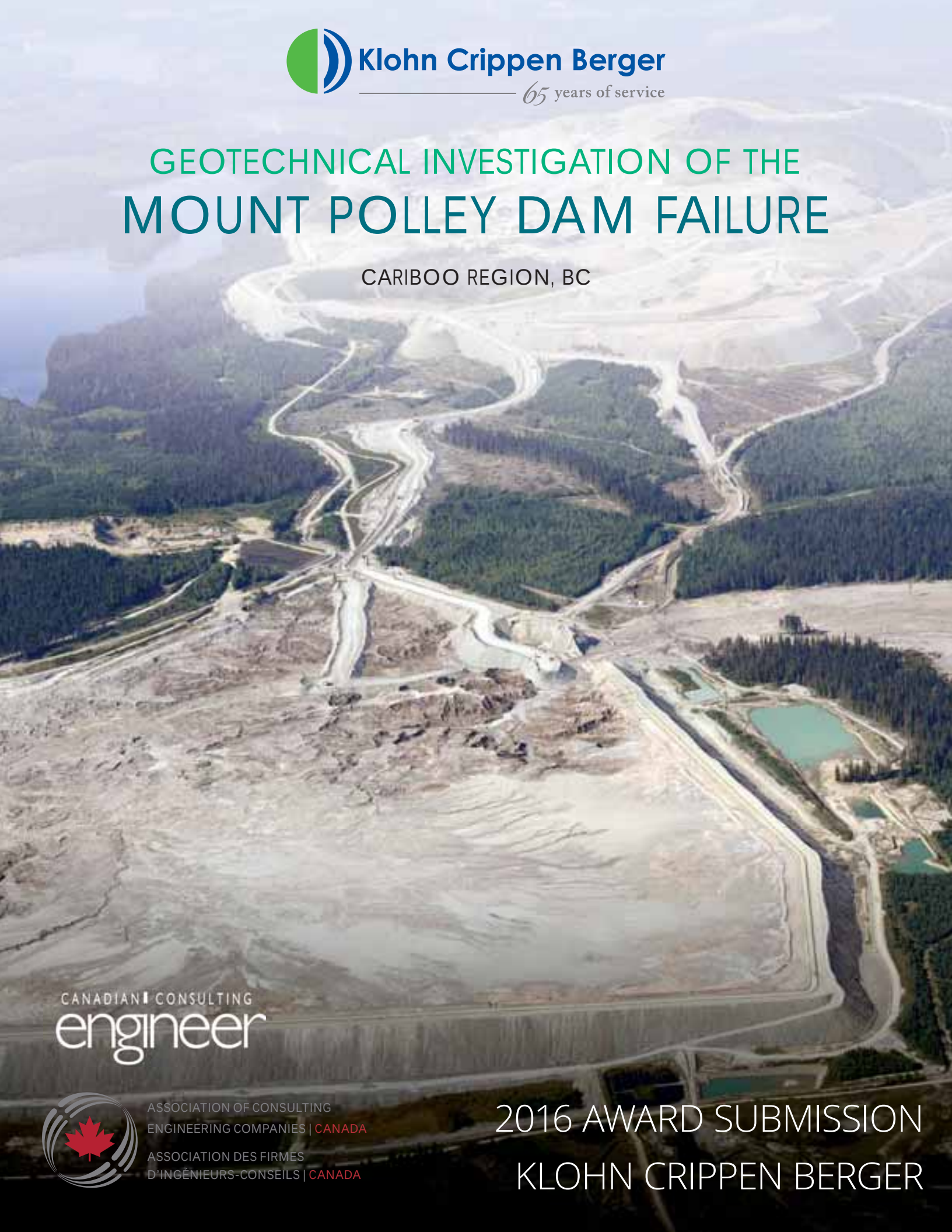
Klohn Crippen Berger

65 years of service

GEOTECHNICAL INVESTIGATION OF THE MOUNT POLLEY DAM FAILURE

CARIBOO REGION, BC



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2016 AWARD SUBMISSION

KLOHN CRIPPEN BERGER

innovation

On August 4, 2014, the tailings impoundment at Mount Polley Mine breached, resulting in the release of an estimated 17 million m^3 of water and 8 million m^3 of tailings solids that flowed into Polley Lake, Hazeltine Creek and Quesnel Lake.

The Mount Polley mine site is located 11 km from the town of Likely in the interior of British Columbia. Tailings are retained by a U-shaped dam abutting a natural slope on the northwest side. The tailings dam comprises three embankments: the Main Embankment on the southeast side, the South Embankment bounding the southwest side and the Perimeter Embankment bounding the northeast side. The dam failed between Stations 4+110 and 4+350 at the highest section of the Perimeter Embankment.

KCB was retained by the Ministry of Energy and Mines (MEM) to support their inquiry into the dam breach. As part of this work, KCB conducted forensic geotechnical investigations to gather the necessary factual data to support the technical assessment of the dam failure mechanism – how the dam failed. Definition of the failure mechanism was an important step in MEM's subsequent evaluation of the root causes leading to the failure event.

KCB planned and executed a detailed sequence of geotechnical investigations and studies to determine the geology of the soils and bedrock below the dam, to re-construct the as-built (pre-failure) section of the dam based on construction records, and to characterize the geotechnical properties of the foundation soils and dam fill materials. This work included six months of field and laboratory studies, and a comprehensive review of design, construction and operational records.

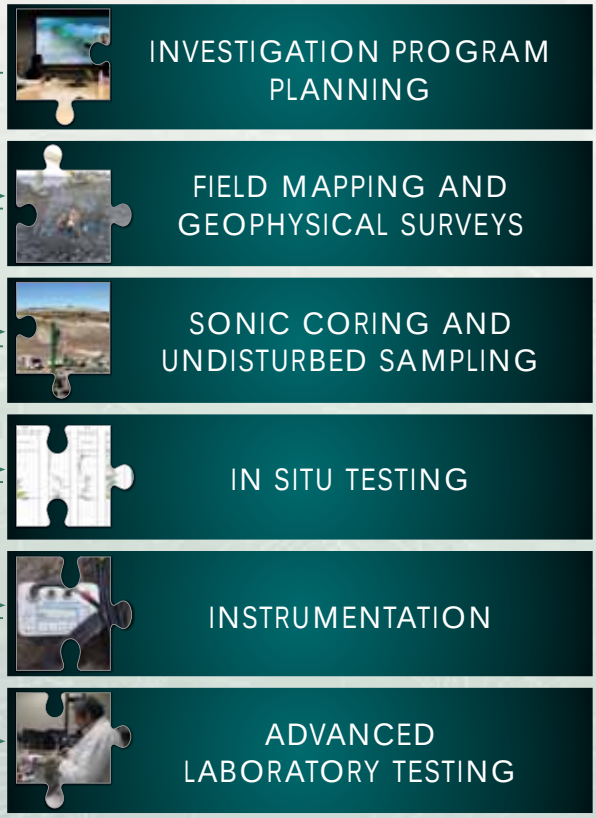
Geo-forensic field work took six months and included over 1,000 soil index property tests

The investigation program drew from KCB's 65 years of experience in geotechnical studies and tailings dam design in British Columbia and elsewhere, and incorporated investigative techniques developed from our previous investigations of the 1995 Omai tailings dam failure in Guyana and the 1998 Los Frailes tailings dam failure in Spain.

The results of KCB's work provided the definitive basis for understanding the geology of the dam site and, ultimately, how the dam failed by sliding on a thin layer of glaciolacustrine clay at a depth of 10 m below the dam. The methods of the investigative studies and determination of the failure mechanism will be an essential reference for the future design of tailings facilities not only in British Columbia, but across Canada and worldwide.

complexity

KCB conducted a detailed geotechnical investigation of the breach area to assess the mechanism of the dam failure. This work included 6 months of field and laboratory studies followed by investigative analyses of the failure mechanism. The geo-forensic field investigation included:



- Mapping of the failure area
- Seismic and resistivity geophysical surveys
- 24 sonic coring holes and undisturbed sampling
- In situ testing including SPT, CPT and vane shear
- Instrumentation: 22 piezometers to assess the water pressures in the foundation soils and 5 inclinometers which were able to record post-failure creep movements along the sliding plane in the foundation.

The laboratory work was extensive and included:

- Over 1,000 basic soil index property tests
- Over 50 advanced soil strength and behaviour tests

The geology is complex involving multiple glacial till and glaciolacustrine layers deposited during several advances and retreat of the glacial ice sheets over 10,000 years ago. The dam ultimately failed on a weak clay layer in the foundation referenced as the Upper Glaciolacustrine Unit (UGLU). This clay layer was only 2 m thick and located 10 m below the dam.

The Quaternary geology of the Mount Polley Mine is complex, involving multiple glacial till and glaciolacustrine layers deposited during several advances and retreats of glacial ice sheets over 10,000 years ago. Moreover, available pre-failure information on the site geology below the failed dam was limited in number and depth. Consequently, a carefully staged investigation program was necessary to define the geology of the site and then to investigate the geotechnical properties of the governing soil units influencing dam stability.

social and / or economic benefits

The mining industry has been impacted severely by the high profile failures of tailings dams around the world. Each failure has threatened public safety, impacted the environment, and diminished the economic livelihood of both the affected community and the mining companies involved. Critically, these events have eroded the social license of mining as a sustainable industry and meaningful steps must be taken to prevent future failures in order to re-establish the confidence of the public at large, governments and all stakeholders in the mining industry.

In order to change and improve practices for safely managing mine tailings, it is essential that each dam failure is studied exhaustively so that the failure mechanism is clearly defined and the engineering profession, mine operators and regulatory bodies can apply the findings and lessons to the design, operation and maintenance of tailings facilities. This was the clear goal and achievement of KCB's investigation studies.

environmental benefits

On August 4, 2014, the tailings impoundment at Mount Polley Mine breached, resulting in the release of an estimated 17 million m3 of water and 8 million m3 of tailings solids that flowed into Polley Lake, Hazeltine Creek and Quesnel Lake. The tailings dam breach was one of the largest in the world by volume. The environmental impact in the area will be felt for years.

Not long after that, we witnessed the tragedy in Samarco which was a destructive force impacting the downstream community and costing lives.

An understanding of failures such as these will help to shape best practices moving forward with the hope to eliminate critical failures such as these.

meeting client's needs

KCB planned and executed a strategically phased approach to the investigation studies to accomplish the project's needs. Ultimately, the foundation of the dam was found to include three distinct till units, two glaciolacustrine clay layers, and two distinct glaciofluvial sand and gravel deposits. The critical UGLU clay lay approximately 10 m below the base of the dam. This clay is a high plastic, clay-rich varved lacustrine deposit ranging up to 2 m thick. The areal extent of the UGLU was largely confined to the immediate area of the failed dam.

Using the results of KCB's investigative work, the failure mechanism was assessed by the Independent Review Panel (IRP) commissioned by the Government of British Columbia and by KCB on behalf of MEM. Both the IRP and KCB concluded that the basic failure mechanism of the Mount Polley tailings dam was a sliding failure through a lightly overconsolidated glaciolacustrine clay unit (UGLU) in the foundation, which dropped the dam crest sufficiently to allow the pond to overtop and, within a few hours, to completely breach a portion of the Perimeter Embankment. This mechanism was manifested by the physical evidence of dam displacements and shear movements in the dam foundation recorded by KCB's investigative studies, and was corroborated by back-analyses using the engineering properties of the dam and foundation soils determined by the investigations.

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CARIBOO REGION, BC

BRITISH COLUMBIA | Mining and Mineral Resources Division — Ministry of Energy and Mines

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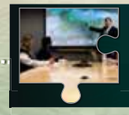
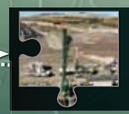
Klohn Crippen Berger (KCB) was retained by the Ministry of Energy and Mines (MEM) to support their inquiry into the breach. As part of this work, KCB undertook comprehensive forensic geotechnical investigations to assess the mechanism of the dam failure. This work included six months of field and laboratory studies followed by investigative analyses of the failure mechanism.

The results of KCB's work provided the basis for understanding how the dam failed, and will also be an essential reference for the future design of tailings facilities in BC. These data were also provided to the Independent Expert Engineering Panel and used in their report issued January 30, 2015.



INVESTIGATION PROGRAM PLANNING

FIELD MAPPING AND GEOPHYSICAL SURVEYS



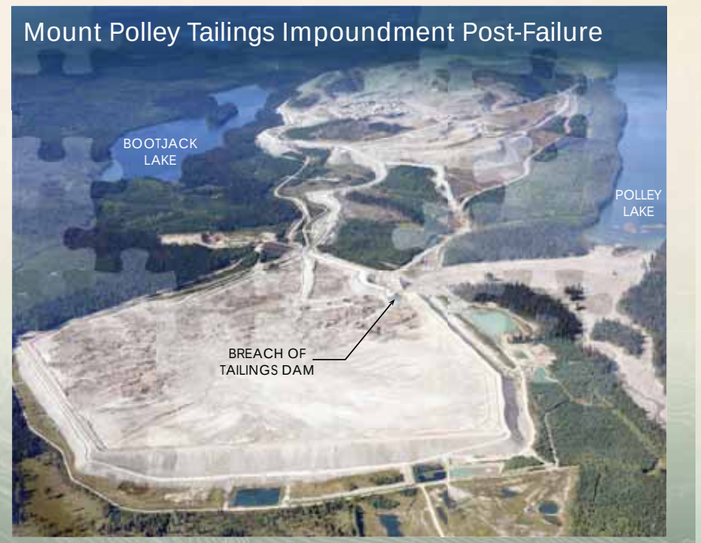
SONIC CORING AND UNDISTURBED SAMPLING

IN SITU TESTING

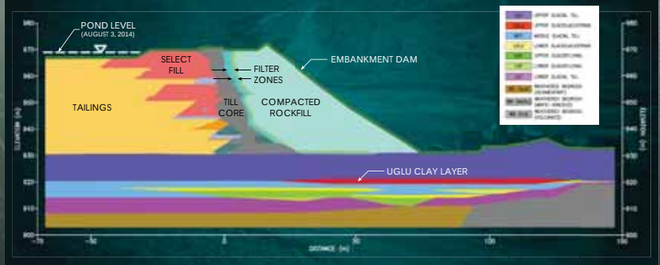
INSTRUMENTATION

ADVANCED LABORATORY TESTING

Mount Polley Tailings Impoundment Post-Failure



Pre-failure Dam Section and Foundation Geology



Upper Glaciolacustrine Unit (UGLU)

The site geology is complex with multiple glacial till and glaciolacustrine layers deposited during several advances and retreats of glacial ice sheets over 10,000 years ago. The dam ultimately failed on a weak high plastic clay layer in the foundation referred to as the Upper Glaciolacustrine Unit (UGLU). This clay layer is only 2 m thick and located 10 m below the dam.

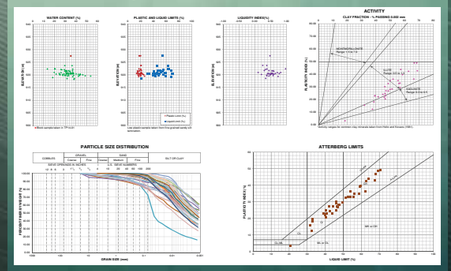
The properties and strength of the UGLU were studied extensively in KCB's field and laboratory studies.

Field examination of sonic drill core

Undisturbed UGLU clay outside failed dam area

Disturbed UGLU clay below failed dam

Index Properties of UGLU



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photos

MOUNT POLLEY TAILINGS IMPOUNDMENT POST-FAILURE

FIELD EXAMINATION OF SONIC DRILL CORE

UNDISTURBED UGLU CLAY OUTSIDE FAILED DAM AREA (LEFT)
AND DISTURBED UGLU CLAY BELOW FAILED DAM (RIGHT)

RECORDING OF INSTALLED VIBRATING WIRE PIEZOMETERS

illustrations

UPPER GLACIOLACUSTRINE UNIT (UGLU)

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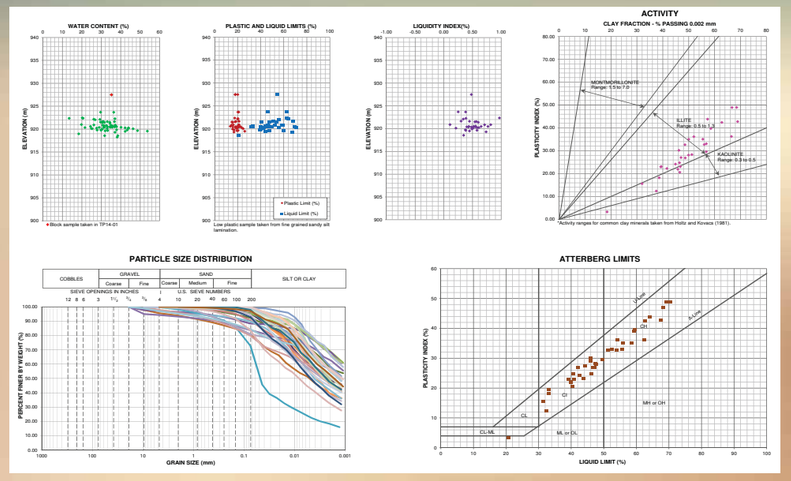
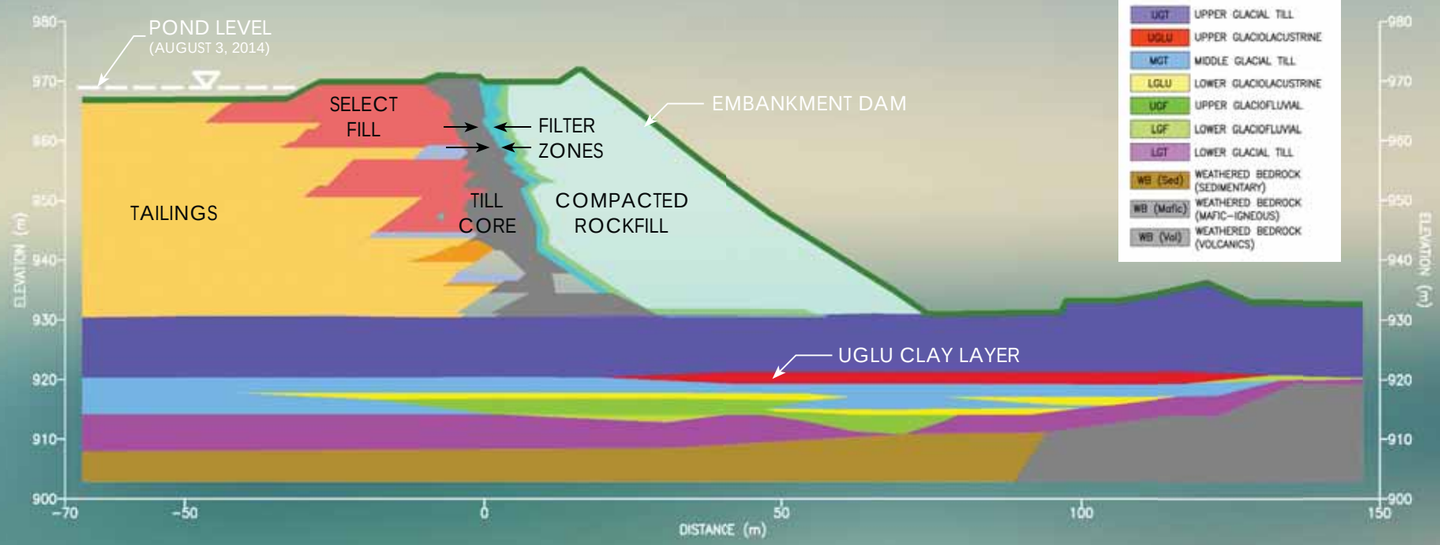
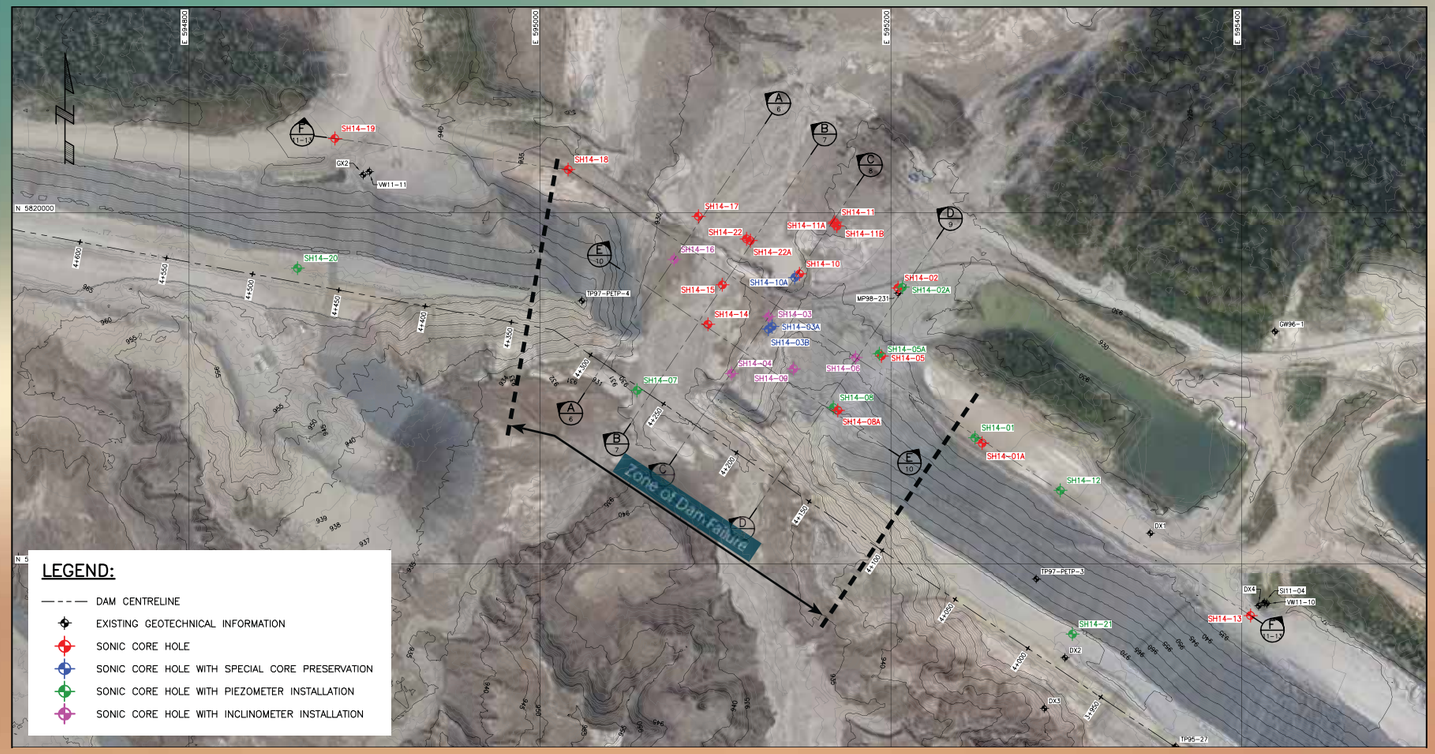


Index Properties of UGLU

RE-CONSTRUCTED EMBANKMENT SECTION AND FOUNDATION GEOLOGY



SONIC CORE HOLE LOCATIONS WITH AIR PHOTO OVERLAY

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