safety emergency.

It is anticipated that during a flood event the reservoir will be filled very rapidly, early warning and detection systems will be activated, and plant operators will be on site to inspect the dam. Should dam safety concern be raised at that time, presumably, the Diversion Inlet gates would be closed immediately and the Low Level Outlet (LLO) be opened immediately.

However, Austin Engineering recommends that consideration be given for the addition of a secondary LLO to be utilized if an emergency drawdown of the reservoir is required and provide a secondary means of dewatering should the main LLO become plugged, damaged, or inoperable. This secondary LLO could be set at an interim elevation between the Emergency Spillway and the existing LLO, slightly above the elevation of the anticipated top of sedimentation and provide additional assurance that the reservoir can be dewatering should a higher than anticipated silt load be mobilized.

2.1.15 Riprap for Wave Runup

The Off-Stream Storage Reservoir will take up to 30 days to dewater following a flood event. It is unclear how soon after a flood event that dewatering of the reservoir will begin, as a flood event will likely introduce floodwaters downstream of the reservoir that need to be passed and addressed prior to discharging from the Off-Stream Storage Reservoir. As such, there is a period of time that the reservoir is likely to stay at the full pool or near full pool condition. During this time, wave run up and wind events are likely to occur.

The final preliminary design (Ex 159) does not indicate any riprap on the upstream face of the Storage Dam. While the structure is not continuously operated, it will be subject to the design cases and loads associated with wind setup and wave run up over its lifespan. Austin Engineering recommends that riprap armouring be included along the upstream face of the Storage Dam.

2.2 Geotechnical Considerations

During our geotechnical analysis, models were developed in RocScience and GeoStudio software packages. We undertook static analysis, seepage analysis, and seismic analysis, along with rapid drawdown and rapid filling analysis of the structure to obtain an overall indication of the geotechnical stability and level of safety of the proposed infrastructure.

As discussed earlier, Austin Engineering has undertaken a design-check level geotechnical modelling exercise based on the available data published on the NRCB website.

Models have been created based on the sections for the Floodplain Berm and the Storage Dam with inputs from the available geotechnical information. It should be noted this does not confirm the validity of geotechnical field data collection, and therefore, the analysis is based on the assumption that the field data collected is correct and reliable for analysis.

Results of our stability analysis were compared with minimum required safety factors provided in the CDA Dam Safety Guidelines (CDA, 2013), which are summarized in Table 8 and Table 9.

Table 8. Minimum Factors of Safety for Slope Stability – Static Assessment (CDA, 2013)

Loading Conditions	Minimum Factor of Safety	Slope
End of construction before reservoir filling	1.3	Upstream and Downstream
Long-term (steady state seepage, normal reservoir level)	1.5	Downstream
Full or partial rapid drawdown	1.2-1.3	Upstream

Table 9. Minimum Factors of Safety for Slope Stability – Seismic Assessment (CDA, 2013)

Loading Conditions	Minimum Factor of Safety
Pseudo-Static	1
Post-earthquake	1.2-1.3

2.2.1 Slope Stability Review

The slope stability material parameters and details of the geotechnical analysis performed by Stantec were provided in Exhibits 175 to 178 (Appendix D Volumes 1 to 4).The material properties shown in Appendix D Volume 4 (Ex 178) have been updated compared to values provided in the Draft Preliminary Design Report (Stantec, 2017).

Our slope stability analysis cross sections for the Storage Dam and Floodplain Berm reflect the geometry and layers detailed in Ex 159 but used material properties derived from the Draft Preliminary Design Report (Stantec 2017), as we only received Ex 175 to 178 on February 1st, 2021. The cross sections showing our slope stability analysis results are provided in Appendix A.

2.2.1.1 Storage Dam

For the Storage Dam, we performed an analysis for Section B shown on drawing 73396C-470 (Ex 159 page 305), which corresponds to station 23+175.

The results of the stability analysis review for the Storage Dam are summarized in Table 10 and the Stantec results were found in Table 41 of Ex 159 (page 193 to 194) and in Ex 178 (starting from page 296).

Table 10. Slope stability analysis results: Storage Dam

Loading Conditions	Minimum Calculated Factor of Safety		Slope
	Stantec	Austin Engineering	
End of construction before reservoir filling	1.6	1.8	Downstream
End of construction before reservoir filling	1.6	1.8	Upstream
Long-term drained	1.6	1.8	Downstream
Long-term drained	1.6	1.8	Upstream
Rapid drawdown (partial)	-	1.8	Upstream
Rapid drawdown (full)**	1.4	1.3	Upstream
Pseudo static	0.9*	0.7*	Downstream
Pseudo static	1.0	0.7*	Upstream
Post-earthquake	1.5	1.9	Downstream
Post-earthquake	1.6	1.5	Upstream

* below CDA Dam Safety Guidelines minimum recommended safety factor, additional review is recommended
**based on the current 30 day drawdown this is unlikely to occur

Austin Engineering performed an analysis for rapid filling of the Off-Stream Storage Dam based on the water level increasing from 1187 m to 1212 m over 35.6 hours. The results are summarized in Table 11 and we noted no concerns with the design cross section during rapid filling from a stability perspective.

Table 11. Rapid reservoir filling analysis results: Off-stream Storage Dam

Reservoir Filling Duration	Minimum Calculated Factor of Safety	
	Upstream	Downstream
10 hours	2.0	2.2
20 hours	2.0	2.15
30 hours	2.4	2.15
35.6 hours	2.8	2.1

2.2.1.2 Floodplain Berm

During our review of the Stantec slope stability analysis and results, we performed a verification analysis for Section B shown on drawing 73396C-270 (Ex 159 page 271), which corresponds to station 1+600.

The results of the stability analysis review for the Floodplain Berm are summarized in Table 12 and the Stantec results were found in Table 27 of Ex 159 (page 147) and in Ex 178 (starting from page 149).

It should be noted that the results shown in Ex 178 (starting on page 149) show the analysis has been conducted with Impervious Fill Zone 1A on the downstream dam face rather than Random Fill Zone 2A as shown on Section B of drawing 73396C-270 (Ex 159 page 271). The slope stability analyses should be reviewed to determine if results are impacted with material properties for Random Fill Zone 2A applied on the downstream face.

Table 12. Slope stability analysis results: Floodplain Berm

Loading Conditions	Minimum Calculated Factor of Safety		Slope
	Stantec	Austin Engineering	
End of construction before reservoir filling	1.5	1.3	Downstream
End of construction before reservoir filling	1.6	1.7	Upstream

Loading Conditions	Minimum Calculated Factor of Safety		Slope
	Stantec	Austin Engineering	
Long-term drained	1.5	1.3	Downstream
Long-term drained	1.6	1.7	Upstream
Rapid drawdown (partial)	1.6	1.6	Upstream
Rapid drawdown (full)	1.6	1.2*	Upstream
Pseudo static	1.0	0.75+	Downstream
Pseudo static	1.3	0.9+	Upstream
Post-earthquake	1.5	1.3	Downstream
Post-earthquake	1.6	1.7	Upstream

*at lower threshold of CDA Dam Safety Guidelines minimum recommended safety factor
+below CDA Dam Safety Guidelines minimum recommended safety factor, additional review is recommended

Austin Engineering performed an analysis for rapid filling of the Floodplain Berm based on the water level increasing from 1205 m to 1218.34 m over 1 hour. The results are summarized in Table 13 and we noted no concerns with the design cross section during rapid filling from a stability perspective.

Table 13. Rapid reservoir filling analysis results: Floodplain Berm

Reservoir Filling Duration	Minimum Calculated Factor of Safety	
	Upstream	**Downstream**
Empty	1.7	1.4
3 hours	1.6	1.4
4 hours	1.8	1.4
5 hours	2.1	1.4

2.2.2 Seismic and Deformation Analysis

2.2.2.1 Site Specific Seismic Hazard Assessment

The site specific seismic hazard assessment for the SR1 Project completed by Stantec (Ex 178) is an extensive study and has encompassed historical seismicity from the Canadian Composite Seismicity Catalogue (CCSC11) for Western Canada and The Alberta Geological Survey (AGS) database. To define the Earthquake Design Ground Motion (EDGM) with an Annual Exceedance of Probability (AEP) of 1:10,000 for the SR1 Project, two alternative seismic source models were developed. One is a regional source model and the other is a local source model taking into account all potential seismic sources capable of contributing to the SR1 site.

We are of the opinion that Stantec's probabilistic analysis approach is sufficient and consider the EDGM values for an AEP of 1:10,000 developed for the SR1 site to be conservative. Moreover, this study was reviewed by expert and leading researcher Dr. Atkinson. and adequately fulfills the CDA Dam Safety Guidelines (CDA, 2013) requirements.

2.2.2.2 Pseudo-Static and Deformation Analysis

Stantec's seismic analysis of the Storage Dam found that the required CDA Design Safety Guidelines (CDA, 2013) minimum factor of safety for the pseudo-static scenario was not achieved for all sections analysed. The lowest factor of safety (0.7) was seen at Section 22+500.

Section 10.3.5.7 of the Final Preliminary Design Report (page 194 of Ex 159) indicates that a deformation analysis was completed for the Off-Stream Storage Dam and the resulting deformation (0.23 m) was less than the 1.0 m threshold, and therefore the low factor of safety was not a concern.

The deformation analysis results presented in Section 10.3.5.7 of the Final Preliminary Design Report (page 194 of Ex 159) indicate that sufficient freeboard will be maintained following a seismic event, but the Storage Dam design does not mitigate against slope failure during an earthquake. We recommend that the Storage Dam design be modified to ensure the minimum CDA factor of safety of 1.0 be achieved for the pseudo-static scenario and this 0.23 m deformation is reviewed, particularly at the low level outlet, to ensure the concrete conduit is not likely to be damaged during a seismic event.

The minimum factor of safety for the Floodplain Berm during pseudo-static loading is 1.0 (at Section 1+600).

Typically, when performing a Dam Safety Review, if the pseudo-static factor of safety is less than 1.0, a recommendation to made to the dam owner to start planning for dam modifications to increase the pseudo-static stability. It would be imprudent to construct a new dam with a safety factor at or below the CDA minimum safety factor thresholds.

Access to all Appendices to Ex 159 was requested on January 27th, 2021. Exhibit 175 to 178 (Appendix D – Geotechnical, Volumes 1 to 4) were uploaded to the NRCB website on February 1st, 2020. At the time of this filing, we are reviewing Ex 175 to 178 and may provide further comment on the overall embankment and design characteristics with regard to seismic deformation and geotechnical failure at a later time.

2.2.3 Differential Settlement

The Off-Stream Storage Dam has a large self weight and is likely to generate settlement over time. In addition, the dam will likely experience differential settlement due to underlying foundation conditions. In other words, the settlement will be greater where the overall weight of the dam is greater and less where the thickness of the dam fill (height) tapers out. This is of particular concern at the Low Level Outlet (LLO), where we are likely to see differential settlement between the intake through the core of the dam and the discharge conduit on the downstream side.

This differential settlement must be considered, as the current LLO design indicates concrete conduit, a rigid pipe system, is to be utilized. Based on the anticipated settlement within this portion of the dam and that stresses are likely to be quite significant due to the settlement over time, we recommend considering a more flexible conduit for discharge from the LLO.

Differential settlement may also result in a loss of crest height over time. As the Off-Stream Storage Dam will not be operating continuously, inspection routines may not visually assess settlement along the crest of the dam. As such, surveys must be conducted on a regular basis to assess whether settlement along the crest of the dam is negatively affecting the overall storage capacity or freeboard of the reservoir.

If it is found that settlement along the crest of the dam is lowering the overall crest of the dam, instrumentation set points will need to be adjusted to maintain adequate freeboard during diversion of flood waters, and the emergency spillway elevation may ultimately require review if the maximum anticipated settlements are reached over time.

2.2.4 Fracking Exclusion Zone

During a review of the available documentation on the National Resources Conservation Board (NRCB) website, Austin Engineering did not encounter any reference to fracking induced seismic events. As a significant amount of fracking has been undertaken within Alberta, the approval to commence construction of the Off-Stream Storage Reservoir should be contingent on establishing a dedicated fracking exclusion zone surrounding the project extents. This zone is to be established by the design engineers to ensure that the Project structures are not damaged due to local fracking activity.

2.2.5 Springbank Road

During filling of the Off-Stream Storage Reservoir, a portion of Springbank Road will temporarily act as dam until the reservoir level equalizes on both sides of the road. At this time, the design does not clearly indicate whether stability assessments for Springbank Road have been undertaken. If not, a slope stability analysis of the impacted section of Springbank Road should be conducted to ensure that the road is stable during and after reservoir filling and that the road meets the CDA Dam Safety Guidelines (CDA, 2013), as shown in Table 8 and Table 9. We do however note that a failure of this roadway will be contained within the reservoir but may impede access during an emergency.

In addition, it is unclear if the design has considered installing drainage culverts below Springbank Road. If not, we recommend that drainage upgrades Springbank Road be included in the final project design.

2.2.6 Future Use Changes

It is possible that in the future, the Off-Stream Storage Reservoir may be used for more than flood mitigation purposes. Climate change and population growth may reduce the ability of Glenmore Reservoir to meet future demands adequately. It is feasible that in the years ahead, the City of Calgary may decide to supplement the City's water supply by changing SR1 to a permanently wetted system. Consideration should be given to future changes in the purpose of SR1, particularly in regard to the Emergency Spillway location and capacity.

2.3 Operational Considerations

2.3.1 Dam Commissioning

2.3.1.1 First Fill and Commissioning

It is Austin Engineering's understanding that the Off-Stream Storage Reservoir will not undergo first fill and commissioning, which is typical of earthfill embankment dam reservoirs. Commissioning and first fill practices are typically undertaken in a very prescribed manner, with design engineers on site to review the first fill process. Prior to first filling, a number of trigger levels are typically identified for items such as the phreatic surface, subsidence, displacement in the upstream-downstream direction, settlement, and sloughing. As the Off-Stream Storage Reservoir is likely to be utilized for the first time during flood conditions, the likelihood of having the design engineers available on site for this initial diversion is low to moderate.

Austin Engineering has concerns over the first fill of the reservoir occurring during a flood event, as a high percentage of reservoir failures occur during the first fill. It would be prudent to include a requirement for first fill and commissioning within the Approval to Construct for the SR1 Project to occur directly following construction, in a controlled manner during a non-flood event. Should this requirement not be included, an instrumentation and monitoring plan, as described in the following section, should be clearly outlined and designed to close the Diversion Inlet gates and commence immediate emergency discharge from the Low Level Outlet should any trigger levels be met. However, Austin Engineering believes it would be more prudent to have the first fill and commissioning undertaken outside of a flood event to reduce the risks to the SR1 structures and downstream occupants, infrastructure, and environmental habitats.

2.3.1.2 Instrumentation

The current information available on instrumentation for the Project is included in Appendix D Vol 4 Section 12.10 (Ex 175 page 262 to 263 and 339 to 341).

Due to the limited number of operators of the structure and the high risk during first fill, Austin Engineering stresses that instrumentation must be carefully considered.

Instrumentation Human-Machine Interfaces (HMIs) should be located in proximity to the Diversion Inlet gates to provide operators with accurate, real-time information sufficient to make informed decisions when operating both the Diversion Inlet gates and Service Spillway Obermeyer weir.

Instrumentation for the structure should include settlement monitoring, slope inclinometers, piezometers (vibrating wire), in addition to water level monitoring within both reservoirs (SR1 and Glenmore) and the flow monitoring immediately upstream of the Diversion Structure.

Each piece of instrumentation should have reliable logic controls and trigger levels determined in advance. Should the first fill condition happen without adequate presence of design engineers, the instrumentation should be connected to the Diversion Inlet gates to first alert operators, then within a prescribed period of time, to automatically stop flow into the reservoir should any of the instrumentation trigger levels be reached.

2.3.1.3 Risk of Failure Bathtub Curve

For most dams, risk of failure typically follows a bathtub curve, where there is a higher likelihood of failure in the initial commissioning and start up of the structure. The risk of failure declines as the start up and commissioning concerns are mitigated and moves to a lower risk throughout the lifetime of the structure. As the structure begins to reach the end of life, the probability of failure increases.

As the Off-Stream Storage Reservoir is to be utilized on a periodic basis only during high river flow flood events, the reservoir will undergo many “first fill”-type events during its lifetime. This unique scenario increases the likelihood of failure of the Off-Stream Storage Reservoir over its lifetime compared to a conventional embankment dam. Additionally, as the periods between these fills are likely to be far apart (annually at best, but potentially much further apart), potential issues and lessons learned from previous fill events may not be remembered or effectively communicated and incorporated into updated operational procedures.

To help mitigate the overall operational risks, Austin Engineering recommends developing a thorough first fill and commissioning plan that addresses the higher operational risk inherent to the filling of the reservoir during flood events. This first fill and commissioning plan should be included as an integral part of the Operation, Maintenance and Surveillance manual.

2.3.2 Operation, Maintenance and Surveillance Manual

Although there have been numerous documents submitted to the NRCB for the project to date, there is no dam Operation, Maintenance and Surveillance (OMS) manual material available. The operation of such a reservoir is critical for control of flood waters, and operational constraints and assumptions need to be properly outlined as part of the design for thorough understanding prior to approval of the project. The operational assumptions, triggers, water levels, inflows and outflows needed to be properly documented for stakeholders, such as the Community of Springbank, to properly assess the Project’s impact on the community. We recommend that a dam Operation, Maintenance and Surveillance manual be created in a draft format, as a minimum, prior to approval of the SR1 Project.

Information on the diversion system operation, inspection, and testing requirements should be documented in a draft Operation, Maintenance and Surveillance manual before commencing construction. The procedures for closing access to Springbank

Road, when the Diversion Inlet gates are open (during testing, emergency response exercises, and actual flood diversion) should be well documented before commencing construction.

2.3.3 Operational Accountability

Review of the documentation for the SR1 Project indicates that Alberta Parks will be the operator of the diversion structure. However, without the availability of the Operation, Maintenance and Surveillance manual for review at this time, it is unclear what the operational accountability for the structure will be, including (for example):

- Who will ultimately oversee the safe operation of the structure?
- Who will ensure that dam safety operators receive adequate training and that they received continued training on a regular basis?
- What are the operating assumptions under an emergency condition?
- How far will the operators likely be stationed from the reservoir?
- What are the emergency flood flow operations of the reservoir?

It is imperative that the Operation, Maintenance and Surveillance manual addresses the overall training and operation plan, including operational accountability for the structure.

2.3.4 Inspection and Testing

Section 14.1 of Ex 159 (page 227) describes the required annual inspection and testing requirements for SR1 Project facilities. No information is provided in Ex 159 regarding schedules for more frequent surveillance activities.

We recommend that the draft OMS manual document clearly identifies the requirements for, at a minimum, the following:

- Monthly site surveillance under normal conditions;
- Daily site surveillance during flood usage or first fill;
- Instrumentation results review;
- Annual inspections; and
- Post flood inspections.

As the Storage Dam has been assigned an extreme consequence classification, we recommend that a formal inspection be completed twice annually, whether the dam is utilized or not.

2.3.5 Dam Safety Management System

2.3.5.1 Records

No details have been provided on how records relating to dam safety will be kept. The following is a list of records should be kept and managed by the SR1 owner:

- Safety management plan
- Records of all inspections completed
- Dam Safety Review reports
- Operators and key personnel training records
- Policies and standards related to dam safety
- Dam Emergency Plan including contact information for notification of property owners and residents in critical inundation areas
- OMS manual
- Maintenance records

We recommend that the OMS manual provide details of who will be responsible for keeping the records listed above and ensuring that all items are completed and updated as required.

2.3.5.2 Training

Typically dam operators receive training on an annual basis and become familiar with weekly, monthly, and annual inspection requirements. They also become familiar with the day-to-day operations, such as opening and closing the gates, maintenance activities, and a general familiarity of the site. This familiarity of the site has frequently been shown to aid in early detection of many dam safety incidents. As the Off-Stream Storage Reservoir will only operate during large flood events, it is unlikely that operators will establish this type of familiarity. Therefore, operator training and very specific operating procedures must be a primary focus of the Operation, Maintenance and Surveillance manual, along with regular inspections of the facility, in order to establish the operators' familiarity and reduce the risk of operator error or failing to notice a key dam safety concern during filling of the reservoir under flood conditions.

In addition to operator familiarity, there are also concerns regarding travel to and from the facility in the event of a flood. There is a large travel distance from Calgary to the dam. Although we are unsure where the operators will be located when a flood event occurs, travel times must be taken into consideration to ensure that flood forecasting is adequately undertaken to provide operators with an adequate response time to reach the reservoir in time to divert water during a major flood event.

2.3.5.3 Public Safety

Ex 159 Section 11.0 (page 217) describes how public safety measures will be implemented for the SR1 Project and includes the use of signage, sirens, and fencing.

One risk to public safety requiring additional consideration is the management of public recreational use of the Elbow River at the SR1 Diversion Structure. Section 11.3 of Ex 159 (page 220) describes how recreations uses of Elbow River will be able to use designated portage routes in the river right floodplain that circumvents the Diversion Structure via a path on the Auxiliary Spillway.

We recommend the following points be considered and addressed:

- Will public access on the Auxiliary Spillway path impact on the performance of the fuse plug?
- If public do not see (or ignore) the warning signage and traverse through either the Service Spillway or the Diversion Inlet, what are the risks of harm to the public and likelihood of damage to infrastructure (particularly the Obermeyer weir at the Service Spillway)?
- Has any consideration been given to the use of security cameras around the SR1 facilities to monitor for recreational users before operating systems?
- How quickly do the Diversion Inlet gates open and close? Can the opening and close rate be controlled to minimize risks to the public?
- How quickly does the Service Spillway weir bladders fill and drain? Can this filling and deflating rate be controlled to minimize risks to the public?

Austin Engineering is recommending that approval of the Project does not go forward without submission of a draft safety management plan.

2.3.6 Flood Forecast System

In order for the Off-Stream Storage Reservoir to achieve its desired outcome of flood protection for the City of Calgary and residents downstream of the Glenmore Reservoir, Austin Engineering recommends putting a flood forecast system in place with real-time monitoring of trigger levels and predictive modelling. Instrumentation associated with the predictive and real-time monitoring of flood events may or may not currently be in place, but it has not been utilized before to inform the optimal operation of a diversion structure; nor has past predictive modelling for flood events been utilized as a part of emergency response procedures and operation of a structure such as the SR1 reservoir.

It is imperative that a flood forecast system be implemented with real-time predictive monitoring and that critical locations within the river system upstream of the SR1 reservoir are instrumented to provide relevant data on a real-time basis. The forecast system and instrumentation would use data such as snowpack, temperature changes, flood flow, rainfall events, and other meteorological data that may be utilized to properly predict and forecast floods within a short time span in order to quickly mobilize operators to the SR1 reservoir for operation of the structure. It should be noted that considerable time and effort will be required to establish the algorithms for adequate real-time prediction of flood events, along with the infill of data and selection of optimal monitoring locations within the river system upstream of the SR1 Project. These should be considered as soon as practicable within the project schedule, as failure to operate the structure correctly due to inadequate flood forecasting would significantly impact the effectiveness of the Project.

2.3.7 Flood Operation Curves

Although an Operation, Maintenance, and Surveillance manual for the SR1 Project is currently unavailable, Austin Engineering has identified that the critical operation of the structure will rely upon a proper prediction of inflow floods and flood flow diversion and discharge curves. As such, prior to the diversion structure going into operation, we recommend that flood operation curves be developed for the SR1 Project. These flood operation curves must indicate trigger levels, upon which the operator can make reliable decisions for operation of the Diversion Inlet gates, and critical discharge levels from the reservoir and the Low Level Outlet to ensure that the SR1 structure can operate to maximum efficiency and minimize flood impacts below the SR1 and Glenmore Reservoirs.

2.3.8 Dam Emergency Plan and Emergency Response

Austin Engineering notes there is an alarming absence of emergency planning documentation within the SR1 Project submissions to the NRCB. The emergency planning associated with such a structure would need to include consultation and cooperation with numerous stakeholders and emergency response personnel from the various counties and municipalities between the Off-Stream Storage Reservoir and Calgary, and possibly communities downstream of Calgary.

Austin Engineering is recommending that approval of this project does not go forward without submission of a draft dam emergency plan and emergency response plan, which at a minimum identifies affected stakeholders and emergency response groups.

2.3.9 Emergency Access to the Facility

As the Off-Stream Storage Reservoir is being designed to specifically handle emergency conditions, access should be carefully considered. At least two routes should be maintained for access roads required to provide operator access to the Diversion Inlet, Control Building, Service Spillway, and the Low Level Outlet on the Storage Dam to ensure that operations can occur during either a dam emergency event or a high water flood event.

An access road has been designed adjacent to and along the entire length of the Diversion Channel on the right side bank crest (looking downstream). Connections to this access road have been provided from both Highway 22 and Township Road 242.

As noted in Ex 159 Section 11.2.6 (page 219), Springbank Road will be flooded and inaccessible when diverting flood waters into the Off-stream Storage Reservoir. Highway 22 will still be accessible (if raised above the flood waters as planned).

Access to the Diversion Inlet, Control Building, and Service Spillway is via either Highway 22 or Township Road 242 and then turning south onto the access road adjacent to the Diversion Channel. Note this access roadway should be sufficiently large to accommodate fuel and maintenance vehicles, including cranes, for future maintenance.

Access to the west end of the Storage Dam is via either Highway 22 or Township Road 242 and then turning northwest or north, respectively, onto the access road adjacent to the Diversion Channel. An emergency pathway off Springbank Road can provide an access to the east end of the Storage Dam.

Access to the Floodplain Berm, Auxiliary Spillway, and Service Spillway south of the Elbow River will be provided from an access road off Highway 8.

2.3.10 Operator Access to Diversion Inlet Gates and Service Spillway

Austin Engineering notes that walkway access must be maintained to the Diversion Inlet gates and the control system for the Service Spillway weir to allow for deflation of the weir and closure of the gates in the event the reservoir is nearing critical full pool levels.

The final preliminary design (Ex 159) indicates a walkway access directly upstream of the Diversion Inlet gates (drawing 73396S-331 Ex 159 page 343). However, it is unclear whether operators will be provided with direct access to operate hoist breaks in the event of an emergency, including access to critical information from instrumentation and monitoring equipment.

We recommend that the final design consider access to critical locations for manual operation during high flood flow events and provision of backup generators to provide power to critical instrumentation and systems should loss of power occur.

2.3.11 Diversion Inlet Gates Fail-Closed Requirement

Due to the design of the Off-Stream Storage Reservoir, the Diversion Inlet gates closure must be able to reliably slow or stop the intake of water into the reservoir. The design assumption for the Emergency Spillway appears to be that at least one of the Diversion Inlet gates must be closed once the Emergency Spillway starts discharging.

However, there are cases, such as loss of power, mechanical issues, or an instrumentation failure, that may cause both intake gates to remain in the open position. As such, Austin Engineering recommends that the Diversion Inlet gates be designed to fail closed in the event of a power loss (i.e., if power to the intake gates is lost, the gates will automatically close under their own weight).

The final preliminary design (Ex 159) appears to have used a vertical slide gate system; it is unclear whether the drive mechanisms for these gates are designed to fail closed under the weight of the gate.

As the mechanical and electrical details for the project have not been provided at this time, we believe it is imperative to the safety of the overall diversion system that the Diversion Inlet gates fail closed under their own weight.

As a possible alternative to a fail-closed design, the gate system could utilize a manual hoist brake release system where the gate could be dropped under its own weight at the discretion of the operator in the event of a power loss. A system of this nature would likely rely on a hoist drum or cable brake system, allowing the operator to lower the gates in the event of a power loss and the Off-Stream Storage Reservoir reaching a critical level but introduces human error or potential delays in gate closures so is less favourable than a fail-closed gate system.

Table 5-2 on Page 106 of Ex 20 indicates that in the case of mechanical failure preventing typical gate operation, the gate hoists (wire rope) will have hoist brakes that can be released allowing the gates to be lowered. It is unclear whether this applies to the draft preliminary design only or is still relevant to the final preliminary design. In either case, if implemented in the final design, we recommend that the hoist brakes be capable of manual release.

2.3.12 Control Building

The current preliminary design (Ex 159) shows the Control Building is to be located on the right (east) bank of the Diversion Inlet at an elevation above the top of the Diversion Inlet gates. While this elevation (1219 m) should be sufficient for the design flood event (2013 flood event), it is possible that a larger event may occur within the operating lifespan of the Off-Stream Storage Reservoir.

We recommend that the Control Building and adjacent access area be located at or above 1219 m to prevent damage or access issues to the building during a high flood event when reliable control of the diversion system is essential.

Consideration should be given to helicopter access near the Control Building in the case of damage occurring to the access road along the Diversion Channel between Township Road 242 and the Diversion Inlet and we recommend a clear landing area be included in the final design.

2.3.13 Mechanical and Electrical Details

Austin Engineering notes that the design documentation for mechanical and electrical systems is currently unavailable for the project during this stage of the review. The overall safe operation of the project relies heavily on the selection of mechanical equipment, the design of the electrical system (including backup electrical circuitry and backup generators), and instrumentation and monitoring to ensure safe operation of the structure. If mechanical and electrical designs are not available prior to approval of the project, we recommend that the design basis, logic, and design requirements for the mechanical and electrical systems be thoroughly outlined and provided to the NRCB for review and assessment. This will ensure that the operation conditions and risks associated with the Diversion Inlet gates, Service Spillway weir, monitoring equipment, water level sensing, and logic associated with each of these components is adequately presented prior to the decision for approval, as we note that the decision for approval may include requirements for the mechanical and electrical systems to operate in a specific manner.

2.3.14 Emergency Backup Generator

We recommend that a plan for emergency backup power be included as part of the overall Project scope, with emergency power being capable of powering all monitoring equipment and instrumentation, the Diversion Inlet gates, and the Service Spillway weir, and provide a reliable Human-Machine Interface (HMI) for operators with power in a convenient location. The emergency backup generator should be set to automatically start in the event of a power outage, with an automatic transfer switch to provide real-time backup power. This backup generator should not be located in an area where flood flows could impede the safe operation of the generator or obstruct operator access for re-fueling should a power outage extend over a long period of time.

2.3.15 Reservoir Dewatering

A reservoir dewatering plan should be developed to detail safe or optimum dewatering rates for various reservoir water levels using the Low Level Outlet in the Storage Dam.

The reservoir dewatering plan should address the following:

- When to start reservoir draining. i.e. during or after fish salvage operations have been completed, once specific flood levels downstream are reached, etc.
- Once low storage levels are reached, how quickly should the remaining volume be emptied to prevent undesirable conditions developing? For example, stagnant ponds of water promoting mosquito population growth.
- What sorts of inspections need to occur during and after the dewatering process?
- Post dewatering clean up requirements.

We recommend that the OMS manual include a section detailing reservoir dewatering requirement post flood.

2.3.16 Intake Screens

The final preliminary design details for the intake on the Low Level Outlet (LLO) do not adequately show the screening of the intake tower. A significant quantity of silt is anticipated to be mobilized and deposited within the Off-Stream Storage Reservoir during a flood event. This silt will settle to the bottom of the reservoir and affect the ability of the LLO to discharge water from the reservoir.

As the silt builds up over time, the intake screens for the intake tower will be inundated with silt and the tower will need to draw water from higher elevations. As such, the intake screen arrangement needs to be able to accommodate silt deposits anticipated within the reservoir and be able to drawdown water to the top of the anticipated silt deposit. Following water drawdown to this point, screens will require some adjustment (or ideally be designed with lower screens) in order to dewater the silt layer to facilitate excavation of the silt material.

We recommend that the screens be designed with sufficient height to accommodate the anticipated silt layer at the bottom of the reservoir.

2.3.17 Silt Removal Access Roads

Austin Engineering notes that a large amount of sediment and silt will be deposited within the Off-Stream Storage Reservoir during a large flood flow event. This silt can build up to a significant thickness, far thicker than traditional excavation and haul equipment can safely traverse.

Austin Engineering recommends that the final design for the SR1 Project includes a thorough plan for building access roads, drainage, and drainage ditches within the reservoir to aid in post-flood silt deposit removal. The plan should include design of drainage infrastructure graded towards the LLO to facilitate maximum dewatering of the silt deposit, along with the locations of access roads and potential stockpile areas. Knowing these locations in advance will allow crews and equipment to work logically and methodically with a pre-established plan to safely remove silt from the reservoir. These access roads will also provide adequate access for fish salvage operations and minimize the amount of time required to salvage fish and remove silt, leading to lower fish mortalities.

2.3.18 Diversion Inlet Gates

The opening and closing of the Diversion Inlet gates is one of the most important design features of the entire project. Operation of the gates appears to be manually controlled, and thus operator knowledge of when to open and close the gates is critical to the success of the flood mitigation works.

If the gates are opened too early, the Off-Stream Storage Reservoir may be full before the peak flow in the Elbow River is reached. If the gates are not opened soon enough, the Glenmore Reservoir may be inundated, resulting in similar consequences as occurred during the 2013 flood.

Determining how and when to open or close the Diversion Inlet gates, will require the operator to have access to the following information:

- Elbow River flows and levels (current and forecasted);
- Off-Stream Storage Reservoir levels and available remaining volumes
- Glenmore Reservoir levels and available remaining volumes
- Clear instructions for how and when to operate

It is unclear how the operator will have access to this information and how the information will even be obtained.

Given the importance of the Diversion Inlet gate operation to both dam safety and project success, we strongly recommend that the operation details (including instrumentation) be developed prior to project approval being granted.

Operational decisions must be properly documented, with operators adequately trained in response procedures, such as operating orders for when the Service Spillway weir is to be raised, when Diversion Inlet Gates are to be opened or closed, and when flow is to be returned to the Elbow River through the Low Level Outlet.

2.4 Environmental Considerations

2.4.1 Fish Salvage

Exhibit 187 is a Memorandum dated January 29, 2021 by Paul Christensen, Senior Fisheries Biologist for the Alberta Environment and Parks – Fisheries Management (AEP-FM). Page 3 of Ex 187 states:

AEP-FM maintains that the proposed means by which fish could be rescued will prove to be extremely challenging and ultimately, limited in effectiveness. High turbidity water combined with high air temperatures provides a very small window in which to attempt fish rescues and creates challenging field conditions that could lead to high immediate mortality. Combined with the very large surface area of the Off-Stream Reservoir, it in unlikely that electrofishing will prove sufficient on a scale that would meaningfully rescue the majority of the entrained fish. This assertion is supported by AEP-FM's experience in 2013 whereby it attempted to rescue fish in ponds and isolated side channels that became stranded by the flood when water levels receded. Ultimately, large ponds proved to be very difficult to effectively rescue fish as warm water temperatures quickly rose and subsequently became an attractant for avian predators to consume dead and moribund fish.

The above excerpt from Ex 187 indicates that fish salvage prior to or during dewatering of the Off-Stream Storage Reservoir will prove to be very challenging and needs further consideration.

As fish salvage will directly impact the reservoir dewatering plan, we recommend the fish rescue plan be developed and incorporated as a subsection of the draft OMS manual prior to the NRCB granting approval for construction.

2.4.2 Reservoir Conditions

If the reservoir cannot be completely dewatered after a flood diversion and sections of ponded water develop within the reservoir, it is possible that new conditions will develop including:

- Undesirable mosquito population growth, which may promote the growth of other species that make burrows in the Storage Dam;
- Changes to vegetation growth and species within the reservoir footprint;
- Impacts to ground water due to seepage; and
- Changes to soil and ground conditions within the reservoir footprint.

These conditions will need to be assessed for impacts to dam safety during routine inspections. We recommend that the draft OMS manual include a post dewatering inspection checklist with these items included.

3.0 SUMMARY OF RECOMMENDATIONS

The objective of our engineering design review was to identify risks with the engineered design and operation of the Off-Stream Storage Reservoir Project and provide recommendations to improve the dam safety aspects of the project and prevent long-term dam safety non-conformances or deficiencies that could negatively affect downstream residents, landowners, infrastructure and have detrimental ecological impacts. A summary of our recommendations resulting from this review is provided in Table 14.

Table 14. Austin Engineering Off-Stream Storage Reservoir Project – Design Review Recommendations

Recommendation Number/ Identified Concern		Recommendation (Summary)
1	Diversion Inlet capacity	The bottom elevation of the access bridge across the Diversion Inlet (to the gate hoists) is shown as 1215.5 m (Ex 159 page 343). The inlet invert elevation is 1211.5 m. This gives a maximum flow depth below the access bridge of 4 m before the water surface hits the bottom of the bridge. Austin Engineering recommends the Diversion Inlet maximum discharge capacity be reviewed and modelled with the access bridge in place. We recommend that the Diversion Inlet access bridge design be reviewed to ensure that adequate freeboard (between the bridge and water surface) is achieved during passage of the design flow of 600 m^3/s.
2	Emergency Spillway discharge capacity	The Emergency Spillway maximum discharge capacity (360 m^3/s) is less than the Diversion Channel design flow or the maximum diversion intake flow. A reassessment of the Emergency Spillway should be considered to increase the discharge capacity from 360 m^3/s to 600 m^3/s (or to match the maximum capacity of the Diversion Inlet). The safety of the Storage Dam should not rely solely on the ability of operators (or electrical systems) to close the Diversion Inlet gates.
3	Diversion Structure total capacity	We recommend the following: 5. Diversion Inlet capacity be reviewed due to the access bridge breastwall and headwall causing a flow restriction. 6. Stantec should confirm the Elbow River water surface elevation that results in the fuse plug being removed down to an invert elevation of 1215.8 m. i.e. Does the WSE need to be 1217.2 m for a minimum duration of 2.76 hours to remove the entire 208 m long fuse plug, or will a WSE of 1216.9 m be sufficient based on the erosion starting at the pilot channels and progressing over the length of the fuse plug over 2.76 hours? 7. More information should be provided on the Diversion Structure rating curve with various operation combinations of the Diversion Inlet, Service Spillway, and Auxiliary Spillway. 8. It should be confirmed that the Service Spillway Obermeyer weir can operate at flow depths greater than 5.8 m (with debris flow included) in order to safely pass the IDF in combination with the Auxiliary Spillway.
4	Flood flow estimation uncertainty due to: • Climate Change • Limited historical records prior to 1934 • Snowmelt	We recommend that the Probable Maximum Precipitation (PMP) analysis be reviewed as part of the final design to confirm rain-on-snow has been included in the PMP. We recommend that consideration for forest fire and climate change be made as an allowance in the flood flow determination. We recommend an allowance to account for these uncertainties be included within the design flood prior to completing final design of the diversion structure components and sizing of the Diversion Inlet gates and final sizing of the emergency spillway.

<table>
<tr><th colspan="2">Recommendation Number/
Identified Concern</th><th>Recommendation (Summary)</th></tr>
<tr><td>5</td><td>Stoplog slots and gate guide heaters</td><td>Austin Engineering recommends the inclusion of stoplog slots, at a minimum, preferably with at least enough stoplogs to isolate one intake gate, upstream of the Diversion Inlet gates to facilitate annual testing, reduce the requirements for fish salvage during testing and allow for future maintenance of the gates.

In addition, due to the cold climate in the region for portions of the year and the necessity to keep the system functional, we recommend the inclusion of gate guide heaters.</td></tr>
<tr><td>6</td><td>Emergency Spillway flow conveyance</td><td>We recommend that the outlet of the Emergency Spillway be channelized with riprap or other erosion protection between the downstream extent of the Emergency Spillway and the return to the Elbow River to prevent embankment scour on the downstream side.</td></tr>
<tr><td>7</td><td>Auxiliary Spillway</td><td>We recommend the Diversion Inlet gate operation between WSEs of 1216.9 m and 1217.2 m be documented, as well as contingencies for the following conditions:
• The fuse plug does not operate as expected; or
• Activation of the fuse plug causes water quality (sedimentation and turbidity) issues downstream.</td></tr>
<tr><td>8</td><td>Flood protection between Service Spillway and Glenmore Dam</td><td>We recommend flood maps be produced, showing the flood extents within the Elbow River between the Service Spillway and the Glenmore Dam, for Service Spillway discharge flows of 160 m^3/s, 760 m^3/s and 1600 m^3/s. The three flood maps should be used to determine impacts and identify if flood protection works are required along this stretch of the Elbow River.</td></tr>
<tr><td>9</td><td>Control Building location</td><td>We recommend that the Control Building be located in an area that would not be subject to flooding, or where access to the building will not be impeded by flooding, permitting the SR1 reservoir to continue to be of benefit during a flood event and reduce operational risks during a large flood event.

Consideration should be given to helicopter access near the Control Building in the case of damage occurring to the access road along the Diversion Channel between Township Road 242 and the Diversion Inlet and we recommend a clear landing area be included in the final design.</td></tr>
<tr><td>10</td><td>Factor of Safety of the Storage Dam and Floodplain Berm under pseudo-static loading</td><td>The minimum factor of safety for the Storage Dam under pseudo-static loading is 0.7 (at Section 22+500).

The minimum factor of safety for the Floodplain Berm under pseudo-static loading is 1.0 (at Section 1+600).

It would be imprudent to construct a new dam with a safety factor at or below the minimum CDA Dam Safety Guidelines (CDA, 2013) safety factor thresholds.

We recommend that the design of the Storage Dam be modified to ensure the minimum required factor of safety of 1.0 be achieved for the pseudo-static scenario under seismic loading. Consideration should also be given to increasing the Floodplain Berm factor of safety under this load case.</td></tr>
</table>

Recommendation Number/ Identified Concern		Recommendation (Summary)
11	Fracking exclusion zone	During a review of the available documentation on the National Resources Conservation Board (NRCB) website, Austin Engineering did not encounter any reference to fracking induced seismic events. As a significant amount of fracking has been undertaken within Alberta, the approval to commence construction of the SR1 reservoir needs to be undertaken with a dedicated fracking exclusion zone surrounding the project extents. This zone is to be established by the design engineers to ensure that the SR1 structure is not damaged due to fracking within proximity of the structure.
12	Emergency operation of the Diversion Inlet gates	As the mechanical and electrical details for the project have not been provided at this time, we believe that it is imperative to the safety of the overall structure that the Diversion Inlet gates fail closed under their own weight. Table 5-2 on Page 106 of Ex 20 indicates that in the case of mechanical and electrical failure preventing typical gate operation, the gate hoists (wire rope) will have hoist brakes that can be released allowing the gates to be lowered. If this is implemented in the final design, we recommend that the hoist brakes be capable of manual release. It is unclear how operators will access the hoist breaks in the event of an emergency. As such, we recommend that the final design consider access to this critical location for operation during a high flood flow event, should loss of power occur at the structure.
13	Emergency backup power and automatic switching	As the SR1 project is to function during a large flood event of an emergency nature, we recommend that emergency backup power be included as part of the overall project scope, with emergency power being capable of powering all monitoring instrumentation, the intake gates, and the service spillway weir. The emergency power generator should be set to automatically start with an automatic transfer switch to provide real-time backup power in the event of an emergency. This backup generator should not be located in an area where flood flows could impede the safe operation of the generator or operator access for re-fueling should an electrical outage extend over a long period of time.
14	Springbank Road acting as a dam	We recommend that, if not already considered, drainage upgrades and stability assessments for Springbank Road be included in the final project design.
15	Emergency (secondary) low level outlet through Storage Dam	We recommend consideration be given for the addition of a secondary low level outlet (or enlargement of the current low level outlet) through the Storage Dam to be utilized if an emergency drawdown of the reservoir is needed and requiring dewatering much faster than the current low level outlet would allow. A secondary outlet would be preferable, as this would allow for draw down in the event the primary low level outlet were to fail or become blocked.
16	Intake screen design on low level outlet	The intake screen on the low level outlet (through the Storage Dam) needs to be able to accommodate silt deposits anticipated within the reservoir and be able to drawdown water to the top of the anticipated silt deposit. We recommend that the screens be designed with sufficient height to accommodate (at a minimum) a 1.0 m silt layer at the bottom of the reservoir (or the maximum height of the silt anticipated).
17	Riprap on upstream face of Storage Dam (wave runup)	The preliminary design does not indicate riprap on the upstream face of the Storage Dam. While the structure is not continuously operated, it will be subject to the design cases and loads associated with wind setup and wave runup over its lifespan. Austin Engineering recommends that riprap be included for armouring along the upstream face of the Storage Dam.

Recommendation Number/ Identified Concern		Recommendation (Summary)
18	Differential settlement of the Storage Dam	Differential settlement of the Storage Dam needs to be considered during the design of the low level outlet and associated concrete piping/conduit based on the anticipated settlement within this portion of the dam. Stresses are likely to be quite significant due to the settlement over time. If differential settlement along the crest of the Storage Dam occurs and results in a lowering of the overall crest elevation, instrumentation set points will need to be adjusted to maintain adequate freeboard during diversion of the design flood event.
19	Silt removal within the Off-Stream Storage Reservoir	We recommend that a thorough plan be developed prior to completion of final design to allow for the introduction of access roads, drainage, and drainage ditches within the reservoir, sloped towards the low level outlet (conduit), to facilitate maximum dewatering and provide good access for removal of the silt deposit. Knowing the locations of these access roads, along with potential stockpile locations, in advance will allow for crews and equipment to work logically and methodically with a pre-established plan for removal of the silt from the reservoir. These pre-established access roads will also provide better access for fish rescue and minimize the amount of time required to salvage fish and remove the silt.
20	Dam commissioning	Due to the high-risk and higher probability of failure during first fill, we recommend instrumentation be carefully considered. Instrumentation for the structure should include settlement monitoring, slope inclinometers, piezometers (vibrating wire), in addition to water level monitoring within both the reservoir and the upstream reaches of the river. Each piece of instrumentation should have trigger levels determined in advance by the design engineers. Should the first fill condition then happen without adequate presence of design engineers, the instrumentation could be interlocked with the Diversion Inlet gates to stop flow into the reservoir should any of the instrumentation trigger levels set by the designers be reached during filling. Austin Engineering has concerns over the first fill of the SR1 reservoir occurring during a flood event, as a high percentage of reservoir failures occur during the first fill. It would be prudent to include first fill and commissioning requirements within the SR1 Approval to Construct. Should this not be included, an instrumentation and monitoring plan needs to be clearly outlined, indicating cut-off levels with reliable logic, piezometers, slope inclinometers, and settlement monitors designed to close the intake gates and commence immediate emergency discharge from the low level outlet should any of those trigger levels be met. However, it would be much more prudent to have the first fill and commissioning undertaken outside of a flood event to reduce the risk to downstream occupants, infrastructure, and environmental habitat. A plan for the first fill and commissioning is critical to the operation of the structure and should address the higher risk in early operations of the structure that would occur on a repetitive basis during flood events.
21	Safety Management Plan	We recommend that a draft Safety Management Plan be developed and submitted to the NRCB prior to construction approval being granted.
22	Emergency plans and response	There is a large travel distance from Calgary to the dam. Although we are unsure where the operators will be located when a flood event occurs, this needs to be taken into consideration to ensure that flood forecasting is adequately undertaken to provide operators with an adequate response time to reach the SR1 reservoir in time to divert water during a major flood event. Austin Engineering is recommending that approval of this project does not go forward without submission of a draft dam emergency plan and emergency response plan.

Recommendation Number/ Identified Concern		Recommendation (Summary)
23	Dam break inundation mapping	We recommend that the Storage Dam break inundation mapping be updated to show velocity and flow depths. We recommend that a separate dam break analysis and inundation mapping be produced for the Floodplain Berm for inclusion in the emergency plan.
24	Operation, Maintenance and Surveillance documentation	We recommend that the following be documented prior to project approval: • Elbow River flows that trigger Diversion Inlet gate opening and closing • Glenmore Reservoir levels that trigger the Diversion Inlet gate opening • SR1 Reservoir levels that trigger Diversion Inlet gate closing • All aspects of weir and gate operation including the use of manual versus electrical systems • All aspects of Low Level Outlet operation and Storage Reservoir draining • How forecasting systems be used to predict trends for operation • The overall training and operation plan, including operational accountability for the structures • Roles and responsibilities, particularly in regard to dam safety management • Inspection frequencies and requirements (including monitoring for erosion on the upstream side of the Floodplain Berm) • Maintenance schedules • Instrumentation details and monitoring requirements • All weir flow rating curves (Diversion Inlet, Service Spillway, and Auxiliary Spillway) • Auxiliary Spillway fuse plug operation (and emergency operation) • Floodplain Berm Stage-Storage Curve • Off-Stream Storage Reservoir Stage-Storage Curve • Conditions or events requiring the closure of Springbank Road • Fish salvage requirements prior to Storage Reservoir draining • Storage Reservoir dewatering and sediment removal plan

4.0 REFERENCES

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CLOSURE

Overall, the Springbank Off-Stream Storage Project, if implemented correctly, can achieve its objective of mitigating the impacts from large flood events along the Elbow River. However, we strongly recommend that our recommendations be addressed prior the NRCB granting AT Leave to Construct.

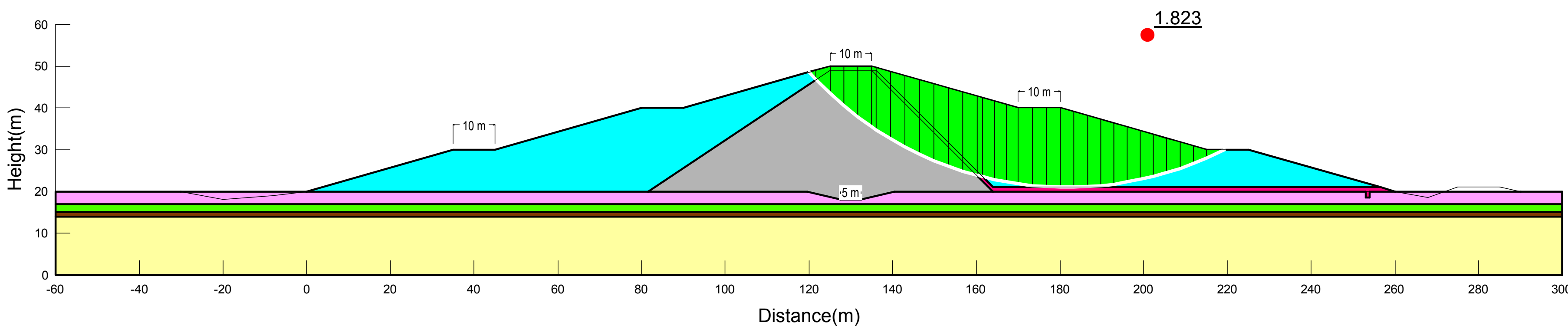
Please contact Austin Engineering for any questions pertaining to this report.

Roger Austin, P.Eng.
Dam Safety Engineer
Austin Engineering Ltd.

APPENDIX A: SLOPE STABILITY ANALYSIS RESULTS

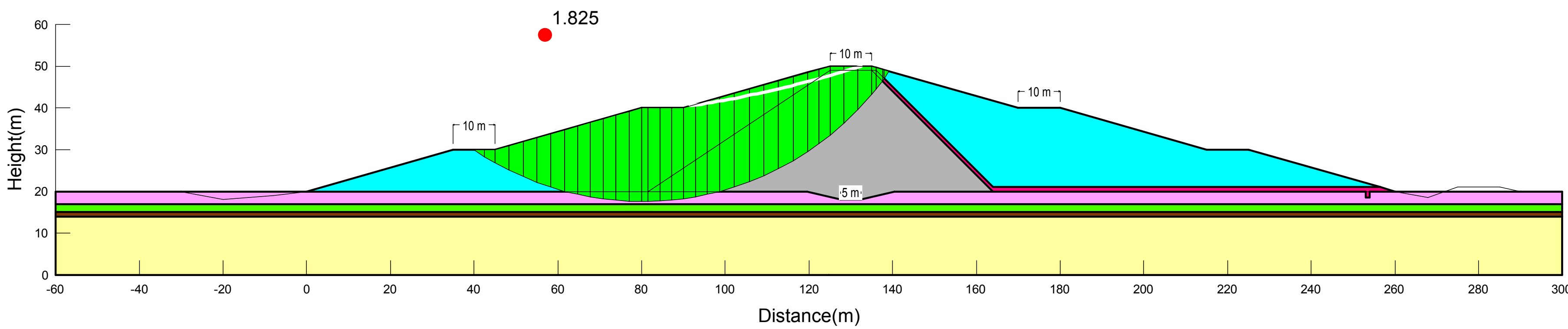
Section 23+175
Off-stream storage embankment dam
Load Case: End of construction before reservoir filling(DS)

Color	Name	Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Phi 1 (°)	Phi 2 (°)	Bilinear Normal (kPa)	Phi-B (°)	Effective Friction Angle (°)
	Drain	Mohr-Coulomb	21	0					30
	Embankment Core	Bilinear	20	0	23	0	235.5	0	
	Embankment Shell	Bilinear	20	0	23	0	235.5	0	
	Fluvial(Unnamed Creek)	Mohr-Coulomb	22	0					35
	Glacial Till	Bilinear	18	0	27	0	235.5	0	
	Mudstone	Mohr-Coulomb	21	0					17.5
	Sandstone	Mohr-Coulomb	21	0					45



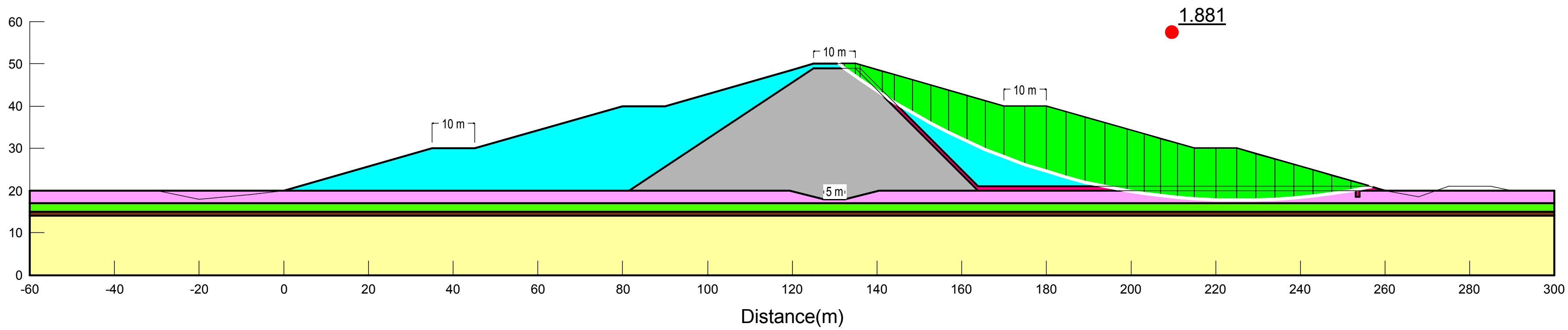
Section 23+175
Off-stream storage embankment dam
Load Case: End of construction before reservoir filling(US)

Color	Name	Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Phi 1 (°)	Phi 2 (°)	Bilinear Normal (kPa)	Phi-B (°)	Effective Friction Angle (°)
	Drain	Mohr-Coulomb	21	0					30
	Embankment Core	Bilinear	20	0	23	0	235.5	0	
	Embankment Shell	Bilinear	20	0	23	0	235.5	0	
	Fluvial(Unnamed Creek)	Mohr-Coulomb	22	0					35
	Glacial Till	Bilinear	18	0	27	0	235.5	0	
	Mudstone	Mohr-Coulomb	21	0					17.5
	Sandstone	Mohr-Coulomb	21	0					45



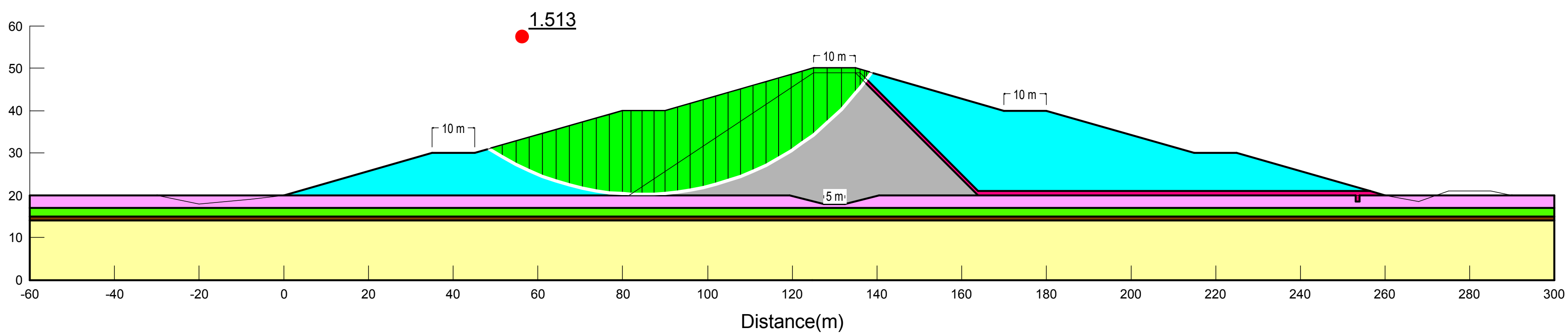
Section 23+175
Off-stream storage embankment dam
Load Case: Post-earthquake (DS)

Color	Name	Model	Unit Weight (kN/m^3)	Effective Cohesion (kPa)	Phi 1 (°)	Phi 2 (°)	Bilinear Normal (kPa)	Phi-B (°)	Effective Friction Angle (°)
	Drain	Mohr-Coulomb	21	0					30
	Embankment Core	Bilinear	20	0	23	0	188.5	0	
	Embankment Shell	Bilinear	20	0	23	0	188.5	0	
	Fluvial(Unnamed Creek)	Mohr-Coulomb	22	0					35
	Glacial Till	Bilinear	18	0	27	0	188.5	0	
	Mudstone	Mohr-Coulomb	21	0					17.5
	Sandstone	Mohr-Coulomb	21	0					45



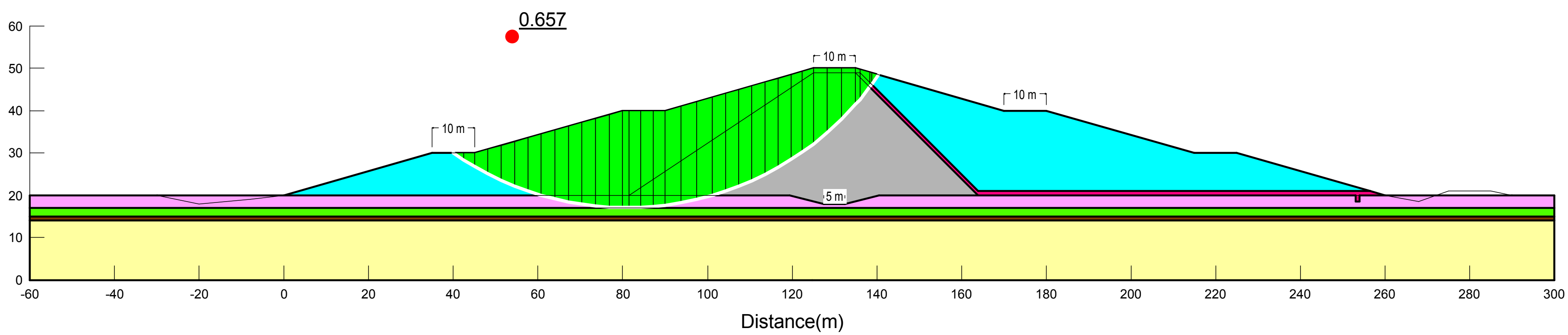
Section 23+175
Off-stream storage embankment dam
Load Case: Post-earthquake (US)

Color	Name	Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Phi 1 (°)	Phi 2 (°)	Bilinear Normal (kPa)	Phi-B (°)	Effective Friction Angle (°)
	Drain	Mohr-Coulomb	21	0					30
	Embankment Core	Bilinear	20	0	23	0	188.5	0	
	Embankment Shell	Bilinear	20	0	23	0	188.5	0	
	Fluvial(Unnamed Creek)	Mohr-Coulomb	22	0					35
	Glacial Till	Bilinear	18	0	27	0	188.5	0	
	Mudstone	Mohr-Coulomb	21	0					17.5
	Sandstone	Mohr-Coulomb	21	0					45



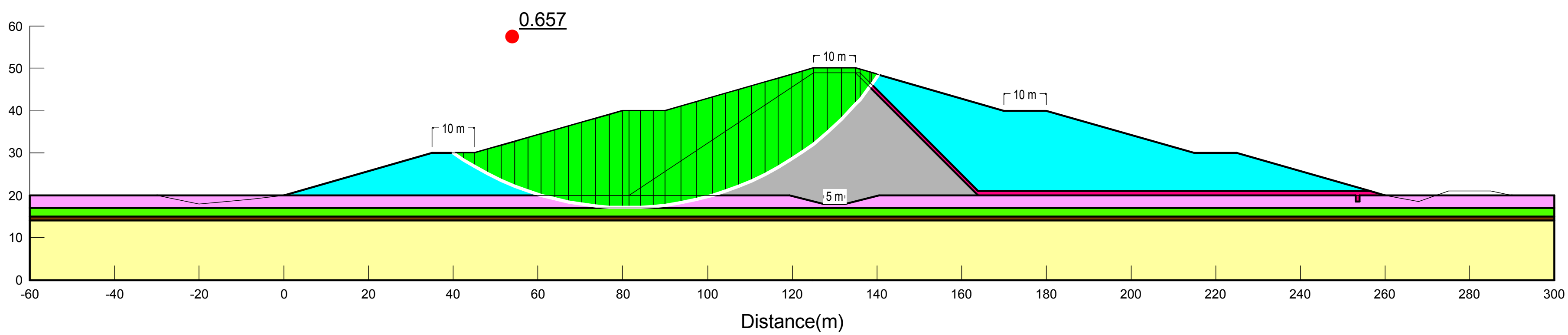
Section 23+175
Off-stream storage embankment dam
Load Case: Pseudo static (DS)

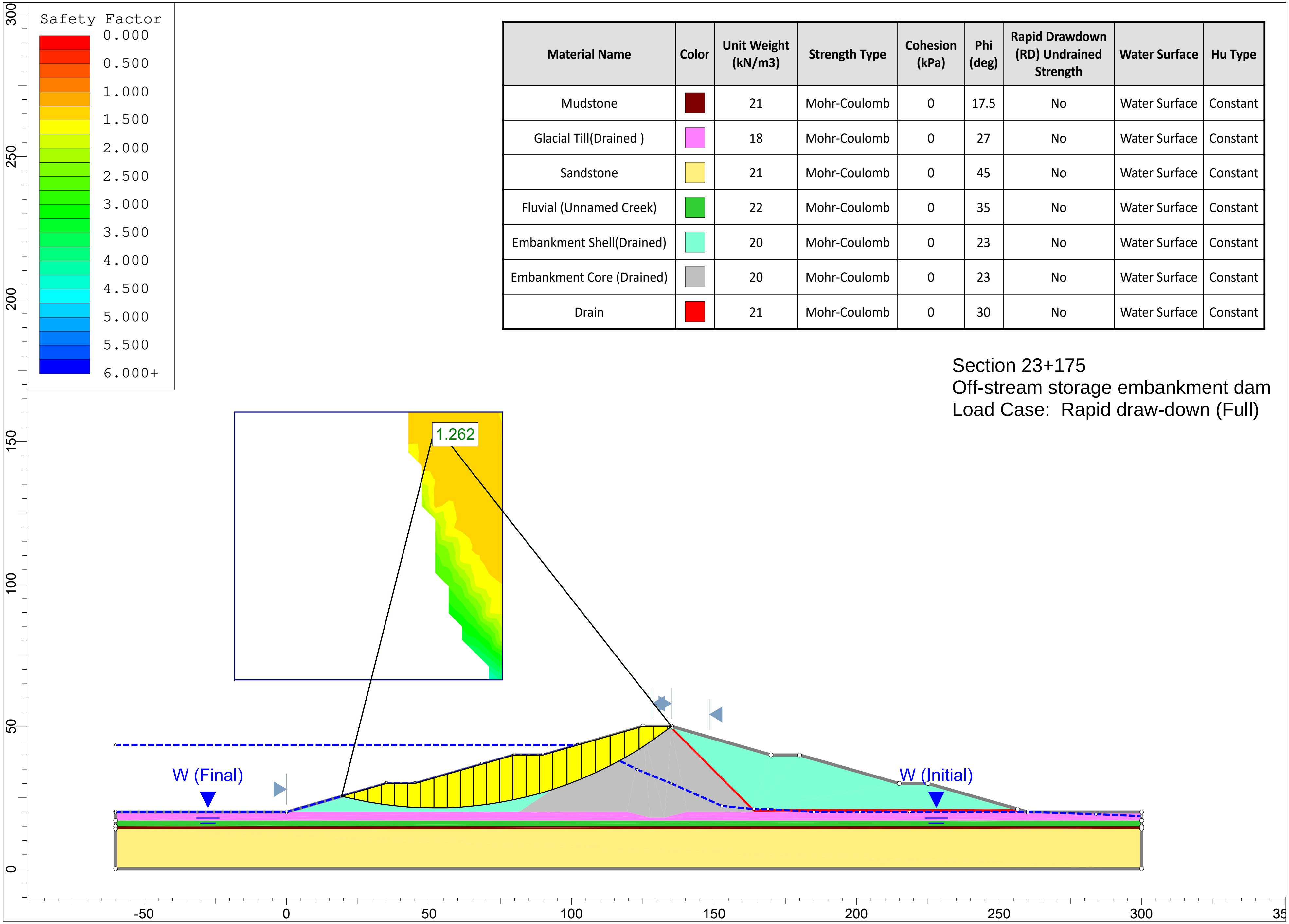
Color	Name	Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Phi 1 (°)	Phi 2 (°)	Bilinear Normal (kPa)	Phi-B (°)	Effective Friction Angle (°)
	Drain	Mohr-Coulomb	21	0					30
	Embankment Core	Bilinear	20	0	23	0	188.5	0	
	Embankment Shell	Bilinear	20	0	23	0	188.5	0	
	Fluvial(Unnamed Creek)	Mohr-Coulomb	22	0					35
	Glacial Till	Bilinear	18	0	27	0	188.5	0	
	Mudstone	Mohr-Coulomb	21	0					17.5
	Sandstone	Mohr-Coulomb	21	0					45



Section 23+175
Off-stream storage embankment dam
Load Case: Pseudo static (US)

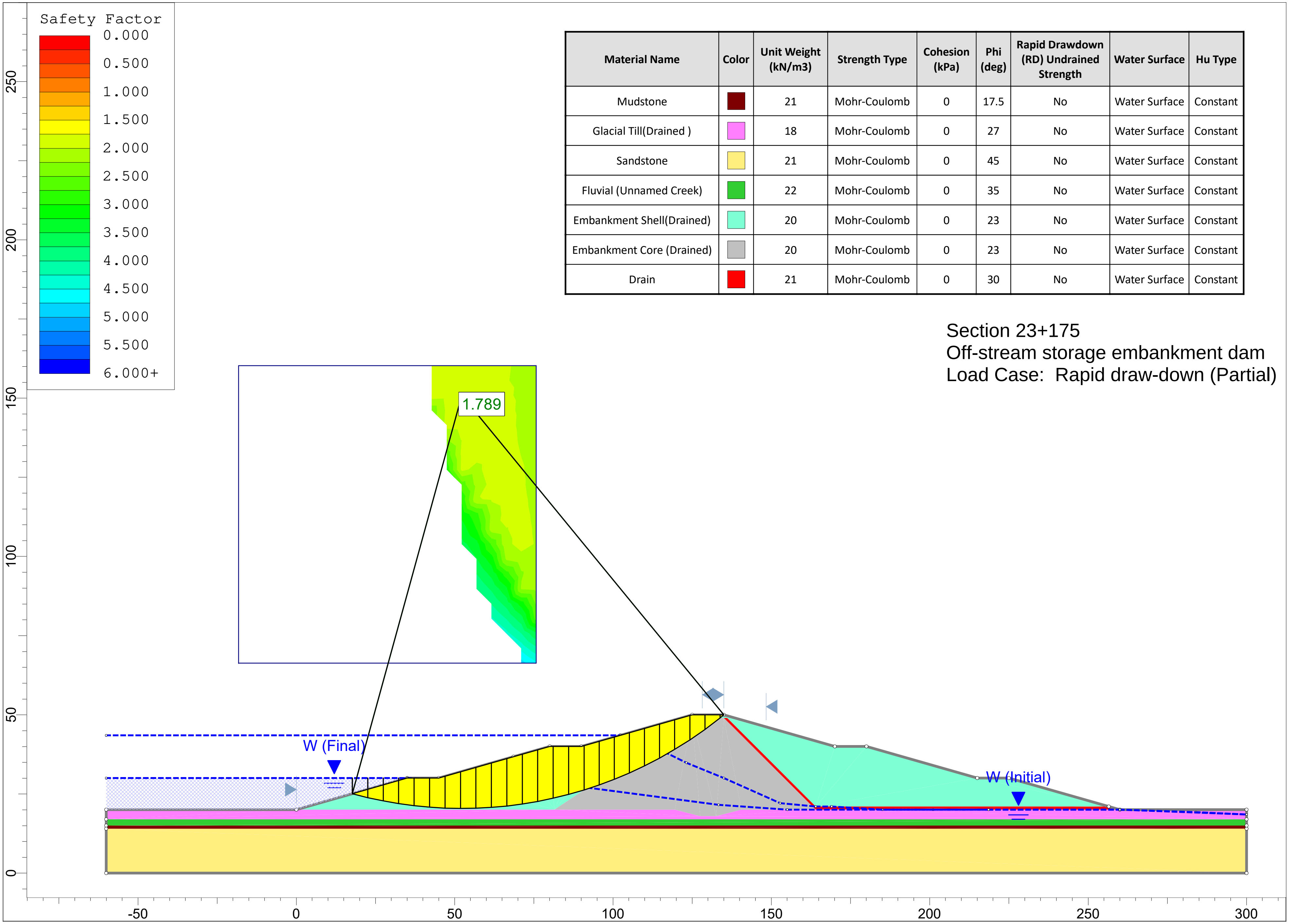
Color	Name	Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Phi 1 (°)	Phi 2 (°)	Bilinear Normal (kPa)	Phi-B (°)	Effective Friction Angle (°)
	Drain	Mohr-Coulomb	21	0					30
	Embankment Core	Bilinear	20	0	23	0	188.5	0	
	Embankment Shell	Bilinear	20	0	23	0	188.5	0	
	Fluvial(Unnamed Creek)	Mohr-Coulomb	22	0					35
	Glacial Till	Bilinear	18	0	27	0	188.5	0	
	Mudstone	Mohr-Coulomb	21	0					17.5
	Sandstone	Mohr-Coulomb	21	0					45



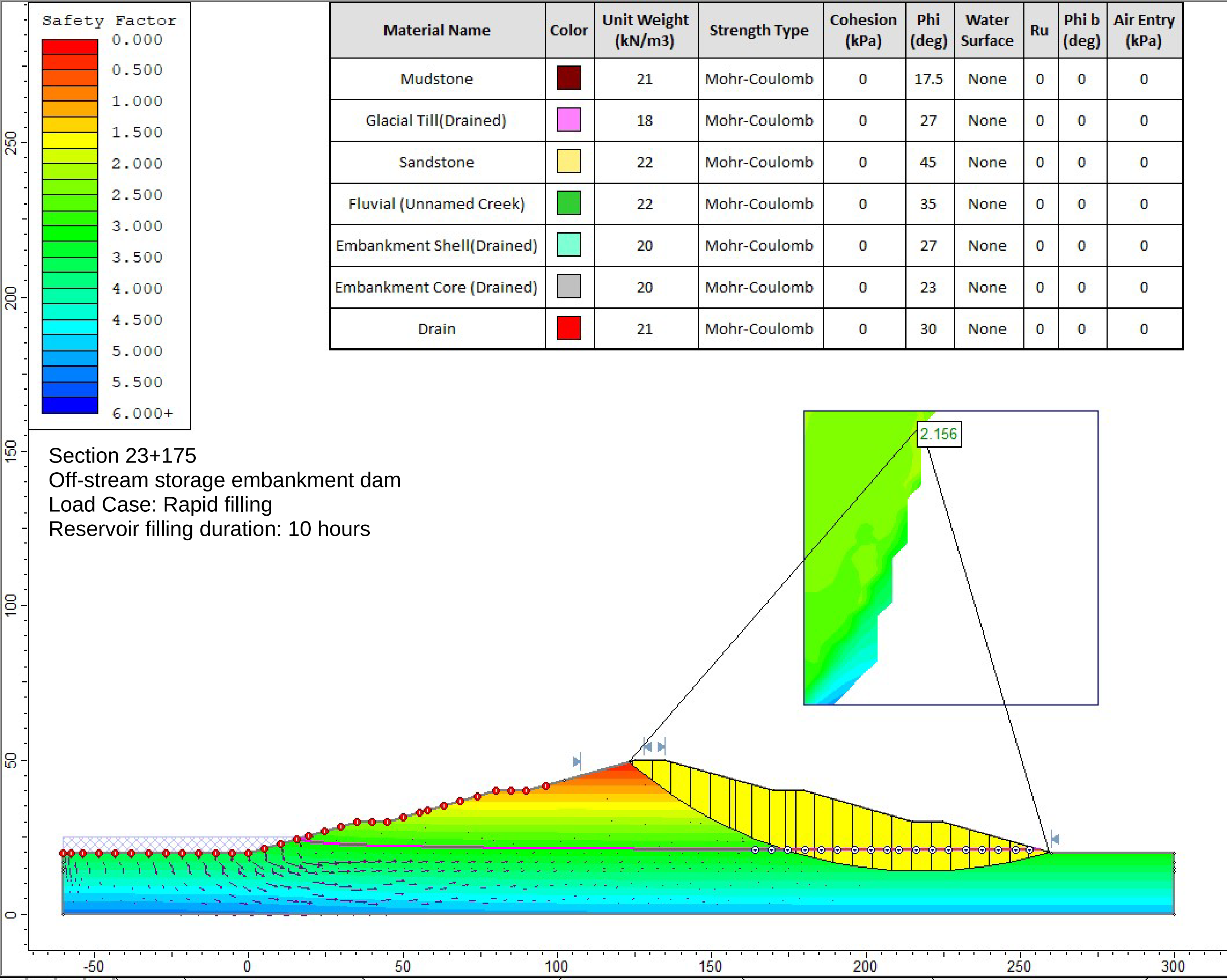


Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Rapid Drawdown (RD) Undrained Strength	Water Surface	Hu Type
Mudstone		21	Mohr-Coulomb	0	17.5	No	Water Surface	Constant
Glacial Till(Drained)		18	Mohr-Coulomb	0	27	No	Water Surface	Constant
Sandstone		21	Mohr-Coulomb	0	45	No	Water Surface	Constant
Fluvial (Unnamed Creek)		22	Mohr-Coulomb	0	35	No	Water Surface	Constant
Embankment Shell(Drained)		20	Mohr-Coulomb	0	23	No	Water Surface	Constant
Embankment Core (Drained)		20	Mohr-Coulomb	0	23	No	Water Surface	Constant
Drain		21	Mohr-Coulomb	0	30	No	Water Surface	Constant

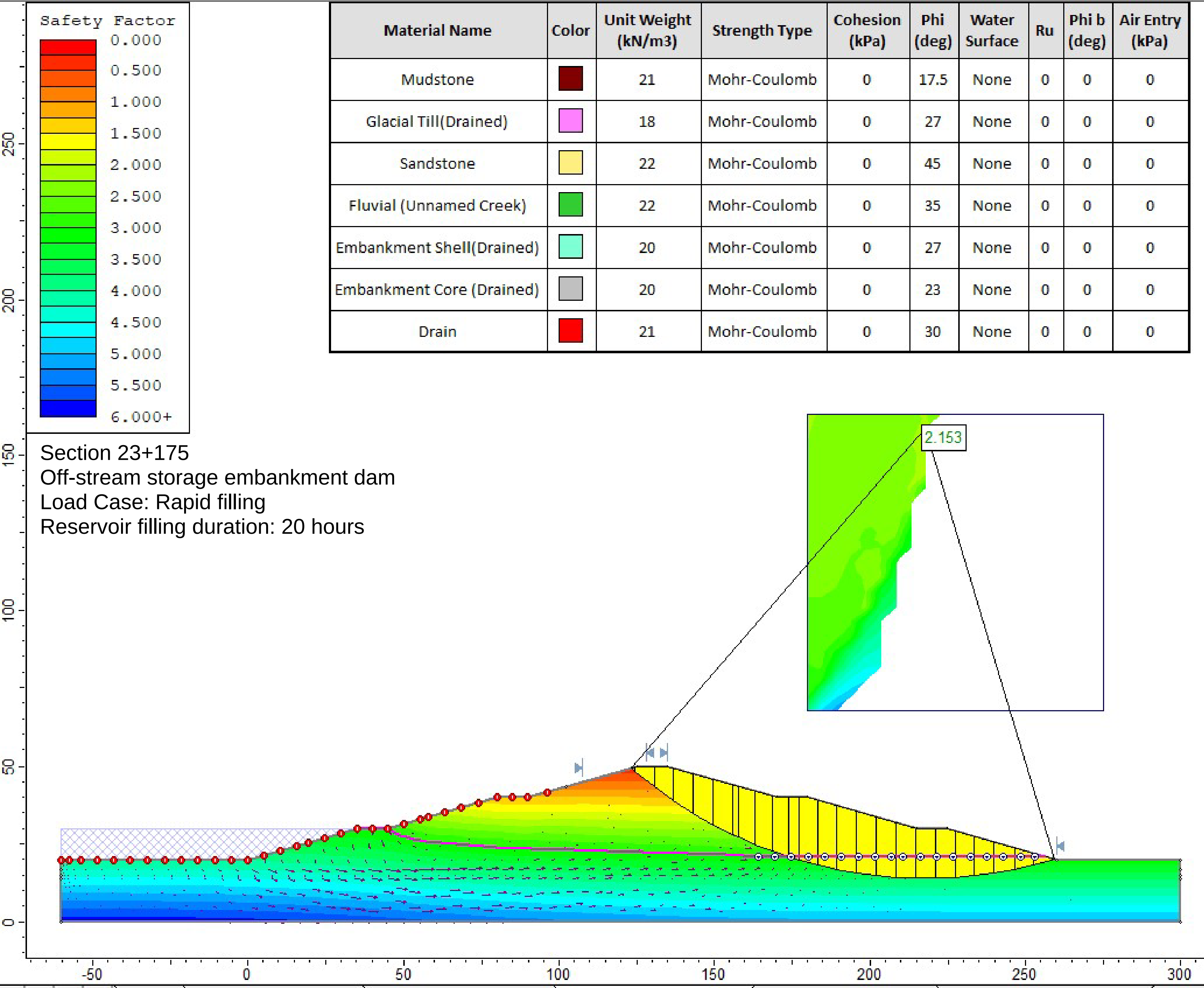
Section 23+175
Off-stream storage embankment dam
Load Case: Rapid draw-down (Full)



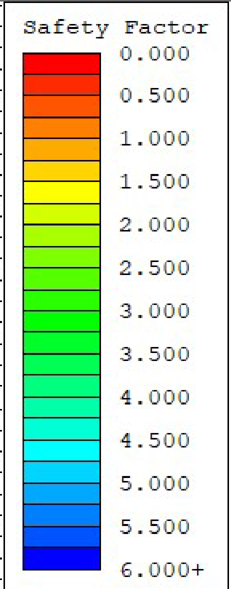
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Rapid Drawdown (RD) Undrained Strength	Water Surface	Hu Type
Mudstone		21	Mohr-Coulomb	0	17.5	No	Water Surface	Constant
Glacial Till(Drained)		18	Mohr-Coulomb	0	27	No	Water Surface	Constant
Sandstone		21	Mohr-Coulomb	0	45	No	Water Surface	Constant
Fluvial (Unnamed Creek)		22	Mohr-Coulomb	0	35	No	Water Surface	Constant
Embankment Shell(Drained)		20	Mohr-Coulomb	0	23	No	Water Surface	Constant
Embankment Core (Drained)		20	Mohr-Coulomb	0	23	No	Water Surface	Constant
Drain		21	Mohr-Coulomb	0	30	No	Water Surface	Constant



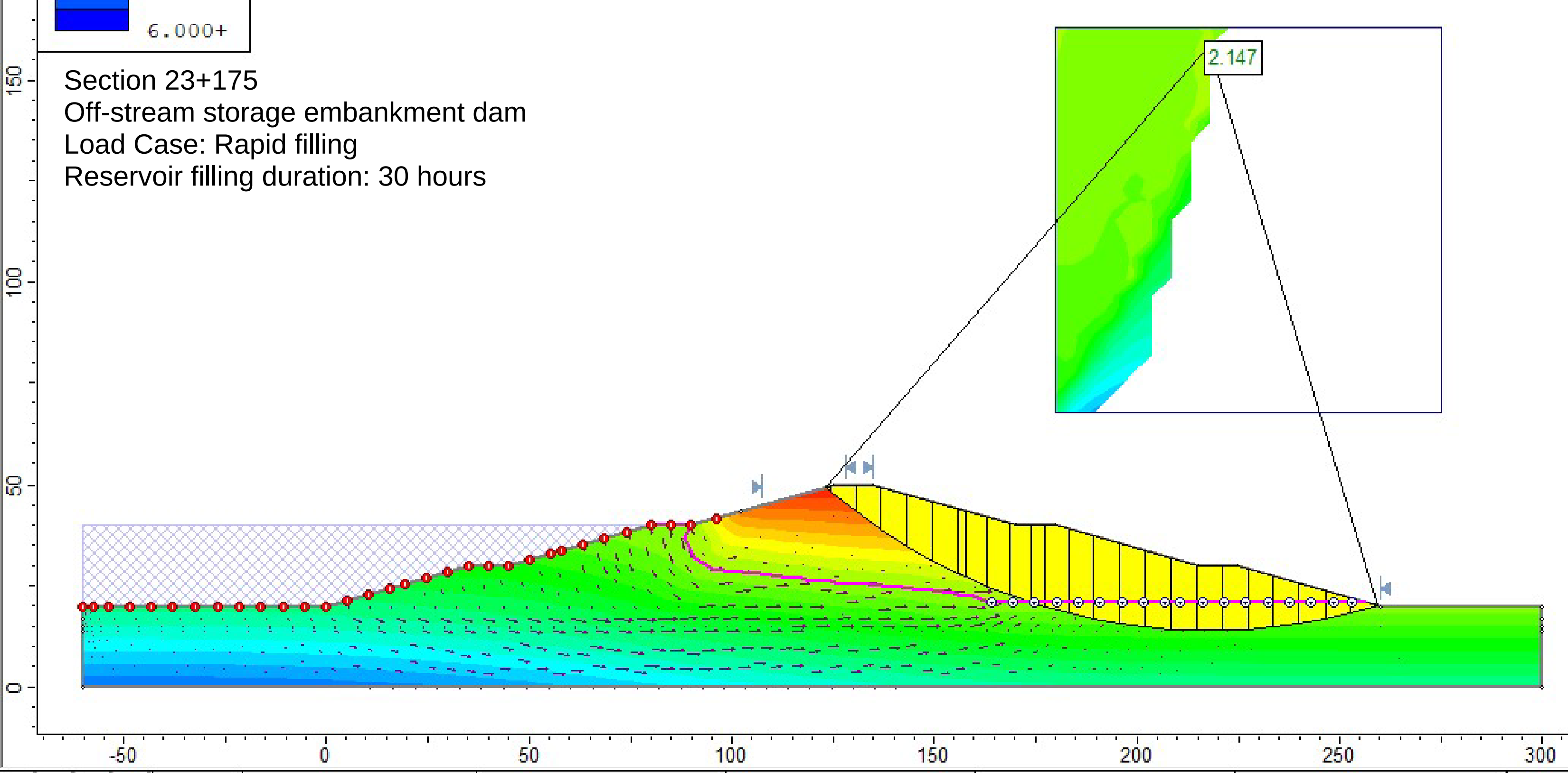
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Ru	Phi b (deg)	Air Entry (kPa)
Mudstone		21	Mohr-Coulomb	0	17.5	None	0	0	0
Glacial Till(Drained)		18	Mohr-Coulomb	0	27	None	0	0	0
Sandstone		22	Mohr-Coulomb	0	45	None	0	0	0
Fluvial (Unnamed Creek)		22	Mohr-Coulomb	0	35	None	0	0	0
Embankment Shell(Drained)		20	Mohr-Coulomb	0	27	None	0	0	0
Embankment Core (Drained)		20	Mohr-Coulomb	0	23	None	0	0	0
Drain		21	Mohr-Coulomb	0	30	None	0	0	0

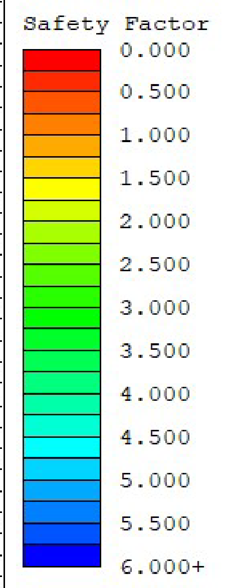


Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Ru	Phi b (deg)	Air Entry (kPa)
Mudstone		21	Mohr-Coulomb	0	17.5	None	0	0	0
Glacial Till(Drained)		18	Mohr-Coulomb	0	27	None	0	0	0
Sandstone		22	Mohr-Coulomb	0	45	None	0	0	0
Fluvial (Unnamed Creek)		22	Mohr-Coulomb	0	35	None	0	0	0
Embankment Shell(Drained)		20	Mohr-Coulomb	0	27	None	0	0	0
Embankment Core (Drained)		20	Mohr-Coulomb	0	23	None	0	0	0
Drain		21	Mohr-Coulomb	0	30	None	0	0	0



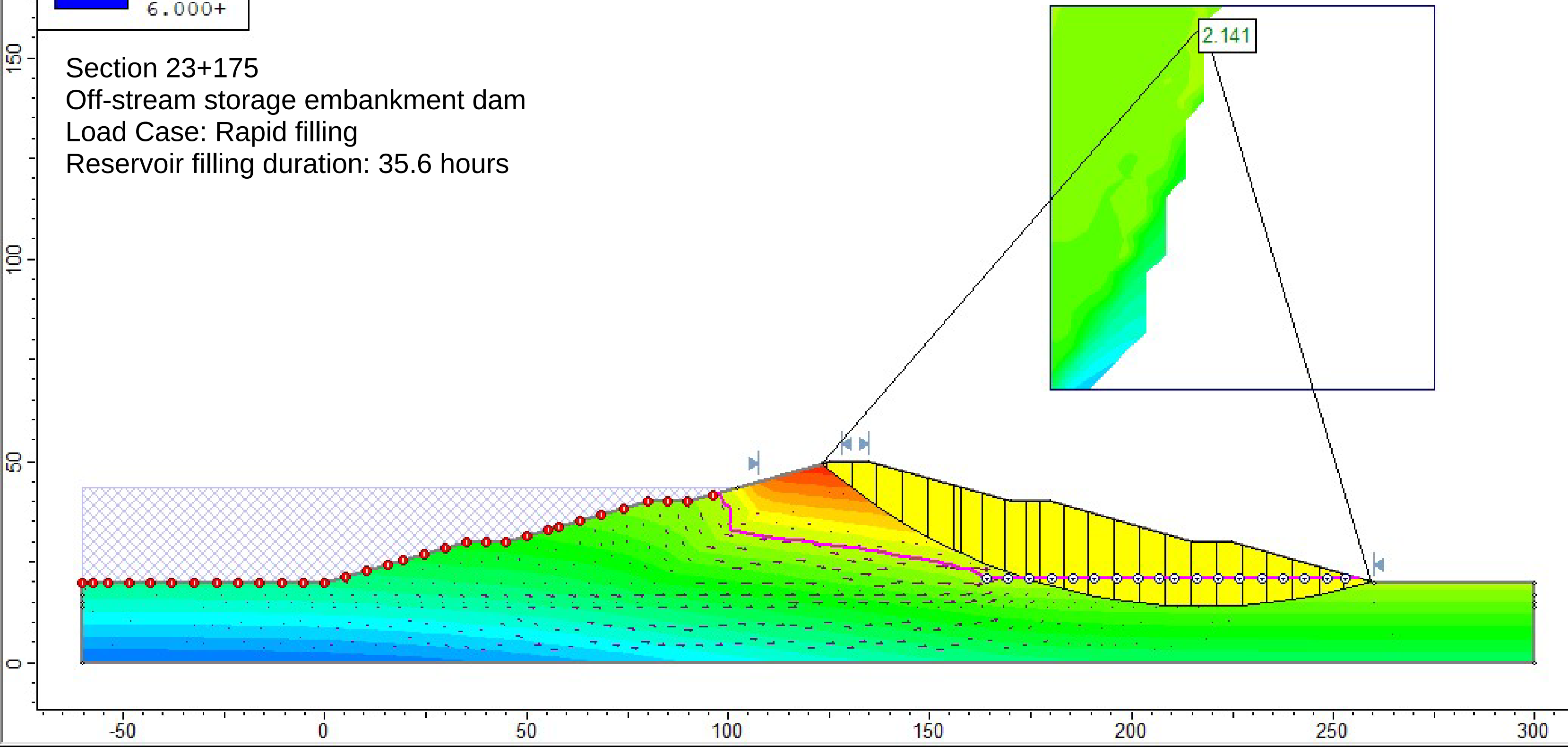
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Ru	Phi b (deg)	Air Entry (kPa)
Mudstone		21	Mohr-Coulomb	0	17.5	None	0	0	0
Glacial Till(Drained)		18	Mohr-Coulomb	0	27	None	0	0	0
Sandstone		22	Mohr-Coulomb	0	45	None	0	0	0
Fluvial (Unnamed Creek)		22	Mohr-Coulomb	0	35	None	0	0	0
Embankment Shell(Drained)		20	Mohr-Coulomb	0	27	None	0	0	0
Embankment Core (Drained)		20	Mohr-Coulomb	0	23	None	0	0	0
Drain		21	Mohr-Coulomb	0	30	None	0	0	0

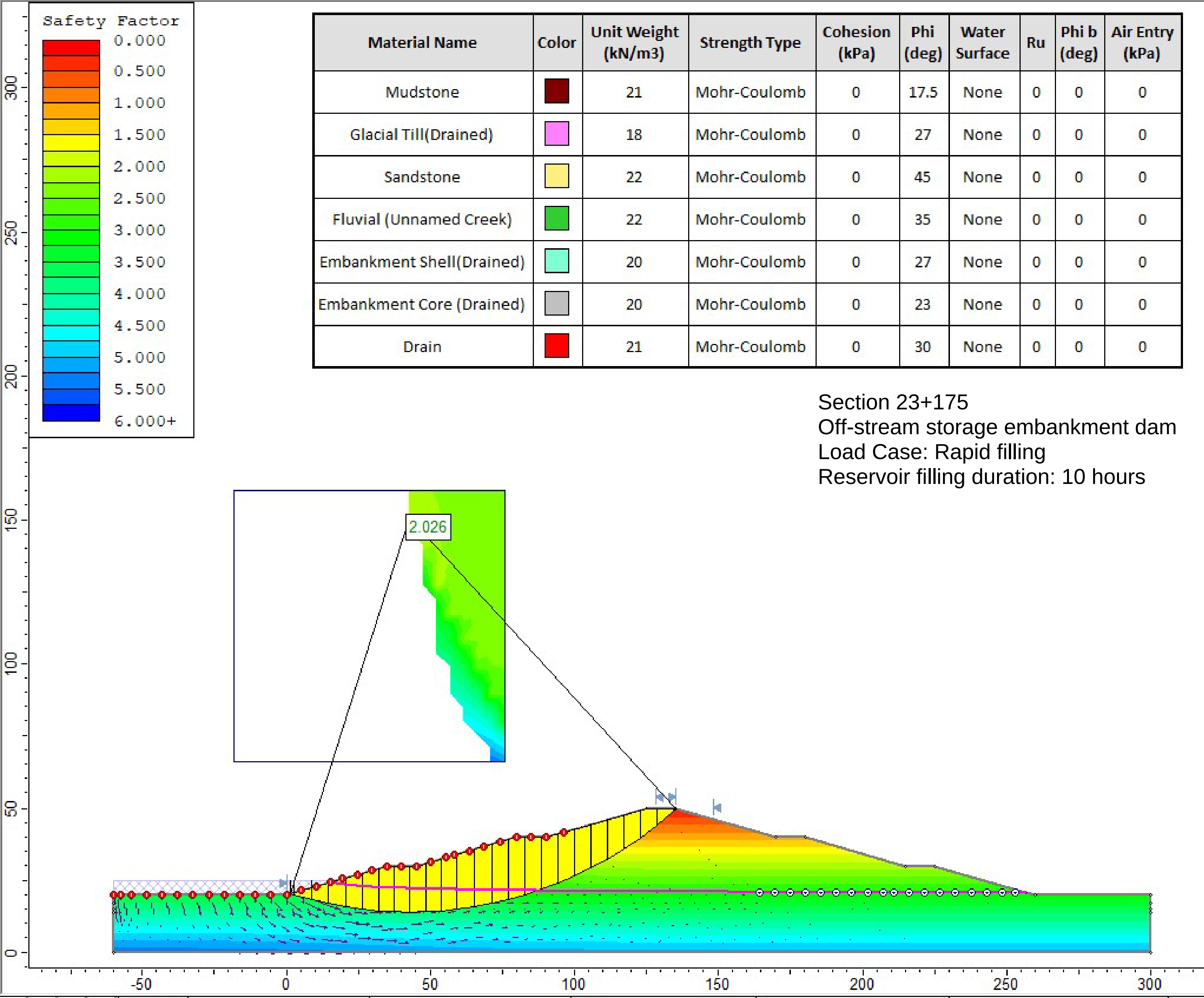




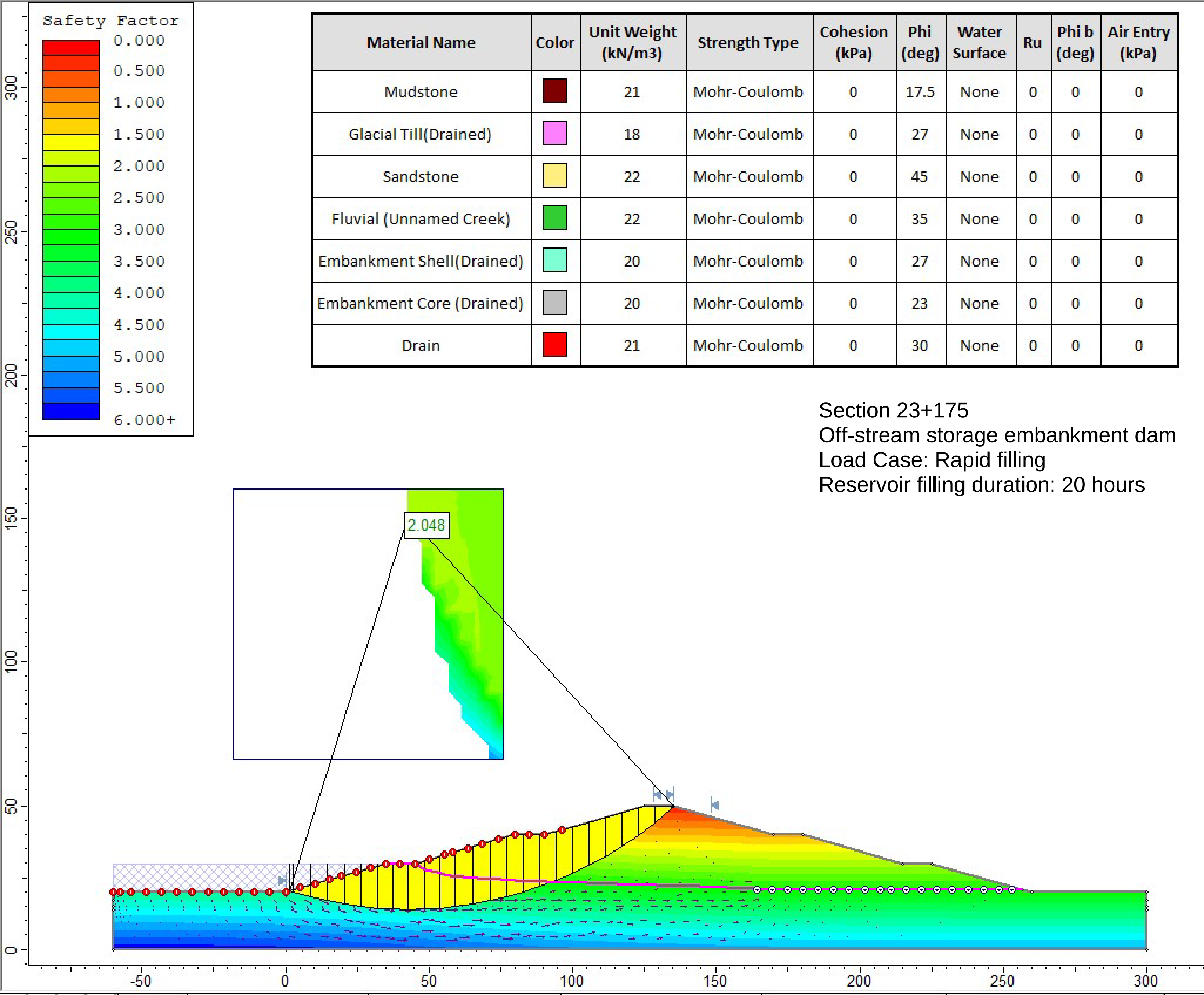
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Ru	Phi b (deg)	Air Entry (kPa)
Mudstone		21	Mohr-Coulomb	0	17.5	None	0	0	0
Glacial Till(Drained)		18	Mohr-Coulomb	0	27	None	0	0	0
Sandstone		22	Mohr-Coulomb	0	45	None	0	0	0
Fluvial (Unnamed Creek)		22	Mohr-Coulomb	0	35	None	0	0	0
Embankment Shell(Drained)		20	Mohr-Coulomb	0	27	None	0	0	0
Embankment Core (Drained)		20	Mohr-Coulomb	0	23	None	0	0	0
Drain		21	Mohr-Coulomb	0	30	None	0	0	0

Section 23+175
Off-stream storage embankment dam
Load Case: Rapid filling
Reservoir filling duration: 35.6 hours

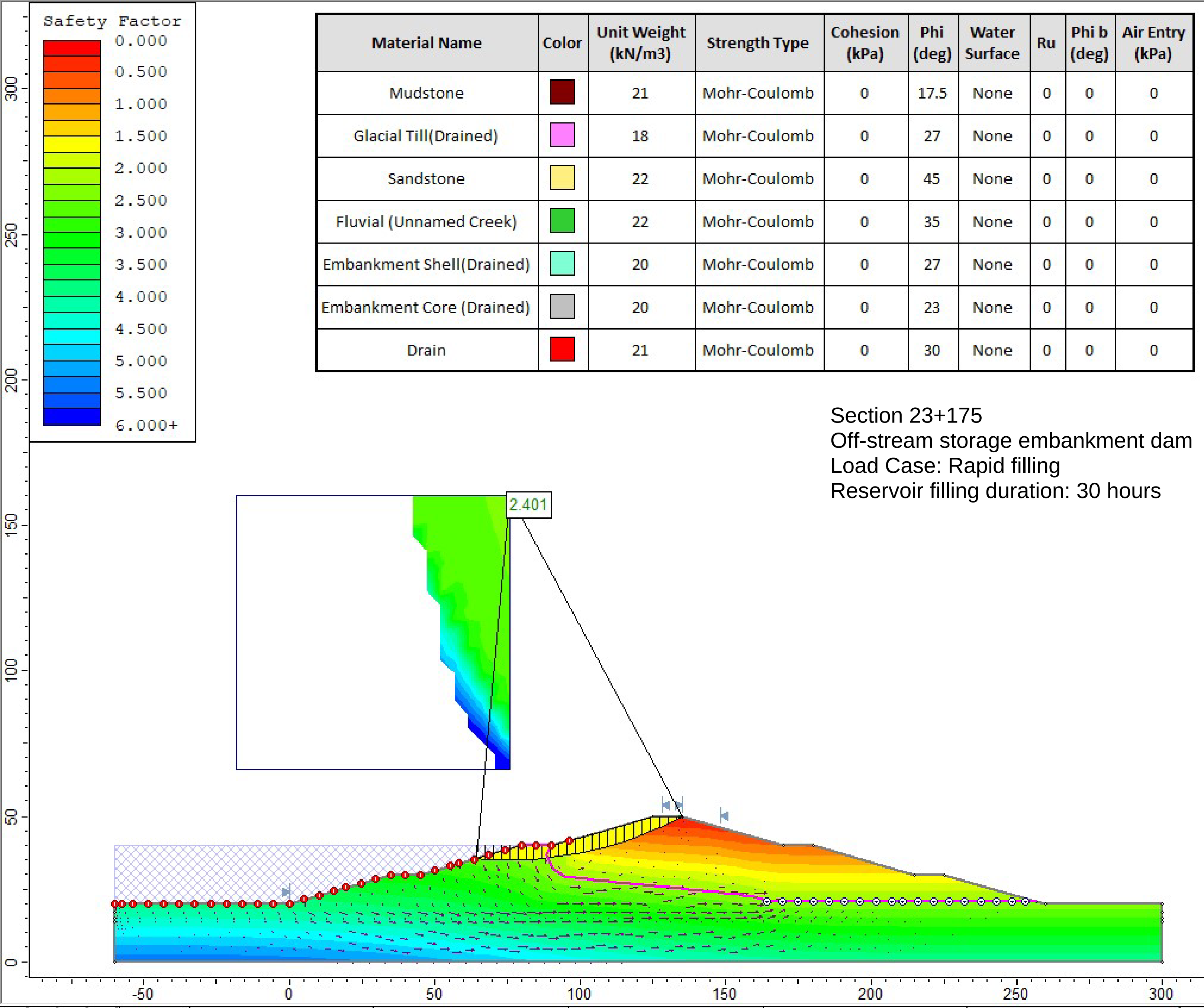




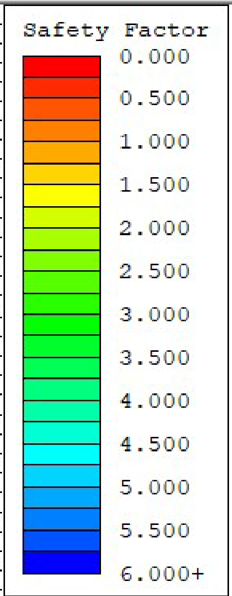
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Ru	Phi b (deg)	Air Entry (kPa)
Mudstone		21	Mohr-Coulomb	0	17.5	None	0	0	0
Glacial Till(Drained)		18	Mohr-Coulomb	0	27	None	0	0	0
Sandstone		22	Mohr-Coulomb	0	45	None	0	0	0
Fluvial (Unnamed Creek)		22	Mohr-Coulomb	0	35	None	0	0	0
Embankment Shell(Drained)		20	Mohr-Coulomb	0	27	None	0	0	0
Embankment Core (Drained)		20	Mohr-Coulomb	0	23	None	0	0	0
Drain		21	Mohr-Coulomb	0	30	None	0	0	0



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Ru	Phi b (deg)	Air Entry (kPa)
Mudstone		21	Mohr-Coulomb	0	17.5	None	0	0	0
Glacial Till(Drained)		18	Mohr-Coulomb	0	27	None	0	0	0
Sandstone		22	Mohr-Coulomb	0	45	None	0	0	0
Fluvial (Unnamed Creek)		22	Mohr-Coulomb	0	35	None	0	0	0
Embankment Shell(Drained)		20	Mohr-Coulomb	0	27	None	0	0	0
Embankment Core (Drained)		20	Mohr-Coulomb	0	23	None	0	0	0
Drain		21	Mohr-Coulomb	0	30	None	0	0	0

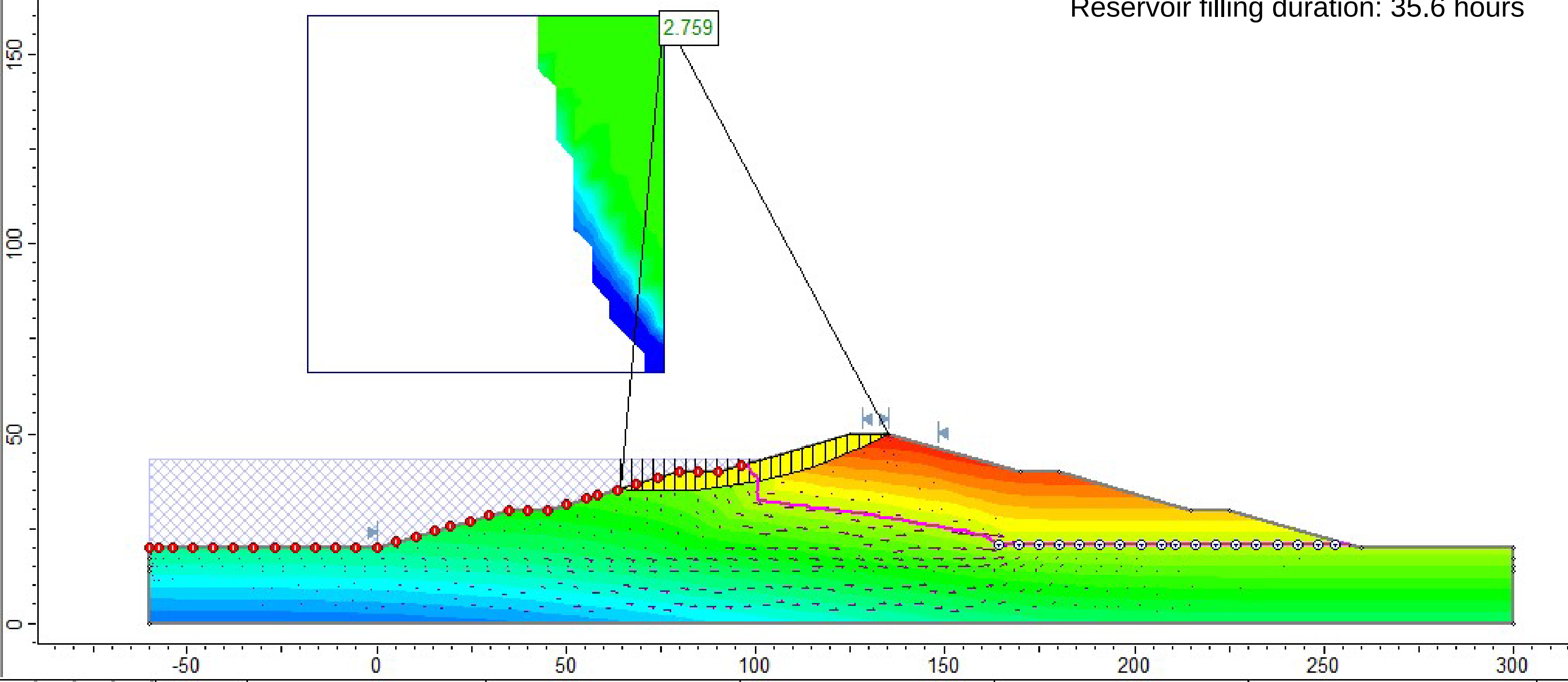


Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Ru	Phi b (deg)	Air Entry (kPa)
Mudstone		21	Mohr-Coulomb	0	17.5	None	0	0	0
Glacial Till(Drained)		18	Mohr-Coulomb	0	27	None	0	0	0
Sandstone		22	Mohr-Coulomb	0	45	None	0	0	0
Fluvial (Unnamed Creek)		22	Mohr-Coulomb	0	35	None	0	0	0
Embankment Shell(Drained)		20	Mohr-Coulomb	0	27	None	0	0	0
Embankment Core (Drained)		20	Mohr-Coulomb	0	23	None	0	0	0
Drain		21	Mohr-Coulomb	0	30	None	0	0	0



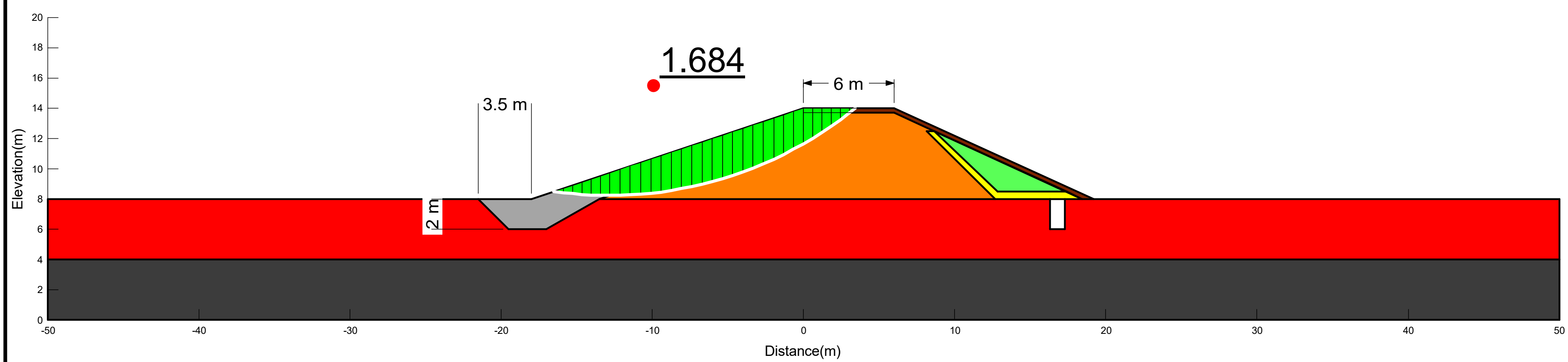
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Ru	Phi b (deg)	Air Entry (kPa)
Mudstone		21	Mohr-Coulomb	0	17.5	None	0	0	0
Glacial Till(Drained)		18	Mohr-Coulomb	0	27	None	0	0	0
Sandstone		22	Mohr-Coulomb	0	45	None	0	0	0
Fluvial (Unnamed Creek)		22	Mohr-Coulomb	0	35	None	0	0	0
Embankment Shell(Drained)		20	Mohr-Coulomb	0	27	None	0	0	0
Embankment Core (Drained)		20	Mohr-Coulomb	0	23	None	0	0	0
Drain		21	Mohr-Coulomb	0	30	None	0	0	0

Section 23+175
Off-stream storage embankment dam
Load Case: Rapid filling
Reservoir filling duration: 35.6 hours



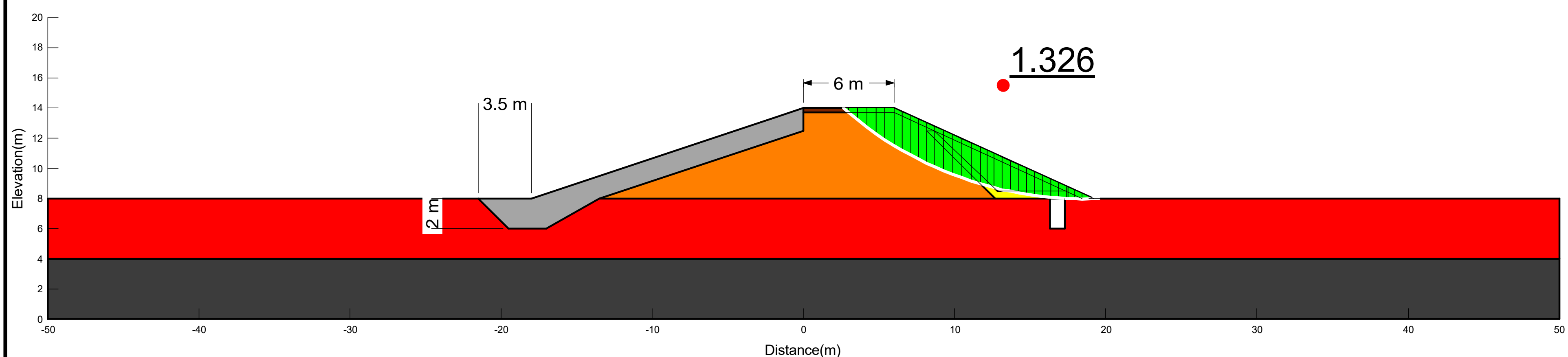
Section: 1+600
Floodplain Berm
Load Case: End of construction before reservoir filling(US)

Color	Name	Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Phi 1 (°)	Phi 2 (°)	Bilinear Normal (kPa)	Phi-B (°)
	Bedrock	Bilinear	25	0	17.5	17.5	0	0
	Fine Filter 3A	Bilinear	21	0	30	30	0	0
	Gravel with Sand and Silt	Bilinear	20	0	27	27	0	0
	Impervious Fill 1A	Bilinear	20	0	23	0	188.47	0
	Random Fill 2A	Bilinear	20	0	27	27	0	0
	Riprap	Bilinear	22	0	38	38	0	0
	Topsoil	Bilinear	20	0	23	0	188.47	0



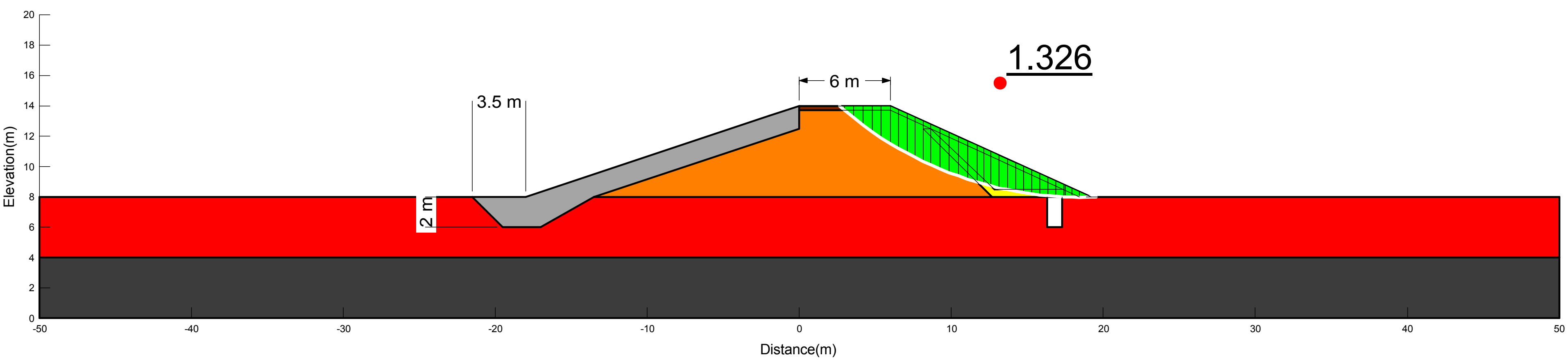
Section: 1+600
Floodplain Berm
Load Case: End of construction before reservoir filling(DS)

Color	Name	Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Phi 1 (°)	Phi 2 (°)	Bilinear Normal (kPa)	Phi-B (°)
	Bedrock	Bilinear	25	0	17.5	17.5	0	0
	Fine Filter 3A	Bilinear	21	0	30	30	0	0
	Gravel with Sand and Silt	Bilinear	20	0	27	27	0	0
	Impervious Fill 1A	Bilinear	20	0	23	0	188.47	0
	Random Fill 2A	Bilinear	20	0	27	27	0	0
	Riprap	Bilinear	22	0	38	38	0	0
	Topsoil	Bilinear	20	0	23	0	188.47	0



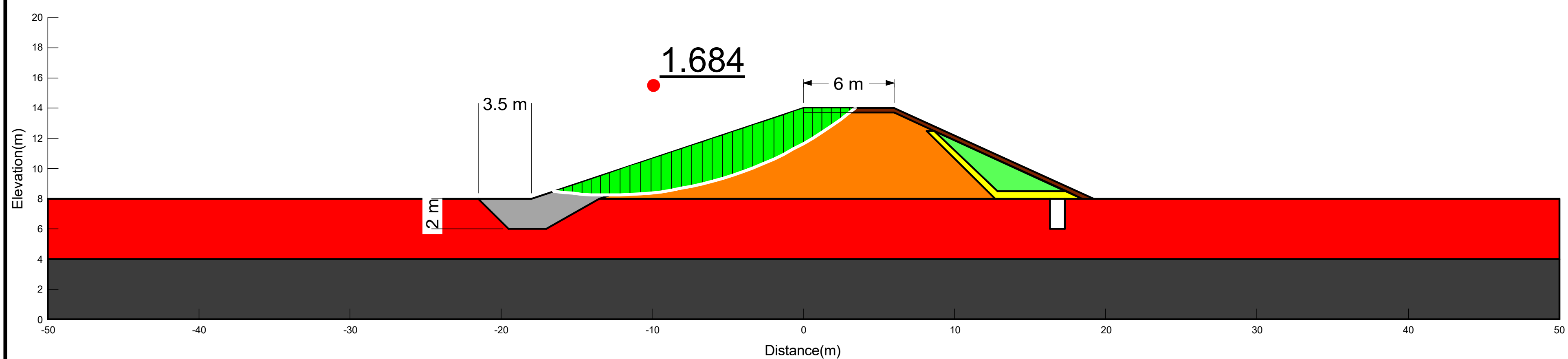
Section: 1+600
Floodplain Berm
Load Case: Post-earthquake (DS)

Color	Name	Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Phi 1 (°)	Phi 2 (°)	Bilinear Normal (kPa)	Phi-B (°)
	Bedrock	Bilinear	25	0	17.5	17.5	0	0
	Fine Filter 3A	Bilinear	21	0	30	30	0	0
	Gravel with Sand and Silt	Bilinear	20	0	27	27	0	0
	Impervious Fill 1A	Bilinear	20	0	23	0	188.47	0
	Random Fill 2A	Bilinear	20	0	27	27	0	0
	Riprap	Bilinear	22	0	38	38	0	0
	Topsoil	Bilinear	20	0	23	0	188.47	0



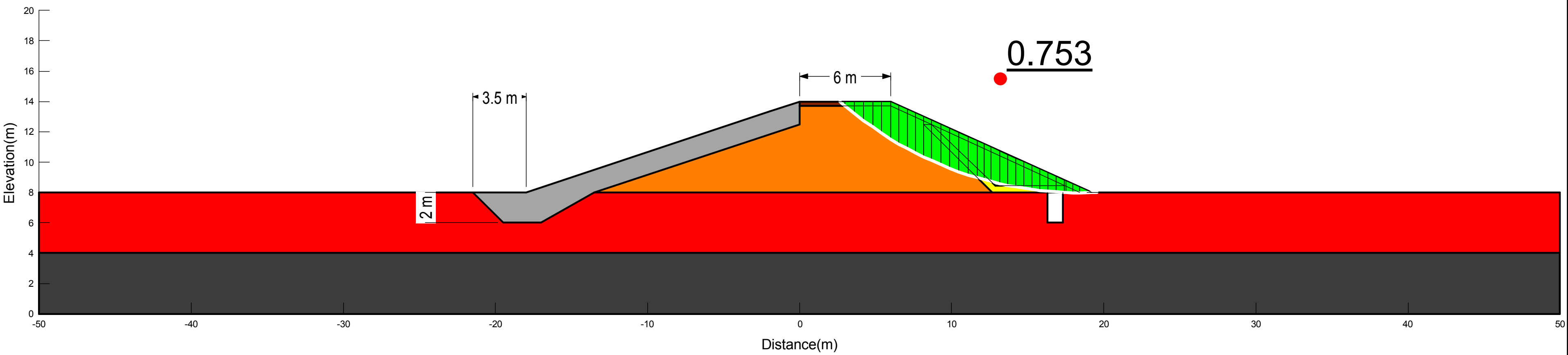
Section: 1+600
Floodplain Berm
Load Case: Post-earthquake (US)

Color	Name	Model	Unit Weight (kN/m^3)	Effective Cohesion (kPa)	Phi 1 (°)	Phi 2 (°)	Bilinear Normal (kPa)	Phi-B (°)
	Bedrock	Bilinear	25	0	17.5	17.5	0	0
	Fine Filter 3A	Bilinear	21	0	30	30	0	0
	Gravel with Sand and Silt	Bilinear	20	0	27	27	0	0
	Impervious Fill 1A	Bilinear	20	0	23	0	188.47	0
	Random Fill 2A	Bilinear	20	0	27	27	0	0
	Riprap	Bilinear	22	0	38	38	0	0
	Topsoil	Bilinear	20	0	23	0	188.47	0



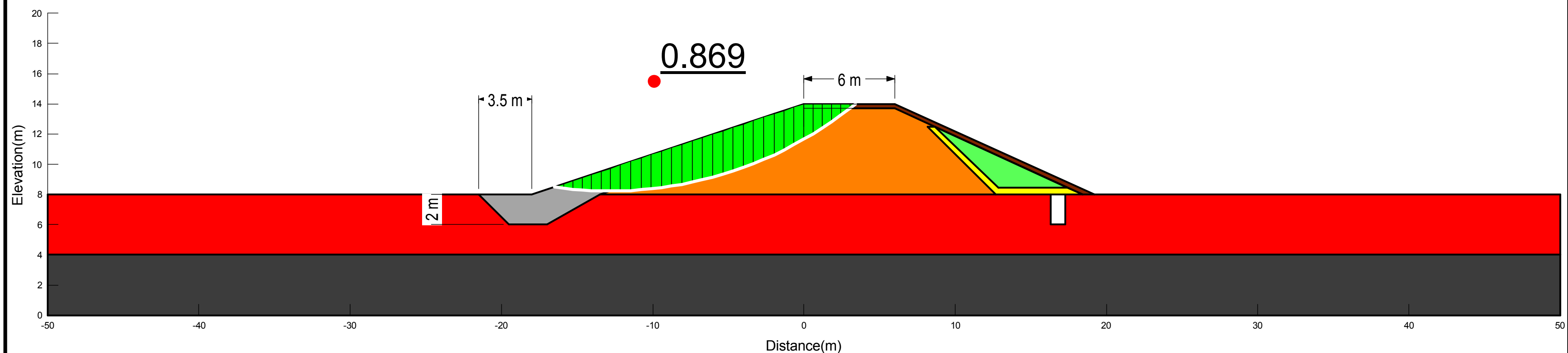
Section: 1+600
Floodplain Berm
Load Case: Pseudo static (DS)

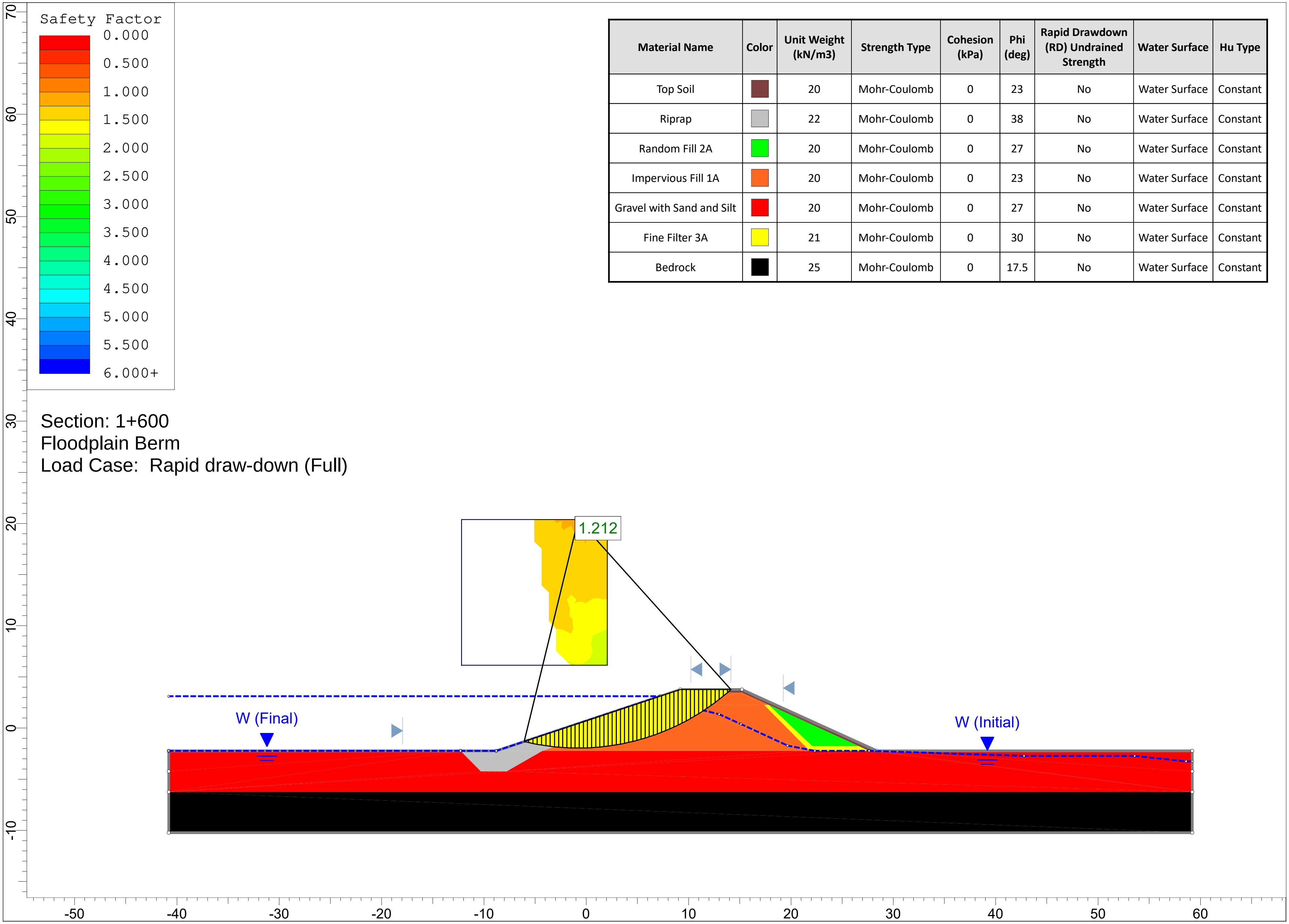
Color	Name	Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Phi 1 (°)	Phi 2 (°)	Bilinear Normal (kPa)	Phi-B (°)
	Bedrock	Bilinear	25	0	17.5	17.5	0	0
	Fine Filter 3A	Bilinear	21	0	30	30	0	0
	Gravel with Sand and Silt	Bilinear	20	0	27	27	0	0
	Impervious Fill 1A	Bilinear	20	0	23	0	188.47	0
	Random Fill 2A	Bilinear	20	0	27	27	0	0
	Riprap	Bilinear	22	0	38	38	0	0
	Topsoil	Bilinear	20	0	23	0	188.47	0



Section: 1+600
Floodplain Berm
Load Case: Pseudo static (US)

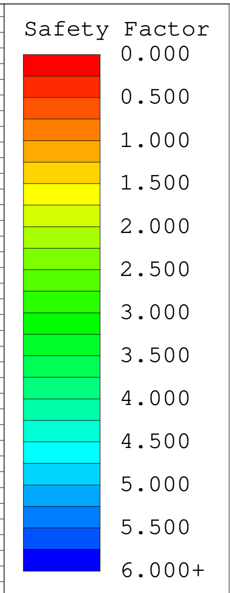
Color	Name	Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Phi 1 (°)	Phi 2 (°)	Bilinear Normal (kPa)	Phi-B (°)
	Bedrock	Bilinear	25	0	17.5	17.5	0	0
	Fine Filter 3A	Bilinear	21	0	30	30	0	0
	Gravel with Sand and Silt	Bilinear	20	0	27	27	0	0
	Impervious Fill 1A	Bilinear	20	0	23	0	188.47	0
	Random Fill 2A	Bilinear	20	0	27	27	0	0
	Riprap	Bilinear	22	0	38	38	0	0
	Topsoil	Bilinear	20	0	23	0	188.47	0





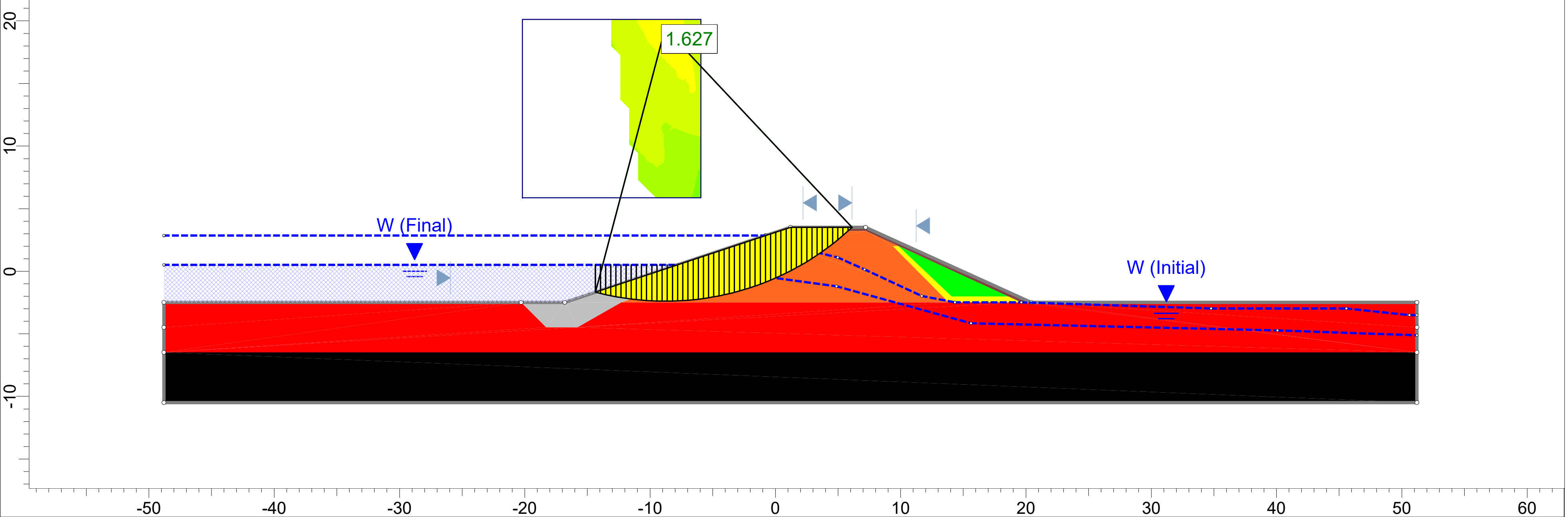
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Rapid Drawdown (RD) Undrained Strength	Water Surface	Hu Type
Top Soil		20	Mohr-Coulomb	0	23	No	Water Surface	Constant
Riprap		22	Mohr-Coulomb	0	38	No	Water Surface	Constant
Random Fill 2A		20	Mohr-Coulomb	0	27	No	Water Surface	Constant
Impervious Fill 1A		20	Mohr-Coulomb	0	23	No	Water Surface	Constant
Gravel with Sand and Silt		20	Mohr-Coulomb	0	27	No	Water Surface	Constant
Fine Filter 3A		21	Mohr-Coulomb	0	30	No	Water Surface	Constant
Bedrock		25	Mohr-Coulomb	0	17.5	No	Water Surface	Constant

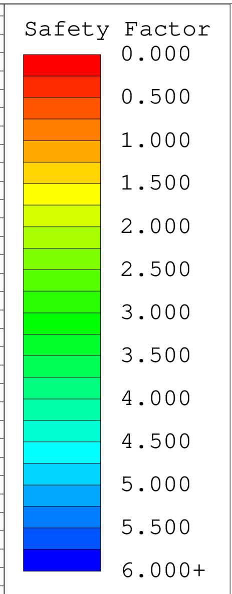
Section: 1+600
Floodplain Berm
Load Case: Rapid draw-down (Full)



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Rapid Drawdown (RD) Undrained Strength	Water Surface	Hu Type
Top Soil		20	Mohr-Coulomb	0	23	No	Water Surface	Constant
Riprap		22	Mohr-Coulomb	0	38	No	Water Surface	Constant
Random Fill 2A		20	Mohr-Coulomb	0	27	No	Water Surface	Constant
Impervious Fill 1A		20	Mohr-Coulomb	0	23	No	Water Surface	Constant
Gravel with Sand and Silt		20	Mohr-Coulomb	0	27	No	Water Surface	Constant
Fine Filter 3A		21	Mohr-Coulomb	0	30	No	Water Surface	Constant
Bedrock		25	Mohr-Coulomb	0	17.5	No	Water Surface	Constant

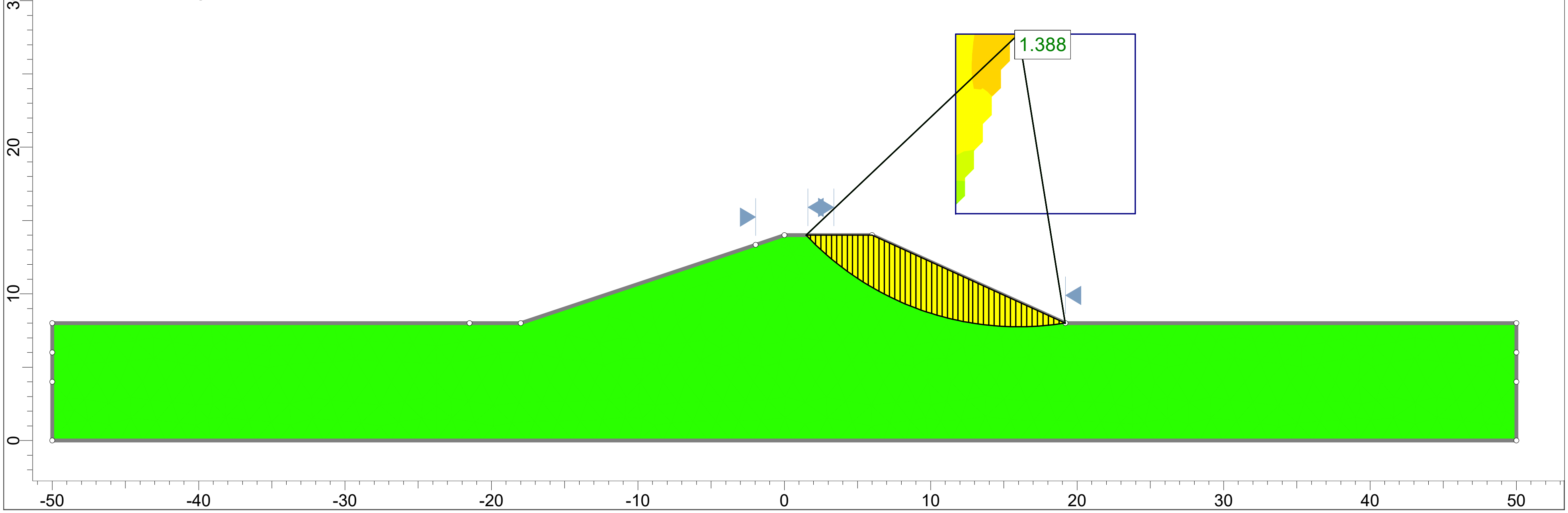
Section: 1+600
Floodplain Berm
Load Case: Rapid draw-down (Partial)

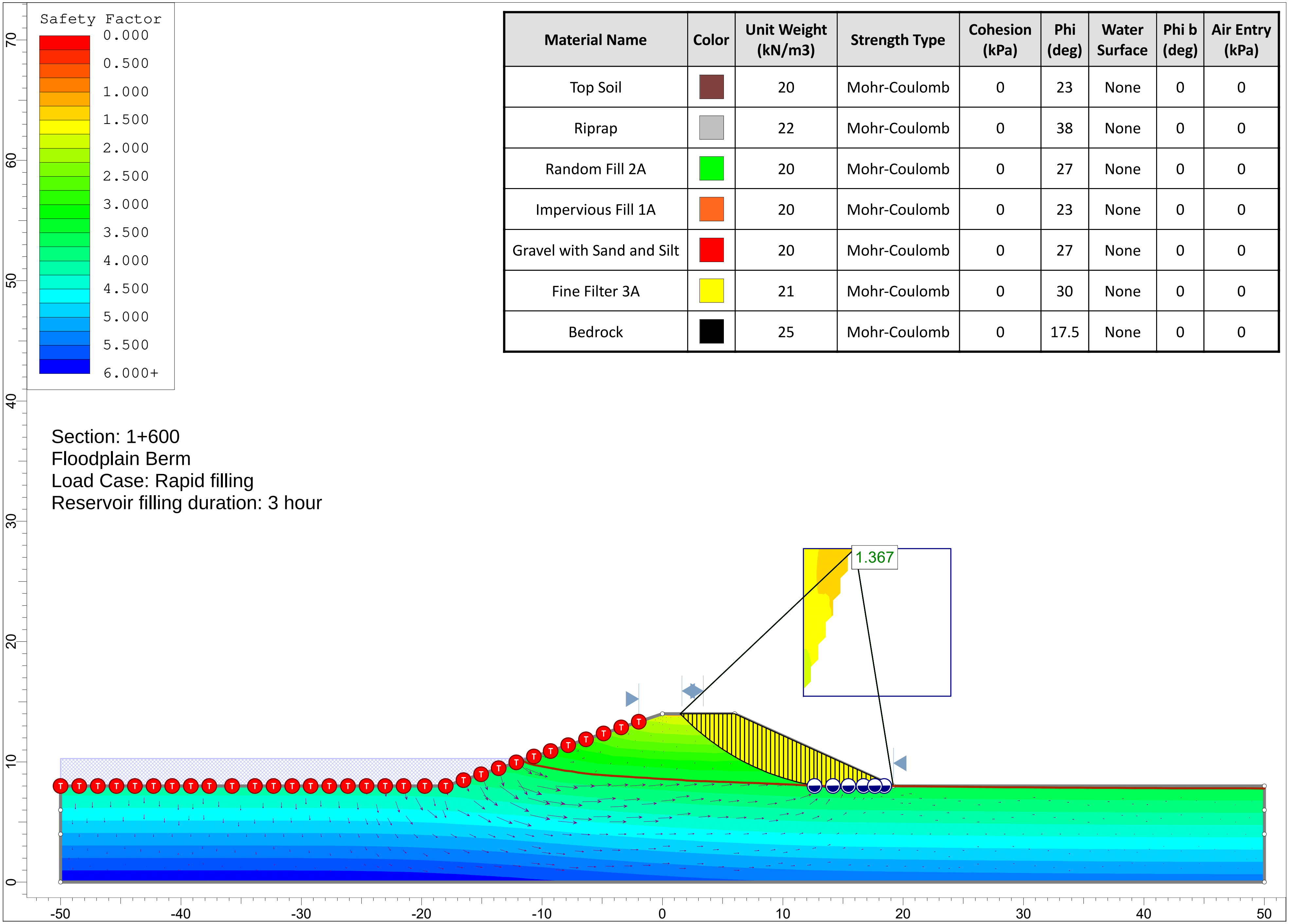




Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Phi b (deg)	Air Entry (kPa)
Top Soil		20	Mohr-Coulomb	0	23	None	0	0
Riprap		22	Mohr-Coulomb	0	38	None	0	0
Random Fill 2A		20	Mohr-Coulomb	0	27	None	0	0
Impervious Fill 1A		20	Mohr-Coulomb	0	23	None	0	0
Gravel with Sand and Silt		20	Mohr-Coulomb	0	27	None	0	0
Fine Filter 3A		21	Mohr-Coulomb	0	30	None	0	0
Bedrock		25	Mohr-Coulomb	0	17.5	None	0	0

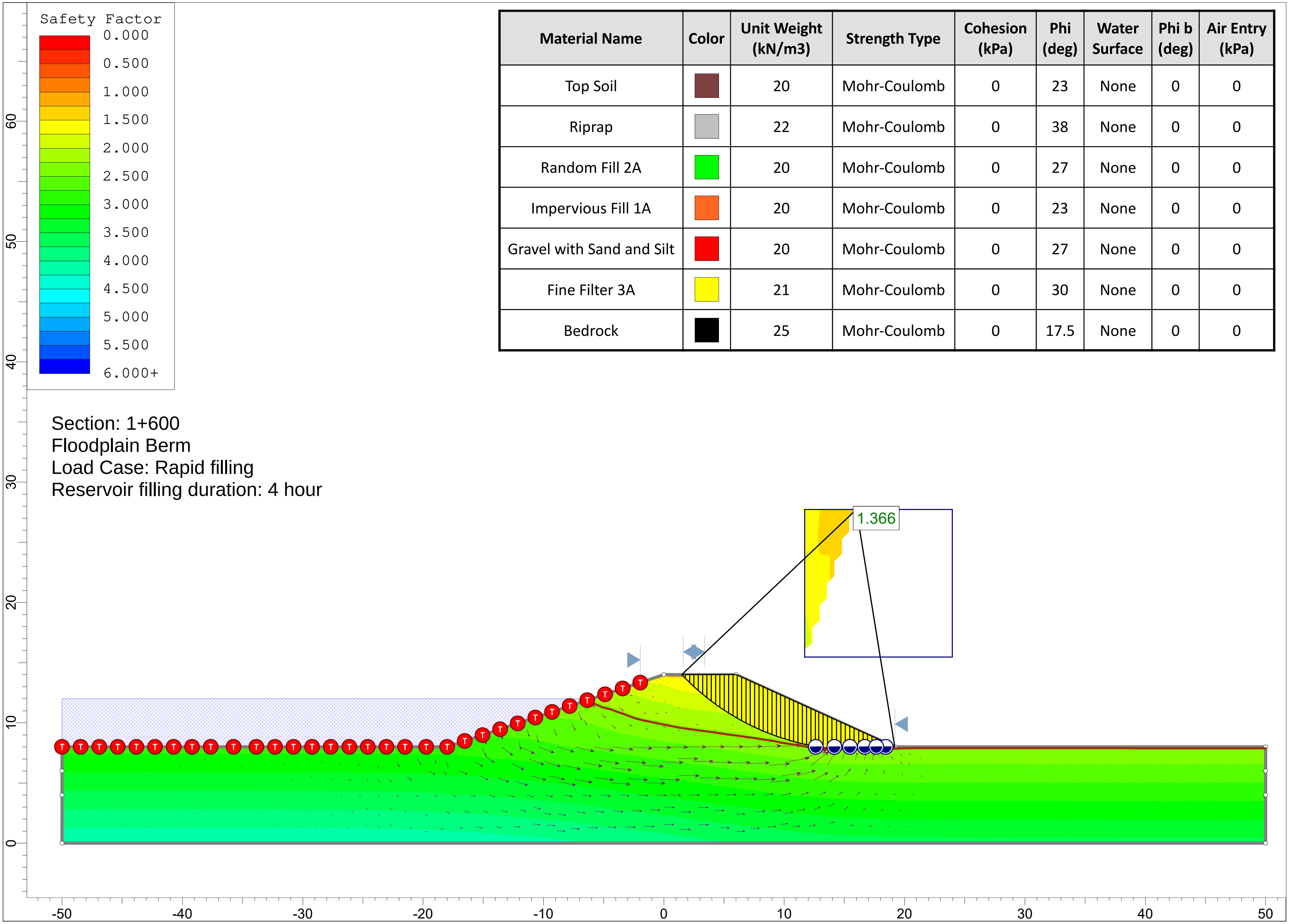
Section: 1+600
Floodplain Berm
Load Case: Rapid filling, Empty reservoir
Reservoir filling duration: 0 hour



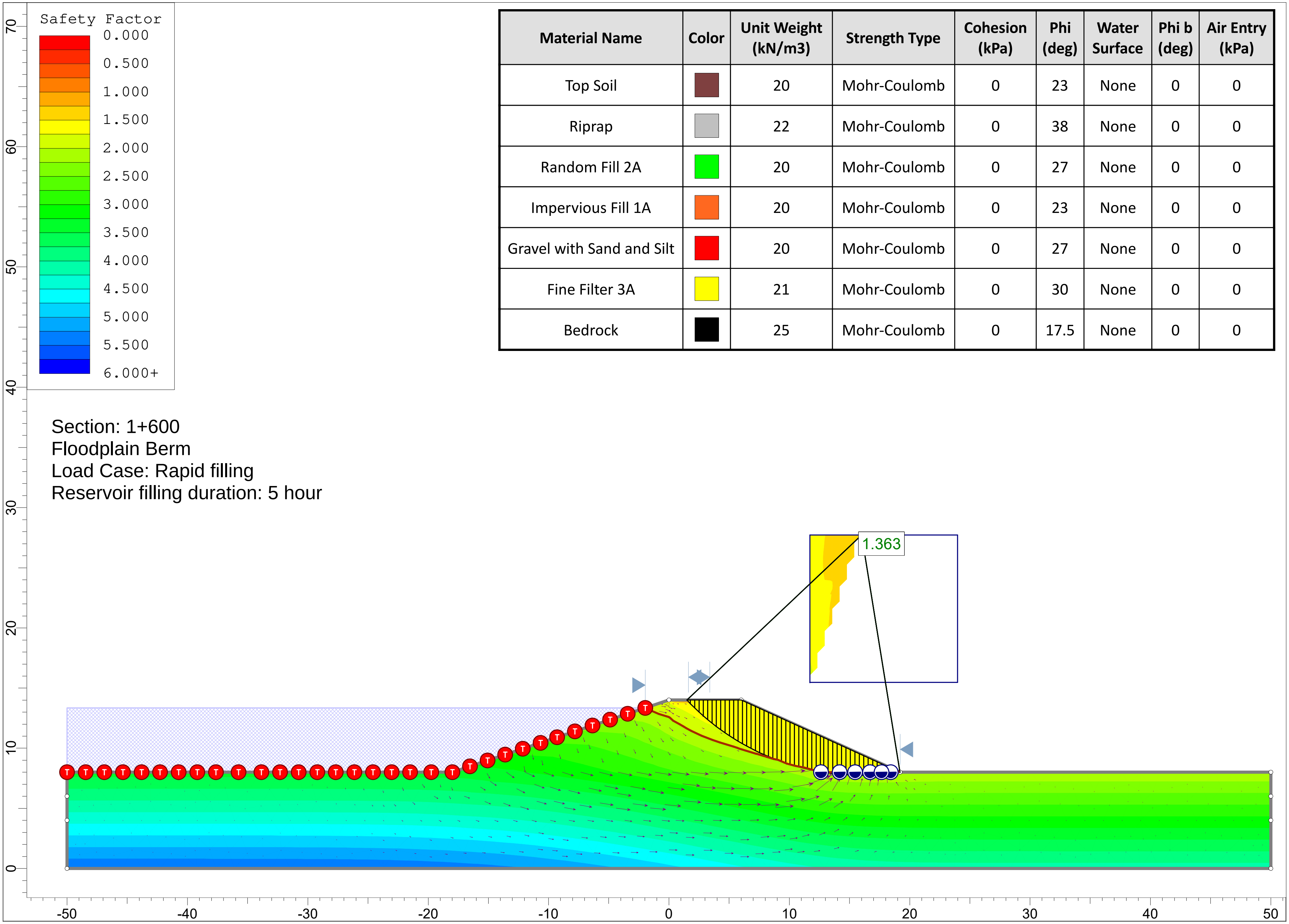


Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Phi b (deg)	Air Entry (kPa)
Top Soil		20	Mohr-Coulomb	0	23	None	0	0
Riprap		22	Mohr-Coulomb	0	38	None	0	0
Random Fill 2A		20	Mohr-Coulomb	0	27	None	0	0
Impervious Fill 1A		20	Mohr-Coulomb	0	23	None	0	0
Gravel with Sand and Silt		20	Mohr-Coulomb	0	27	None	0	0
Fine Filter 3A		21	Mohr-Coulomb	0	30	None	0	0
Bedrock		25	Mohr-Coulomb	0	17.5	None	0	0

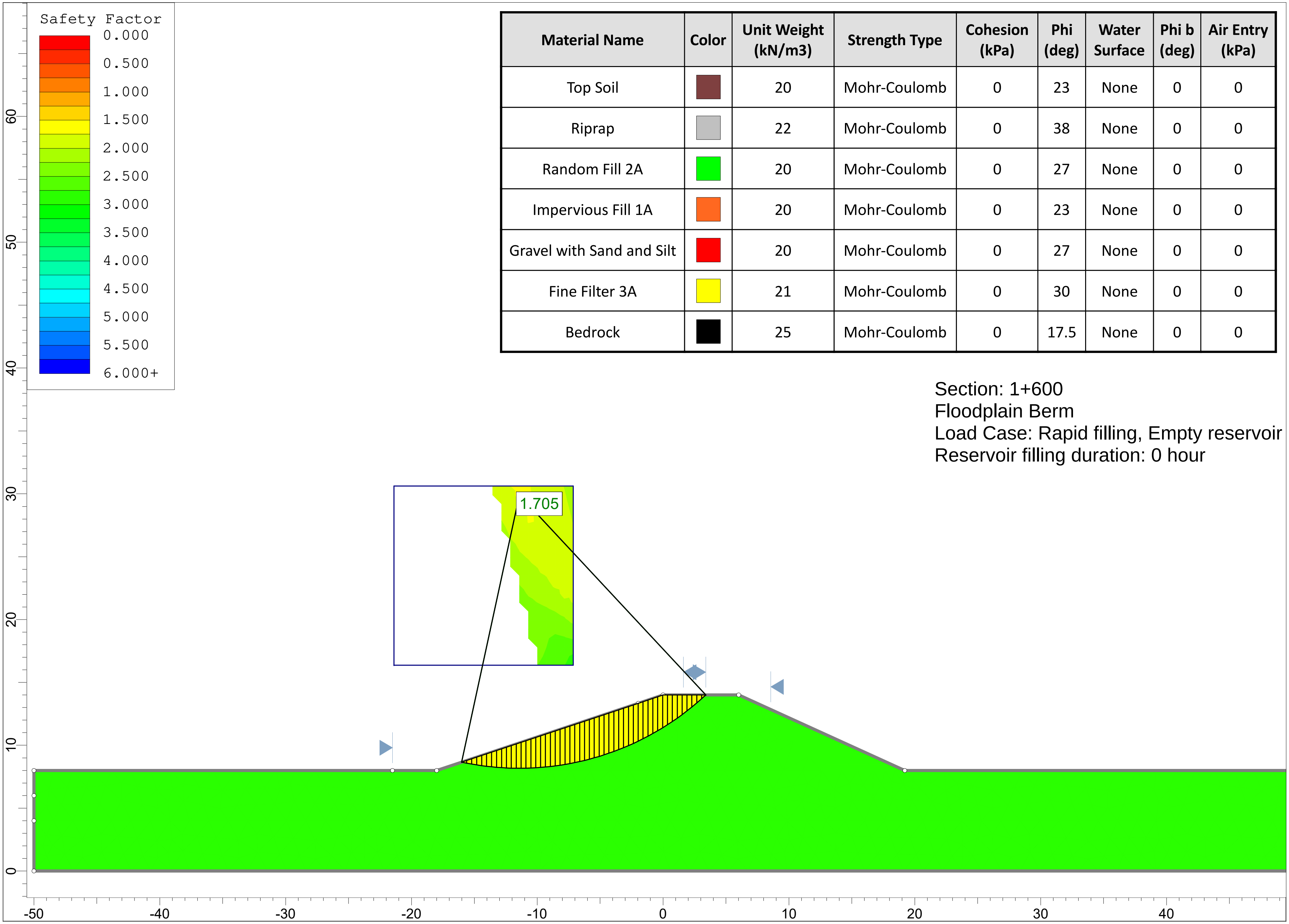
Section: 1+600
Floodplain Berm
Load Case: Rapid filling
Reservoir filling duration: 3 hour



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Phi b (deg)	Air Entry (kPa)
Top Soil		20	Mohr-Coulomb	0	23	None	0	0
Riprap		22	Mohr-Coulomb	0	38	None	0	0
Random Fill 2A		20	Mohr-Coulomb	0	27	None	0	0
Impervious Fill 1A		20	Mohr-Coulomb	0	23	None	0	0
Gravel with Sand and Silt		20	Mohr-Coulomb	0	27	None	0	0
Fine Filter 3A		21	Mohr-Coulomb	0	30	None	0	0
Bedrock		25	Mohr-Coulomb	0	17.5	None	0	0

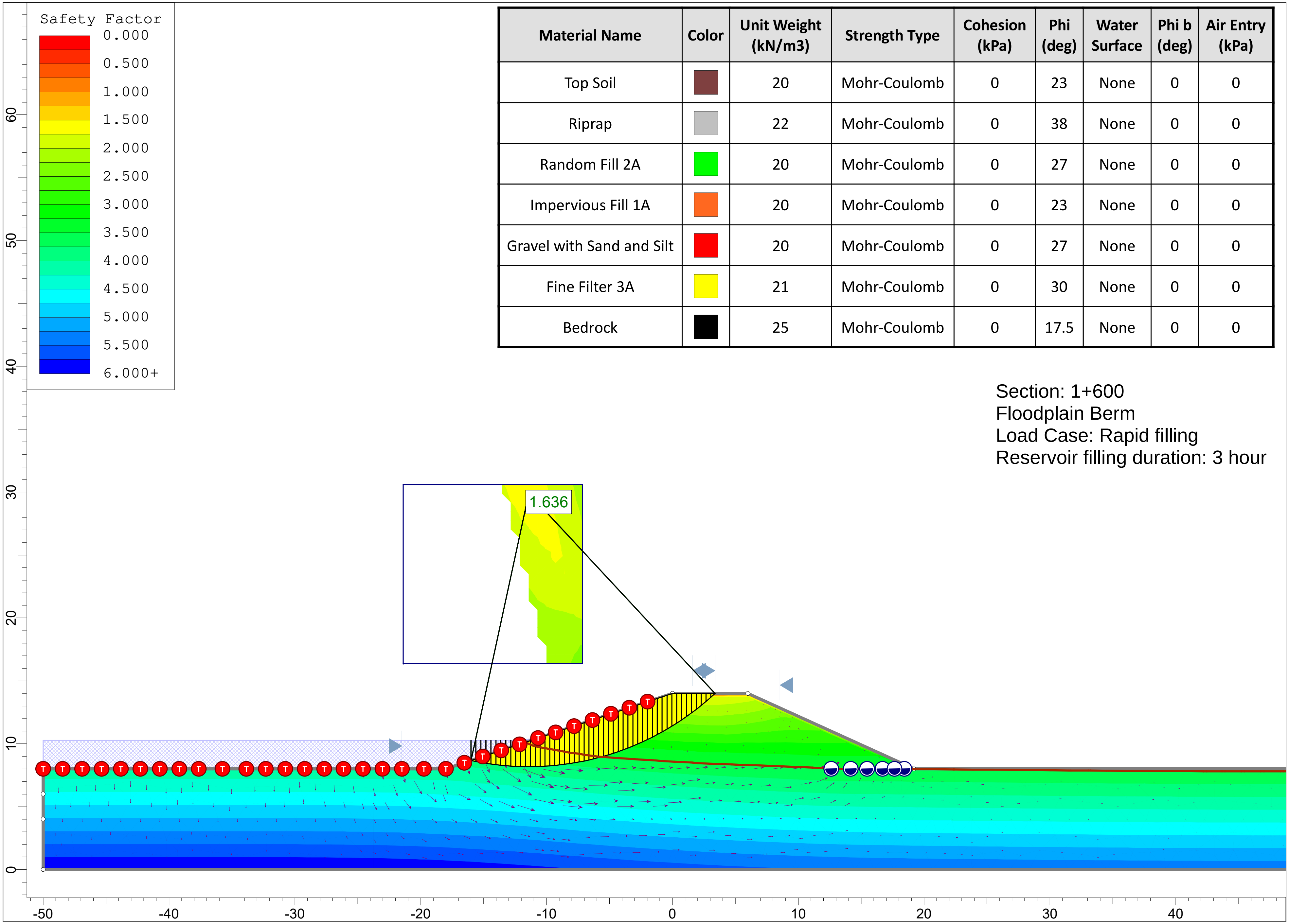


Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Phi b (deg)	Air Entry (kPa)
Top Soil		20	Mohr-Coulomb	0	23	None	0	0
Riprap		22	Mohr-Coulomb	0	38	None	0	0
Random Fill 2A		20	Mohr-Coulomb	0	27	None	0	0
Impervious Fill 1A		20	Mohr-Coulomb	0	23	None	0	0
Gravel with Sand and Silt		20	Mohr-Coulomb	0	27	None	0	0
Fine Filter 3A		21	Mohr-Coulomb	0	30	None	0	0
Bedrock		25	Mohr-Coulomb	0	17.5	None	0	0

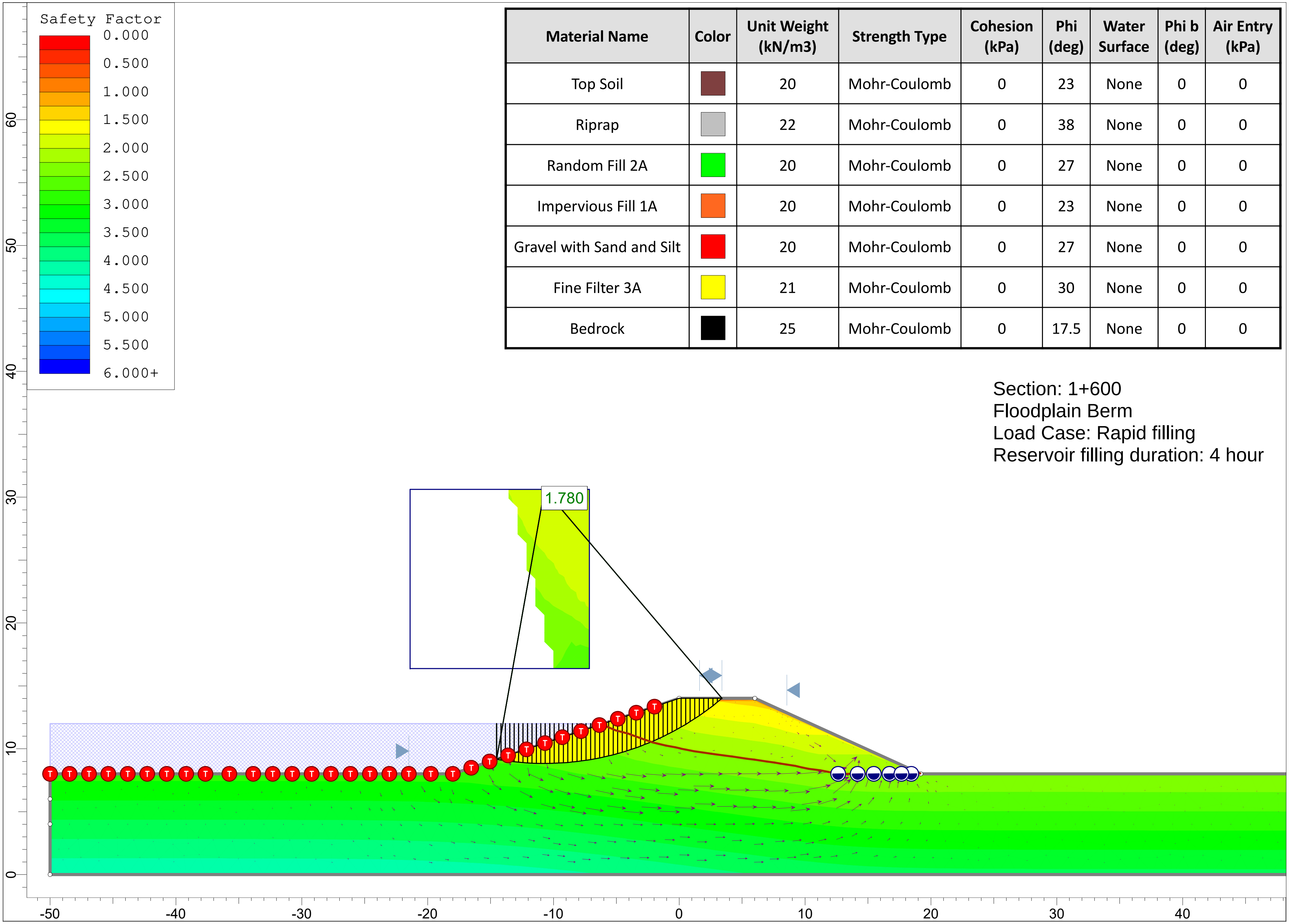


Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Phi b (deg)	Air Entry (kPa)
Top Soil		20	Mohr-Coulomb	0	23	None	0	0
Riprap		22	Mohr-Coulomb	0	38	None	0	0
Random Fill 2A		20	Mohr-Coulomb	0	27	None	0	0
Impervious Fill 1A		20	Mohr-Coulomb	0	23	None	0	0
Gravel with Sand and Silt		20	Mohr-Coulomb	0	27	None	0	0
Fine Filter 3A		21	Mohr-Coulomb	0	30	None	0	0
Bedrock		25	Mohr-Coulomb	0	17.5	None	0	0

Section: 1+600
Floodplain Berm
Load Case: Rapid filling, Empty reservoir
Reservoir filling duration: 0 hour

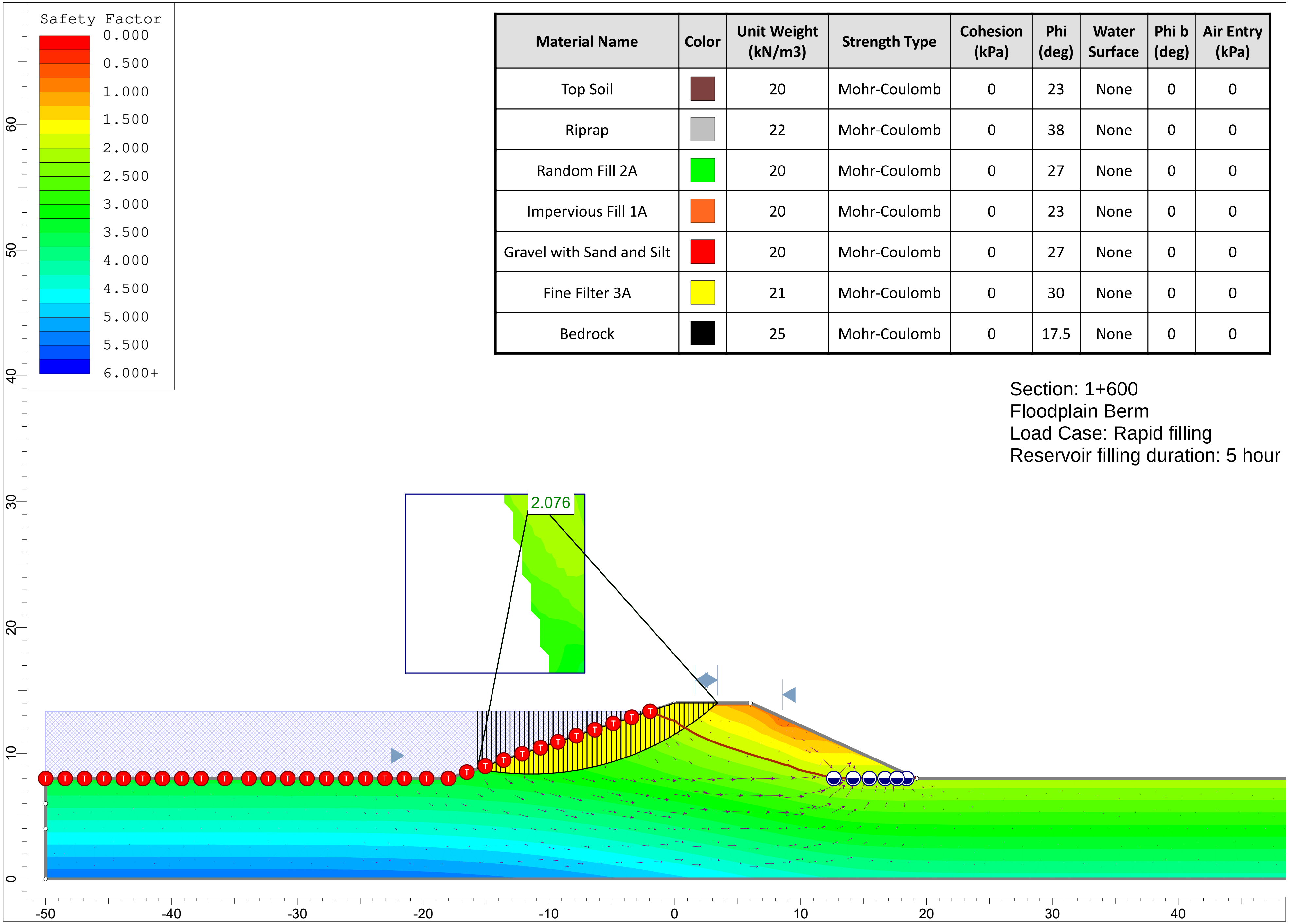


Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Phi b (deg)	Air Entry (kPa)
Top Soil		20	Mohr-Coulomb	0	23	None	0	0
Riprap		22	Mohr-Coulomb	0	38	None	0	0
Random Fill 2A		20	Mohr-Coulomb	0	27	None	0	0
Impervious Fill 1A		20	Mohr-Coulomb	0	23	None	0	0
Gravel with Sand and Silt		20	Mohr-Coulomb	0	27	None	0	0
Fine Filter 3A		21	Mohr-Coulomb	0	30	None	0	0
Bedrock		25	Mohr-Coulomb	0	17.5	None	0	0



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Phi b (deg)	Air Entry (kPa)
Top Soil		20	Mohr-Coulomb	0	23	None	0	0
Riprap		22	Mohr-Coulomb	0	38	None	0	0
Random Fill 2A		20	Mohr-Coulomb	0	27	None	0	0
Impervious Fill 1A		20	Mohr-Coulomb	0	23	None	0	0
Gravel with Sand and Silt		20	Mohr-Coulomb	0	27	None	0	0
Fine Filter 3A		21	Mohr-Coulomb	0	30	None	0	0
Bedrock		25	Mohr-Coulomb	0	17.5	None	0	0

Section: 1+600
Floodplain Berm
Load Case: Rapid filling
Reservoir filling duration: 4 hour



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Phi b (deg)	Air Entry (kPa)
Top Soil		20	Mohr-Coulomb	0	23	None	0	0
Riprap		22	Mohr-Coulomb	0	38	None	0	0
Random Fill 2A		20	Mohr-Coulomb	0	27	None	0	0
Impervious Fill 1A		20	Mohr-Coulomb	0	23	None	0	0
Gravel with Sand and Silt		20	Mohr-Coulomb	0	27	None	0	0
Fine Filter 3A		21	Mohr-Coulomb	0	30	None	0	0
Bedrock		25	Mohr-Coulomb	0	17.5	None	0	0