Quantum Environmental Group
Barrier Wall Presentation
REMTECH 2005
Banff, Alberta
Quantum Environmental Group

DIVISIONS
- Quantum Hazmat Inc.
- Envirogreen Technologies
- Quantum Facilities Inc.
- Windmill Developments Ltd.
- Quantum Remediation Inc.
- Quantum Emergency Response Inc.

PARTNERSHIPS
- Envirogreen Technologies
- Windmill Developments Ltd.
- Quantum Remediation Inc.

ALLIANCES
- Burrard Clean Operations
Quantum Environmental Group
Barrier Wall Presentation

Agenda

• Clay / Clay Bentomat Barrier Walls
• Soil Bentonite Admixture Barrier Walls
• Waterloo Barrier Walls
• Bentonite Slurry Barrier Walls
• Permeable Reactive Barrier / Jet Grout Barrier Walls
• Slurry Slot Excavation / Low Strength Concrete Barrier Walls
• Caisson Walls
Confidential Site – Toronto, ON
Bentomat Liner Cut-off Wall

The Challenge

• Install 270lm vertical impermeable barrier at P/L, at depths from 3-10 mbg in a safe manner that minimized geotechnical and employee risk;

• Design permeability had to be <10E-8 m/s;

• Install upgradient drainage and dewatering system
Confidential Site – Toronto, ON
Bentomat Liner Cut-off Wall

Soil Nailing

• 2m long 3/8” rebar nailed onto vertical excavation face on 2m spacing horizontal and vertical

• Hang 4” steel mesh on protruding rebar

• Tie mesh to rebar and trim protruding rebar
Install French Drain and Wick Drain

- 0.5 m wedge of 19mm crush placed in base
- Wick drain material hung from lifeline and draped down vertical face
- Base elevation of barrier graded to a low collection point to reduce upgradient pore pressure
Hang Bentomat Liner

- Bentomat Liner composed of 3/8” thick bentonite stitched between 2 woven geofabrics
- Cut liner at depth + 1 m
- Clamped to 4.5 m long 2x6 and hung from material lifeline by excavator
- Liner covers French Drain and 0.6 m overlap on adjacent liners
- Backfilled and compacted with hoepack at base
- Backfilled and compacted to grade using sheeps foot roller
Confidential Site – Toronto, ON
Bentomat Liner Cut-off Wall
Bentomat Liner Cut-off Wall
Advantages

• Allows for variable depth profiles
• Can be manufactured to meet a design permeability up to $10^{-12}$ m/s
• Relatively inexpensive barrier material, no field welding required as overlap and hydration form continuous barrier
• Simple to install on slopes
• Can be installed without specialized equipment
Confidential Site, BC - Design/Build
Waterloo Barrier & Insitu LNAPL Collection System

The Challenge

• Design/install an impermeable barrier to 8.5 mbg adjacent to foreshore in very dense till
• Key barrier into low-permeability sediments to prevent short circuiting
• Design/install 13 LNAPL skimmers package in active railyard to collect LNAPL
Confidential Site, BC - Design/Build
Waterloo Barrier & Insitu LNAPL
Collection System
Solution

• Dry excavation of an 8.5 m deep, 1.5 m wide trench backfilled with lightly-compacted sand

• Design, testing and placement of an engineered, low-permeability, soil-bentonite admixture to key barrier into till sediments

• Installation Waterloo Barrier sheet pile wall, with joints flushed and grouted

• Advancement of LNAPL recovery wells

• Design, fabrication, installation and commissioning of 13 LNAPL skimmer unit complete with reservoirs and controls
Soil Bentonite Admixture Design and Testing

- Silty sand (fines/silt content >20%)
- Varying amounts of powdered bentonite
- Compactive effort – 90 to 100% SPD
- Moisture content ~10 to 12%
- Constant Head permeability testing
- K values between 10E-8 to 10E-12 m/s
Preparation of Soil-Bentonite Admixture

- Sieve/moisture analysis of sand stockpile
- Weighing and dry mixing of bentonite and sand
- Sieve analysis of several samples from each stockpile to confirm proper mixing and correct material quantities
- Covering of stockpiles to prevent hydration
Confidential Site, BC - Design/Build
Waterloo Barrier & Insitu LNAPL Collection System

Admixture Placement

• 5 lm, 8.5 m deep at each end of trench
• Excavation to be kept dry to meet 95% SPD
• Method spec. based on lift thickness (1 m) and compactive effort (sec/m²) field tested through densometer readings
• On-site geotechnical engineer performed QA/QC penetration testing from man bucket
Confidential Site, BC - Design/Build
Waterloo Barrier & Insitu LNAPL
Collection System

Erect Driving Rack

• Maintains wall alignment and plumb
• Provides safe work area for sheet handler/threader
• Sufficiently stable soils req’d to support rack, particularly during wind events
Confidential Site, BC - Design/Build
Waterloo Barrier & Insitu LNAPL Collection System

Threading Sheets

- First sheet advanced to ~50% depth
- Entire rack filled with treaded sheets advanced slightly into formation
- Once entire rack filled, sheet driving begins across entire rack
- Vibratory hammer used to advance sheets
Sheet Driving

- Rack used to drive to ~70% penetration, freely driven for remainder
- Rack re-located for next run
- Plumb checked on each sheet while driving +/- 1% off-plumb tolerance
Joint Jetting and Grouting

- Joint cleaned of soil/rock by advancing high pressure water hose down to bottom of joint
- Joint pumped full of low-permeability grout mixture and allowed to harden
- Provides permeability of $10^{-11}$ m/s
Confidential Site, BC - Design/Build
Waterloo Barrier & Insitu LNAPL Collection System

In-situ System Installation
• Advance 100mm diameter recovery wells
• Design, fabricate, install 13 LNAPL skimmer packages
• Install underground electrical to each skimmer
• Skimmers inc. reservoirs, secondary containment and all required electrical controls
• Commission system and prepare operations manual
Engineered Fill Cut-off Walls - Advantages

- Allows for variable depth profiles
- Can be engineered for various design permeabilities (10E-7 to 10E-12 m/s)
  - Sand gradation (> fines content lowers permeability; >20%)
  - Bentonite content
  - Compactive effort (90 to 100 SPD)
- Wall thickness can be designed to meet required flow characteristics
- Allows for post-installation testing of barrier material
- Engineered material is easy to handle and requires no specialized equipment to mix and install.
Waterloo Barrier - Advantages

- Allows for very deep barrier wall (up to 20m)
- Tight continuous interlock filled with grout provides barrier integrity
- Can be driven with conventional pile driving equipment
- Can be removed and reused
- Certified for 1x10E-11 m/s
The Challenge

- Install a 125 m long impermeable barrier to 8.5 mbg to mitigate potential migration of impacts into Quesnel River.
- Design permeability to be $1 \times 10^{-8}$ m/s.
- Barrier to be within 0.6m of an on-site structure.
- Barrier located within 3m of riprap bank / river.
Confidential Site, BC - Design/Build
Bentonite Slurry Wall Barrier

Solution

- Work with consultants to design and subsequently install an 8.5 m deep, 1.5 m wide, 125 m long bentonite slurry wall, backfilled with an engineered, low-permeability soil admixture
- Design and laboratory testing of an engineered, low-permeability, soil-bentonite admixture (trench backfill) to confirm K values
- Design trench slurry mixing and handling plan
- Design of soil admixture (trench backfill) mixing, handling and QA/QC plan
- Design of trench excavation and backfilling plan
- Preparation of Health and Safety Plan
Slurry Trench Excavation – Basic Principles

- Trench wall stability is maintained by excess head of bentonite slurry in the trench (slurry level must be continually maintained above existing gw level)
- Excess head maintained by minimizing loss of slurry to formation by:
  - Reduced K at trench interface as bentonite fills voids in formation
  - Monitoring and maintaining viscosity of bentonite slurry in the trench (temp., % bentonite, % sand)
  - Introducing make up slurry
- Bentonite must be completely hydrated in slurry (mixing procedure, pH, temperature, cat ion conc. dependant) to maintain viscosity and remain available to fill voids at interface
- Hydraulic conductivity of formation reduced as a result of the introduction of bentonite
Field Preparation of Bentonite Slurry

- Water supply conditioned with soda ash to raise pH
- Dry powdered bentonite mixed with water using shear type pumps (mud mixers)
- Slurry re-circulated in baffled mixing tanks for full hydration
- Tested to meet a minimum Marsh cone standard of 38 seconds (viscosity test)
- Pumped to a holding basin and re-circulated in basin
Field Preparation of Soil-Bentonite Admixture (Trench Backfill)

- Weighing and dry mixing of 50% of the required bentonite with sand
- Addition/mixing of the remaining required bentonite in dissolved format (hydration)
- Addition of water to obtain 5”-6” slump test
- Slump test dictates self-placement characteristics of trench backfill
Trench Excavation and Backfilling

- 1 m deep bench excavated
  - control slurry and spoil/attain design depth
- 2 excavators working simultaneously excavating and backfilling
- Slurry maintained at ~1mbg (gw @ 3.5mbg)
- ~15 m of trench open at once
- Trench backfill placed (3H:1V) and self compacting
- Continual depth sounding of trench to confirm depth and backfill location
Bentonite Cut-off Walls - Advantages

- Allows for variable (unknown) depth profiles and direction changes
- Can attain significant depths (limited by machine size)
- Ideal for loose formations with cobbles/gravels (precludes driven barriers)
- Trench backfill can be engineered for various design permeabilities (10E-7 to 10E-10 m/s): Sand gradation and bentonite content
- Wall thickness can be designed to meet required flow characteristics, FOS
- Allows for post-installation testing of barrier material
- Engineered trench backfill material is relatively easy to handle and requires limited specialized equipment to mix and install
- Relatively cost-effective option
- Abundance of technical literature – level of confidence for owners/consultants
The Challenge

- Remove source of special waste heavy metals contamination through excavation.
- Construct a special waste storage facility to accept special waste metal contaminated soils excavated from the site.
- Install an in-ground passive treatment wall to treat metal contaminated water generated on the site prior to discharge to the ocean.
Solution

- Install a 750lm, 18m deep, 2m wide PRB to treat contaminated groundwater prior to discharge to the ocean
- Design guar gum slurry, mixing plant, QA/QC plan
- Mix proprietary trench media, design QA/QC plan
- Excavate/backfill trench simultaneously monitoring depth and backfill profile
- Monitor trench slurry QA/QC to ensure trench stability
- Clay cap on trench
- Jet grouting in area of GVRD water mains
Filter Media Mixing & Testing

- Media comprised 85% pea gravel, 14% compost, 1% lime
- Numerous samples from each batch mixture were tested by owner
  - Composition
  - K (preferential pathway)
- Mixed using a loader with scale bucket and excavator
- Thorough mixing required to ensure no “dead spots” in wall
Guar Gum Slurry Mixing/Testing

- Guar gum (a food thickener) used as it degrades over time - PRB
- Guar gum slurry mixed using oil-field mud plant (shear pump) and stored in a 20000 USG tank
- Plant comprised 3 – 20000 USG tanks
- Slurry breaks down in 48 hours at 18°C
- Finished and trench slurry tested for pH, viscosity and bacterial count
- Make up slurry always required
- 3m Factor of Safety in slurry trench
Confidential Site, BC - Design/Build – Permeable Reactive Barrier

Trench Excavation and Backfilling

- 200T excavator and 125T crane excavating/backfilling simultaneously, 50lm of trench open
- Removal of 20,000m³ of spoil, placement of 18,000m³ of filter media and clay cap
- Real time surveying and monitoring trench depth and backfill profile
- Sheet pile restraint designed for emergency stoppages
Confidential Site, BC - Design/Build – Permeable Reactive Barrier
Gar Gum Slurry Permeable Reactive Barriers - Advantages

- Allows for variable (unknown) depth profiles and direction changes
- Can attain significant depths (limited by machine size)
- Ideal for loose formations with cobbles/gravels (precludes driven barriers)
- Guar gum slurry breaks down (digested by bacteria) over time
  - Does not alter regional hydrogeology
  - Minimal / no deleterious effect on fish/wildlife
- Trench design life can be engineered for varying duration (thickness)
- On-going pump and treat requirement eliminated
- Can be used different contaminants (media specific)
- Ideal for very large sites
Confidential Site, Toronto, ON - Bentonite Slurry, Concrete, Caisson Wall

The Challenge

• Excavate entire site to 11 m below grade – no anchors allowed on City property;
• Shoring mechanism must prevent loss of soil behind shoring wall – compromise off-site utilities;
• Install impermeable barrier on 3 property lines from 6 to 11 m below grade;
• Hydraulic conductivity to be < 10E-8 m/s
Solution

- Installation of H-pile to 11mbg and lagging (inc. rakers) to 7mbg to shore excavation wall on N and E P/L
- Slurry slots excavations backfilled with low strength concrete from 7 to 11mbg on N and E P/Ls to remove impacted soil and provide hydraulic barrier
- Installation of caisson wall on W P/L to 11m below grade to support adjacent parade and provide hydraulic barrier
- Slot excavation of impacts at depth along caisson wall, backfilled with low strength concrete
- Wet excavation of entire central portion of site
H-Pile and Lagging in North and East Portion of Site

- 760 mm caissons open drilled to 11m, filled with H-pile and low strength concrete (4MPa)
- Waler installed at grade and excavation between H-Piles completed with timber lagging installed to 7 mbg
- Once at 4 mbg, rakers welded and set in 30 MPa concrete footings excavated at 7-9 mbg
- Bulk excavation completed to 7 mbg in north and east portion of site, with waler attached at 6.5mbg.
Confidential Site, Toronto, ON - Bentonite Slurry, Concrete, Caisson Wall
Bentonite Slurry/Concrete Wall

- Slots excavated to 11mbg using bentonite slurry to shore excavation wall
- Slot backfilled with low strength concrete to provide impermeable barrier
- Alternating slot technique used with over excavation into adjacent slot to ensure continuous impermeable wall
- Bentonite slurry mixed using shear pump to meet 45 second Marsh Cone viscosity test
Confidential Site, Toronto, ON - Bentonite Slurry, Concrete, Caisson Wall
Bentonite Slurry/Concrete Cut-off Walls – Advantages

- Allows for variable depth profiles
- Allows for installation in unconsolidated material
- Can be engineered for various design permeabilities (10E-8 to 10E-12 m/s)
  - Concrete additives (bentonite) can lower permeability
- Wall thickness can be designed to meet required flow characteristics
- Low strength concrete provides temporary structural excavation support and re-excavateble.
Caisson Wall Barrier Installation

- From 3mbg bench, 13, 915mm dia. open boreholes were drilled on a specified spacing to ~11mbg and filled with an H-Pile and LS concrete to 3 mbg; H-Piles were used in select caissons to construct a shoring support wall.

- Subsequently, 3, 864mm dia. ‘filler’ boreholes were advanced between each of the 13 previously drilled, reinforced and filled boreholes.

- ‘Filler’ boreholes were drilled with a minimum 0.2m overlap into the adjacent caisson and filled with LS concrete; ‘filler’ borehole 2 was drilled first, followed by ‘filler’ boreholes 1 and 3.

- A waler was installed at 3.5 mbg (top of caisson wall) to further stabilize the cantilevered caisson wall.

- Slot excavations were conducted to ~11mbg, with slots backfilled with LS concrete.
Confidential Site, Toronto, ON - Bentonite Slurry, Concrete, Caisson Wall
Concrete Caisson Barrier Walls -
Advantages

Solid structure, cantilevered excavation wall support system
  • can be advanced right at property line
  • no off-site encroachment or agreements necessary
  • no rakers required (simplifies backfilling)
Shoring excavation support and impermeable barrier installed simultaneously
Low strength concrete can be easily excavated for site servicing
  (vs. pulling H-piles and lagging)