Canadian Consulting Engineering Awards 2012 Submission

Innovative Tailings Management

Greens Creek Mine, Alaska

CANADIAN CONSULTING engineer

ASSOCIATION OF CONSULTING ENGINEERING COMPANIES | CANADA
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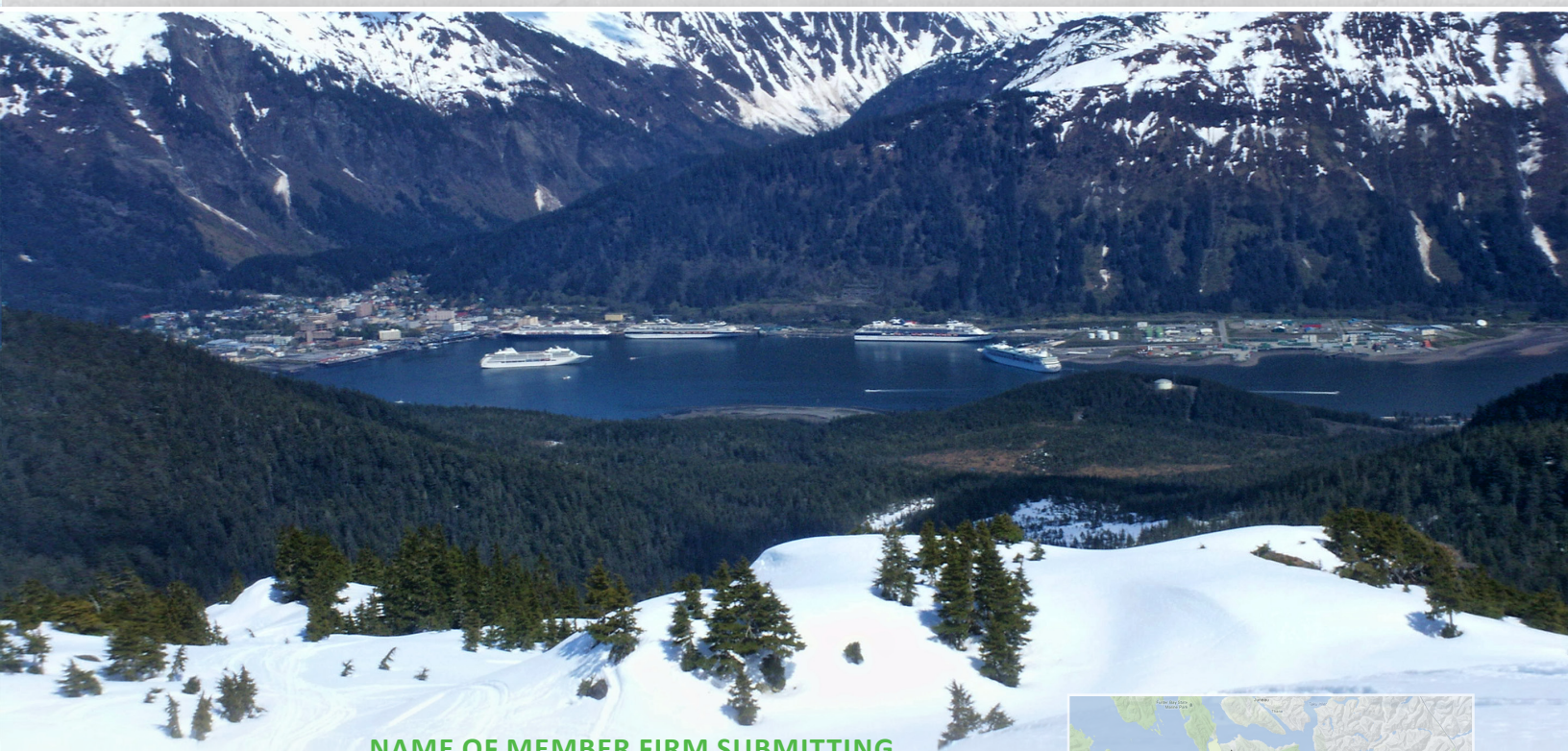
Klohn Crippen Berger



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CONTACT NAME

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PROJECT TITLE

Innovative Tailings Management in a Harsh Climate

LOCATION OF PROJECT

Admiralty Island, Alaska, USA

COMPONENT BEING SUBMITTED

Tailings Disposal Area Expansion: Design, Construction and Operation

CATEGORY OF ENTRY

Natural Resource, Energy and Industry

PROJECT CLIENT

Hecla Greens Creek Mining Company (HGCMC)

PROJECT OWNER

Hecla Greens Creek Mining Company

Innovative Tailings Management

Submitted by: Klohn Crippen Berger

The Hecla Greens Creek Mining Company (HGCMC) polymetallic mine is located on northern Admiralty Island, about 29 kilometers southeast of Juneau, Alaska. A portion of the mine facilities are located within Admiralty Island National Monument.

Admiralty Island is well known for having one of the largest populations of brown bears in the world and is home to many species of salmon, birds, whales, and deer which makes the island a popular destination for tourists. Western Hemlock and Sitka Spruce dominate the prolific rainforest vegetation. This temperate coastal rainforest ecosystem is characterized by cool temperatures and high annual precipitation.

One of the key elements in maintaining a license to operate in such a sensitive area was to find and implement a tailings disposal method that would be safe and effective in this harsh environment while preserving the world class tourism attractions in the area.

The solution was the world's first large dry stack filtered tailings disposal system. The key advantages of this approach is that dry stacks can withstand static and seismic forces, reduces the footprint of the tailings storage by over 50% with no pond and allows wildlife to roam freely without risk and allows for progressive and continuous reclamation of the land.

Klohn Crippen Berger (KCB) was entrusted with the design, construction monitoring and geotechnical input to operation of the Tailings Disposal Area Expansion. Primary objectives of this project were to develop solutions to store de-watered tailings in an environmentally and regulatory sensitive site, and minimize acid rock drainage and visual impacts.

Objectives

The HGCMC was the first mine in the world to adopt the filtered tailings disposal method and is the longest operating. Klohn Crippen Berger's involvement with this facility dates back to the pre-feasibility and conceptual design stages in the early 1980's. Construction of the tailings disposal facility (TDF) commenced in 1988, and tailings placement began in early 1989. In 1993 mine operations were suspended due to low metal market prices. The mine re-opened in 1996 and KCB was asked to assist with the TDF expansion. During the course of this work, major advances were made in the understanding of the seismic behavior of filtered tailings and the design and construction methodology in a cold, wet environment.

To help manage the design, construction and operation of the Tailings Disposal Area Expansion KCB needed to: determine whether dry stack tailings could withstand a major seismic event; develop a plan that could be implemented in a harsh and remote climate while meeting strict regulatory requirements; develop solutions for tailings storage that met rigorous federal and state air and water quality standards; and develop solutions that coexist with wildlife and reduce visual impact.

Continuous operation and a proposed further expansion of the mine, up to an additional 50 years, is important to the economy of Southeast Alaska and the performance of the tailings area to date is a key determinant in the permit application. Technical advances, demonstrated excellence, and environmental stewardship have allowed mine operators to build the confidence of the regulators to permit additional expansions.

Solutions

The work on the TDF included geomembrane-lined cells, upgrading of the water management system, and the construction of infrastructure to support mine operations.

The TDF was designed and constructed with water management structures that intercept and divert surface water and groundwater (non-contact water) away from the tailings stack. The tailings stack incorporated internal drainage structures to promote low phreatic levels. Water coming in contact with the tailings is collected and treated to meet permitted water quality standards, and ultimately discharged to the environment.

The nature of the site posed many challenges that needed to be taken into consideration with regards to scheduling and construction. The site is located on a remote island. Crew, equipment and materials needed to be brought in by boat, construction could not affect the active, continuous mining operation. Construction would stop when free roaming bears entered the site to protect the wildlife and the crew. Extreme weather conditions affected the scheduling of crew and construction.

Innovative Tailings Management

Submitted by: Klohn Crippen Berger

Technical Excellence and Innovation

Greens Creek is a flagship project and an example to other operators as the application of best practice tailings storage. The mine is able to safely coexist with one of the densest brown bear populations in the world and bears can regularly be seen roaming unharmed over the landform. During site selection, careful attention was paid to sight lines which mean that nearby passing cruise ships maintain uninterrupted wilderness views.

Development of the dry stacked tailings method had no precedence in the mining industry but was clearly an absolute key to the mine operation. Issues which had to be dealt with in design were interaction with the environment, closure, seismic stability, wet and cold weather placement, protection of ground water and control of surface water. Regulators needed to be convinced that such a fine material would be stable under the high rainfall climate.

Innovative construction techniques were developed such that tailings could be placed in small areas during all but the wettest of weather, the surface is roll-sealed and gently sloped to prevent infiltration of water. Runoff is collected in settling ponds designed for storm flows, water from the ponds is then sent to a water treatment plant for eventual discharge to the environment after meeting strict water quality requirements.

The all weather placement has to achieve sufficient tailings density such that the storage facility is stable against liquefaction under a potentially very large earthquake off the west coast of Alaska. Conventional methods of in situ testing were not conclusive in regard to the seismic performance of the tailings. The reason for this is that seismic liquefaction assessment methods were developed for natural sand and clay materials, whereas the tailings at Greens Creek Mine is a manufactured material (i.e. crushed rock) with primarily silt sized particles, and is classified as a “transitional” material between the behavior of sand and clay. As such, limited data was available for characterizing these sorts of “transitional” materials for seismic response.

KCB and HGCMC developed a program of high quality in situ sampling and laboratory testing to provide proof that the tailings would remain stable in a major earthquake.

Non-conventional sampling procedures needed to be developed that would allow field staff to collect and transport high quality undisturbed samples from various locations and depths in an existing embankment fill. A new procedure and apparatus was developed for this purpose, and the sampling apparatus was constructed on site. The samples were then transported by the design team to Dr. Michael Riemer’s testing laboratory at UC Berkeley in California which is renowned for seismic testing of fine grained soils. Dr. I.M. Idriss, and Dr. R.W. Boulanger from UC Davis, two of the world’s leading experts in seismic performance and testing of low plastic silts, were retained as advisors for the work.

The design work, construction observations and innovative testing demonstrated that further expansions could go ahead with confidence.

Environmental, Economic, and Social Sustainability and Aesthetic Aspects

The Greens Creek mine is one of the largest private employers in all of Southeast Alaska and is the largest private property tax payer in the City and Borough of Juneau. Mining is a large part of the economy of Alaska currently directly employing over 1,500 people and with up to $10 billion in investment. Mining is under intense scrutiny in the State due to legitimate concerns over safety and environmental impacts. Responsible and rigorously proven tailings disposal is a key to maintaining that economic benefit and the social and legal mandate to operate.

The environmental benefits of the system are numerous and a key is that the work is compatible with the free roaming brown bear population. The bears and an abundance of other wildlife, such as deer and eagles, regularly safely track across the tailings facility without the danger of entanglement that is present with more conventional disposal areas. Bear-human interactions are kept to a minimum by stopping work as the bears traverse the site. The mine also has a high standard of garbage control to discourage bears.

As the first and longest running dry stack tailings disposal facility in the world, the project is the subject of extensive interest in the mining industry. A non exhaustive search of the literature discovered no less than 35 papers on the Greens Creek Tailings. The performance of the facility is also the subject of intense scrutiny by the public, regulators and industry.

Not only is the design and construction of the TDF held up as an example of successful tailings management, but the testing information is being further studied by KCB in collaboration with UBC to benefit tailings management practices across the industry.

Klohn Crippen Berger

Hecla MINING COMPANY

CANADIAN CONSULTING engineer

Innovative Tailings Management, Greens Creek Mine

Client Needs

- Tailings disposal in restricted use National Monument* with high ecological values
- Permit approval by regulators
- Meet rigorous federal and state air and water quality standards
- Acceptance by community and First Nations

* A National Monument in the United States is a protected area that is similar to a National Park and receives the designation directly from the President

Challenges

- Development and operation in a small, remote area located in Admiralty Island National Monument
- Visual impacts to passing cruise ships and monument users
- Strict permitting requirements to control and management of water quality
- Co-exist with one of the densest brown bear populations in the world
- Extreme precipitation and seismic hazard

Solutions & Innovation

- Compaction of filtered tailings in “dry” stack selected
- Minimize project footprint and land disturbance
- No tailings ponds reduce risks to wildlife during production and closure
- Minimized groundwater impacts with synthetic underliner and pipes
- Compacted tailings are seismically stable
- Enables progressive reclamation in stages

Successes

- First dry stacked tailings repository in the world
- 20 years of operation and experience
- Gained acceptance by regulators and stakeholders
- Permitting in process for additional tailings storage capacity
- World recognized case history of successful tailings management

Executive Summary

The Hecla Greens Creek Mining Company (HGCMC) polymetallic mine is located on northern Admiralty Island, about 29 kilometers southeast of Juneau, Alaska. A portion of the mine facilities are located within Admiralty Island National Monument.

Admiralty Island is well known for having one of the largest populations of brown bears in the world and is home to many species of salmon, birds, whales, and deer which makes the island a popular destination for tourists. Western Hemlock and Sitka Spruce dominate the prolific rainforest vegetation. This temperate coastal rainforest ecosystem is characterized by cool temperatures and high annual precipitation.

One of the key elements in maintaining a license to operate in such a sensitive area was to find and implement a tailings disposal method that would be safe and effective in this harsh environment while preserving the world class tourism attractions in the area. The solution was the world's first large dry stack filtered tailings disposal system which offered the following advantages:

- Filtered tailings placed in dry stacks can withstand static and seismic forces
- Reduces the footprint of the tailings storage by over 50% with no pond and allows wildlife to roam freely without risk
- Allows for progressive and continuous reclamation of the land

Klohn Crippen Berger (KCB) was entrusted with the design, construction monitoring and geotechnical input to operation of the Tailings Disposal Area Expansion. Primary objectives of this project were to develop solutions to store de-watered tailings in an environmentally and regulatory sensitive site, and minimize acid rock drainage and visual impacts.

Project Objectives, Solutions and Achievements

Objectives

HGCMC adopted a filtered tailings disposal method where tailings are dried to a soil-like consistency and then compacted. This allowed for the smallest possible footprint of the mine and the least impact on the environment. The HGCMC was the first mine in the world to adopt the filtered tailings disposal method and is the longest operating.

Klohn Crippen Berger's involvement with this facility dates back to the pre-feasibility and conceptual design stages in the early 1980's. Construction of the tailings disposal facility (TDF) commenced in 1988, and tailings placement began in early 1989. In 1993 mine operations were suspended due to low metal market prices. The mine re-opened in 1996 and KCB was asked to assist with the TDF expansion. During the course of this work, major advances were made in the understanding of the seismic behavior of filtered tailings and the design and construction methodology in a cold wet environment.

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Admiralty Island is 4,264 km^2

Greens Creek total property is 47 km^2

Continued operation of the mine and its expanding ore reserve is dependent on flawless operation of this tailings disposal area. Technical advances, demonstrated excellence, and environmental stewardship have allowed mine operators to build the confidence of the regulators to permit additional expansions.

The 15 years of continuous operation and a proposed further expansion of the mine, up to an additional 50 years, is important to the economy of Southeast Alaska and the performance of the tailings area to date is a key determinant in the permit application. The process of dry stack tailings also preserves the material for future exploitation when the industry has developed a process to extract other valuable minerals that remain in the tailings.

Solutions

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The nature of the site posed many challenges that needed to be taken into consideration with regards to scheduling and construction.

1. The site is located on a remote island. Crew, equipment and materials needed to be brought in by boat.
2. Construction could not affect the active, continuous mining operation.
3. Construction would stop when free roaming bears entered the site to protect the wildlife and the crew.
4. Extreme weather conditions affected the scheduling of crew and construction.

Technical Excellence and Innovation

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Annual precipitation on Admiralty Island is in excess of 1450 mm

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Dr. Boulanger and Dr. Idriss were kind enough to provide the following observation:

> *"Klohn Crippen Berger's work on the Greens Creek Project was at the highest levels of technical practice and an example of going the extra mile to bring together a range of technical expertise to address a challenging problem. Their solutions included original technical contributions that were of value to the client and the profession."*

Environmental, Economic, and Social Sustainability and Aesthetic Aspects

The Greens Creek mine is one of the largest private employers in all of Southeast Alaska and is the largest private property tax payer in the City and Borough of Juneau. Mining is a large part of the economy of Alaska currently directly employing over 1,500 people and with up to $10 billion in investment. Mining is under intense scrutiny in the State due to legitimate concerns over safety and environmental impacts. Responsible and rigorously proven tailings disposal is a key to maintaining that economic benefit and the social and legal mandate to operate.

The environmental benefits of the system are numerous and a key is that the work is compatible with the free roaming brown bear population. The bears and an abundance of other wildlife, such as deer and eagles, regularly safely track across the tailings facility without the danger of entanglement that is present with more conventional disposal areas. Bear-human interactions are kept to a minimum by stopping work as the bears traverse the site. The mine also has a high standard of garbage control to discourage bears.

HGCMC pay careful attention to minimizing the visual impact of the project both to cruise ship passengers on ships entering the busy tourist berths in Juneau and to the Admiralty Island wilderness users. Planned closure by covering and greening of the dry stack facility will further reduce potential visual impacts and provide a sustainable habitat for the wildlife and visitors to Admiralty Island.

"Fortress of the Bear(s)", an estimated 1,600 brown bears inhabit the island, outnumbering Admiralty's human residents nearly three to one.

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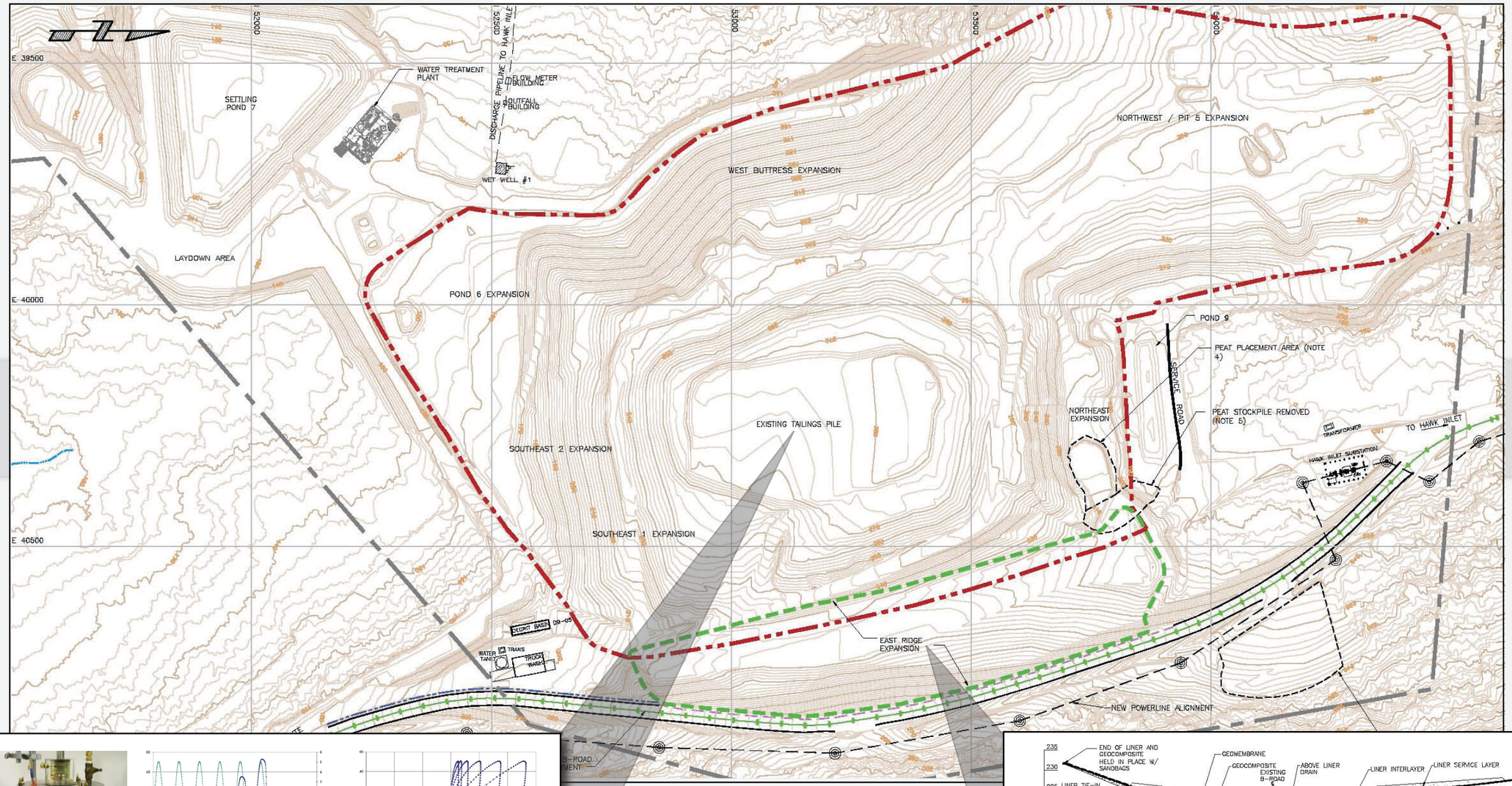
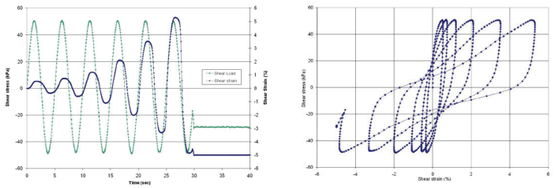
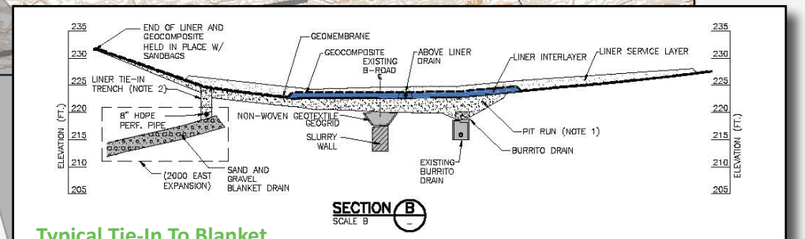
Tailings Facility General Arrangement



Sample preparation



Analyzing seismic liquefaction



Typical Tie-In To Blanket

LEGEND:

- LEASE BOUNDARY
- EXISTING TAILINGS PLACEMENT BOUNDARY
- LIMIT OF ERE LINER PLACEMENT
- MSE WALL
- GUARDRAIL
- JERSEY BARRIER

GENERAL NOTES:

1. BASE TOPOGRAPHY, ROAD, LINER, ALL PIPES AND DRAINS PROVIDED BY HGCMC (SEPT 19, 2011).
2. LOCATIONS AND ELEVATIONS ARE IN FEET UNLESS OTHERWISE NOTED.
3. DITCH ALIGNMENTS NOT SHOWN.
4. PEAT PLACEMENT AREA, NOT OBSERVED BY KCB.
5. PEAT REMOVED AND BACKFILLED WITH 12" STRUCTURAL FILL/ROCK.

Covered storage pile at the mill

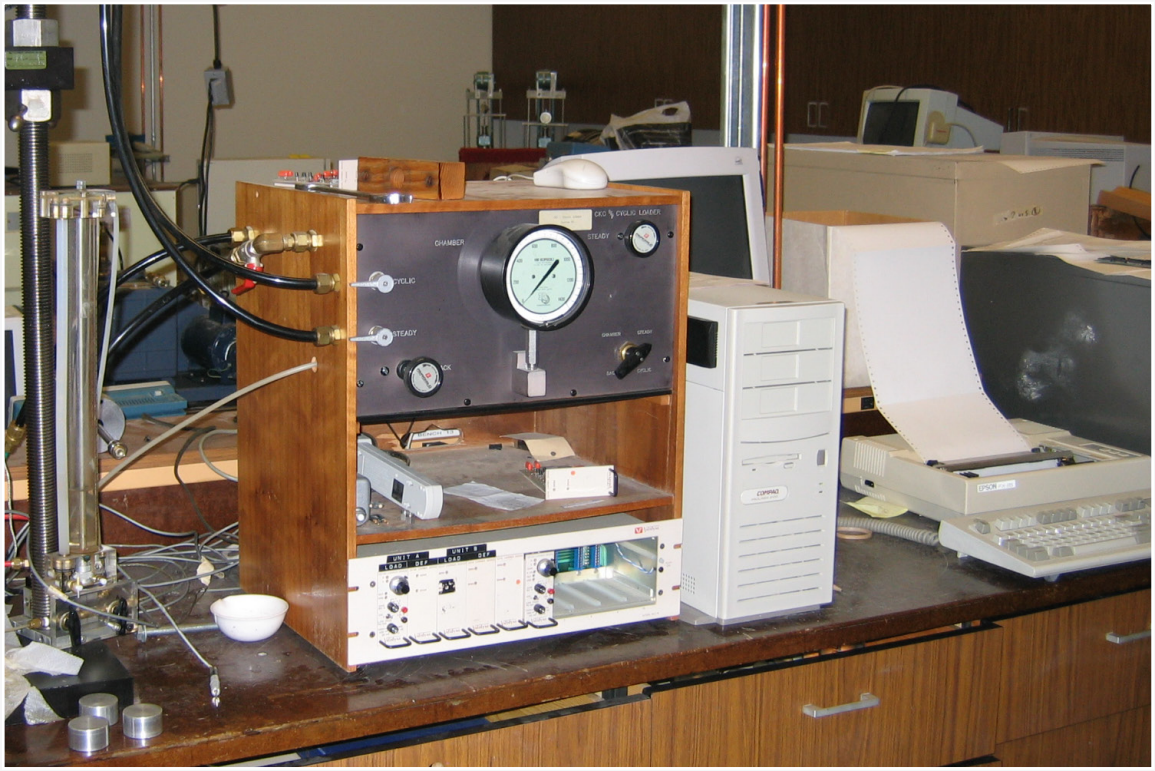
Liner placement

Tailings transported in covered trucks

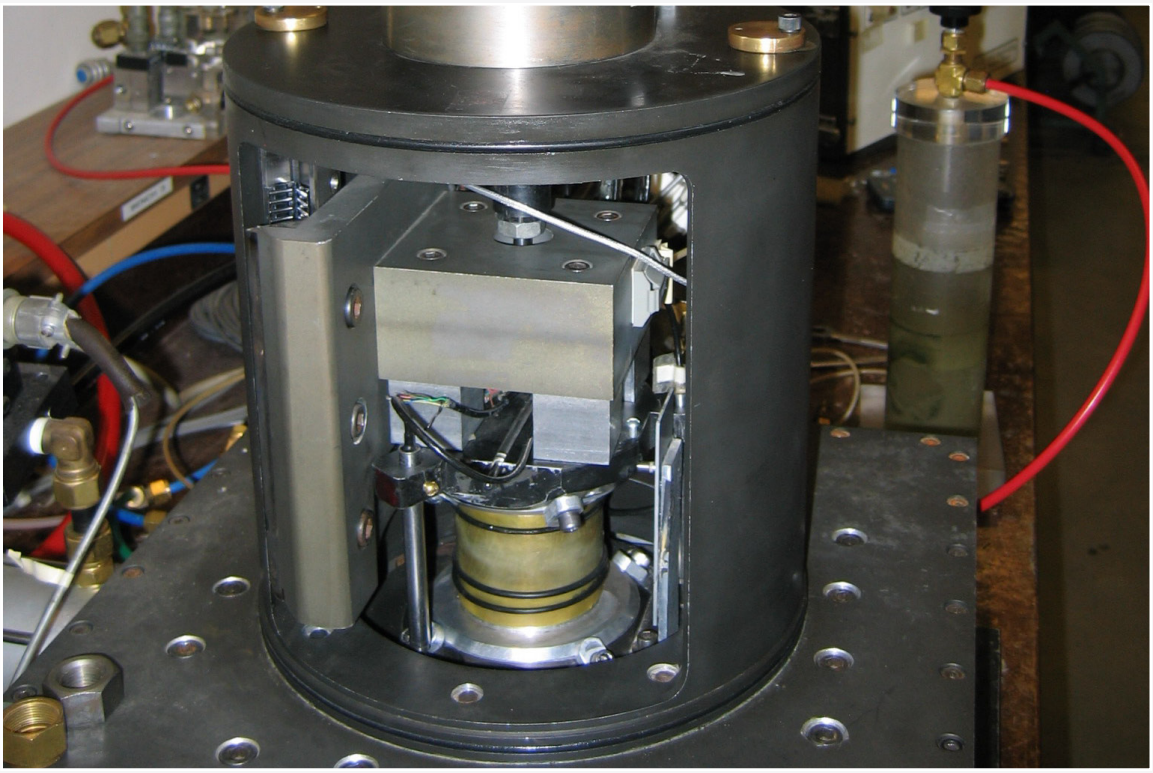
Placement, spreading and compaction of tailings

Sampler setup at test area with sample tube and hydraulic jack in place

Samples in the ground



Cyclic triaxial machine at UC Berkley



Overview of simple shear testing apparatus

Klohn Crippen Berger