Case Study:
Full-Scale *in situ* Electrical Resistive Heating (ERH) Used for the Remediation of a DNAPL Source Zone

West Source Area
OMC Canada, Peterborough, Ontario

RemTech 2014, Banff
Site History: Outboard Marine Corporation (OMC) of Canada Peterborough, Ontario

Small Engine Manufacturing

Environmental Legacy

West Source Area
Site Characterization: Investigations

- Phase 2 type ESAs in the early-2000’s identified TCE-DNAPL impacts below the warehouse.

- Detailed aquitard-aquifer interface assessments in mid-2000’s to characterize: aquitard surface topography, lateral DNAPL distribution, and penetration of impacts into the aquitard (fate and transport)

- Ongoing soil and groundwater sampling to assess: waste classification, contaminant migration, and remedial options.

- High resolution Membrane Interface Probe (MIP) and Electrical Conductivity assessment to define DNAPL source zone boundary with more precision.
Conceptual Site Model:

- PHC (F3) & TCE (in soil)
- LNAPL(?)
- DNAPL

Layers:
- Fine Sand
- Silty Fine Sand Layer
- Coarse Sand Layer
- Fill
- Sand
- Fine Grained, Grey
- DNAPL
- Silty & Clay, Grey

Groundwater Flow (250 m/yr)
Request for Proposal & Contracting Method:

- Request for proposal prepared based on a performance based contract.
  - Included very detailed conceptual site model including: physical geology & hydrogeology, contaminant distribution, details on previous remedial actions including interim P&I and chemical oxidation trials.
  - Defined remediation performance criteria (for payment) for soil and groundwater and the metrics used to assess performance.
  - Selection criteria included rankings for: contractor experience, remediation schedule, technology applicability, prior success and cost.
  - Did NOT defined or specify a specific remediation technology or method.

- Allowed for contractors to present and offer innovative solutions, or multiple solutions for consideration
Contractor & Technology Selection:

- 9 companies invited to bid: 3 general contractors, 3 *in situ/ex situ* bioremediation specialists, 3 thermal specialists.

- 5 bids received with options including *in situ/ex situ* bioremediation, chemical oxidation, excavation, and electrical resistive heating with multiphase extraction. Costs ranged from $2.85M to $4.98M. Schedules ranged from less than 1 year to greater than 4 years.

- Electrical Resistive Heating combined with Multiphase Vacuum Extraction was the selected technology as proposed by Quantum Murray (general contractor) and McMillan-McGee (technology specialist) with a cost of approximately $3.4M and a schedule of approximately 18 months.
Technology Overview:

Electrical Resistive Heating (ERH) or Electro-Thermal Dynamic Stripping Process (ET-DSP™)

- Heating of the subsurface using electrical power.
- Transforming dissolved, sorbed and NAPL phase VOCs (specifically TCE for this project) to vapour thereby improving the subsurface recoverability of these contaminants.
- Boiling point of TCE approximately 85°C, Target temperature 100°C.

Multiphase Vacuum Extraction

- Simultaneous extraction of NAPLs, water, and vapours from the subsurface under vacuum.
Remediation Design Summary:

Two Main Components

1) Soil & Groundwater Heating (ET-DSP)
   - 62 Electrode locations on a 6m triangular grid with PDS and water recirculation.
   - 15 Temperature, pressure, vacuum sensors (with 9 depth discrete temperature sensors per location)

2) Multiphase Vacuum Extraction
   - 27 Multiphase extraction wells placed through remediation zone
   - Vapour and liquid treatment trains

Area to be remediated
1,250m² by 7m deep, or 8,750m³
Electrodes:

- Electrodes (62 locations, 124 electrodes)
  - Monitored instantaneous power and cumulative energy at individual electrodes.
  - Could adjust power delivery to control heating.
  - Water Injection system to prevent dealkalization and maintain subsurface conductivity.
Sensors:

- **Temperature (15 locations, 132 sensors) & Pressure Sensors (10 locations)**
  - Monitored instantaneous temperature to monitor uniformity of heating and process control.
  - Monitored pressure/vacuum for safety reasons (assess to potential buildup of steam).
Extraction Wells:

- **Multiphase Extraction Wells (27 locations)**
  - Monitored influent vapour concentrations, temperature, vacuum pressures and flow rates for continuous process optimization.
Extraction & Treatment:

Combined Influent (Air, vapour, groundwater and NAPL)
- Variable speed high vacuum extraction pump,
- Heat exchangers & vapour-liquid separators

Vapour Treatment
- Primary granular activated carbon (GAC) with stream regeneration and contaminant recovery
- Secondary/sacraficial GAC

Liquid Treatment
- DNAPL/LNAPL/Water Separator, Air Stripper, GAC
- Allowing for the injection of treated water
Remediation Progress Monitoring

- Max Disc. Temp Reaches 85°C at ~28 days
- Mean Temp Reaches 85°C at ~94 days
- Influent Vapour Concentrations
- Theoretical DNAPL Mass Recovered
- Actual DNAPL Mass Recovered (in Tank)
- 50% Removal
- 80% Removal
- Start of Remediation: Feb. 17, 2011
- End of Remediation: Aug. 31, 2011
- Pulsed/Focused MPE During Polishing Phase
Historic TCE Concentrations

Pre-Remediation Baseline Sampling

Mean TCE Concentration

TCE Remediation Target (500 ug/L)

Approx. TCE Solubility Limit

Date

TCE Concentrations versus Time

Remediation Start – Feb 17, 2011

Remediation End – Aug 31, 2011

Confirmation Monitoring 4-Weeks

Confirmation Monitoring 12-Weeks

Confirmation Monitoring 29-Weeks

Additional Sample Events at 1 and 2 years

Performance Monitoring
Achievements:

- **DNAPL removed** (<<1% rule, none measured, approx. 2,000 kg in recovery tank)
- **99.4% mass reduction of chlorinated solvent impacts** (in soil and groundwater)
  - Pre-Remediation mean [TCE] 40,000 to 80,000 ug/L & max [TCE] >300,000 ug/L
  - Post-Remediation mean [TCE] 15 to 72 ug/L & max [TCE] 440 ug/L (3 events over 29 weeks)
  - Post-remediation source zone concentrations lower than down-gradient plume concentrations
- **99.8% of remediation target/objective achieved** (remaining 0.2% due to vinyl chloride exceedance of low level target)
- **Improvements noted in down-gradient plume in the range of 90%** (i.e. 10,000 ug/L to <1,000 ug/L)
- **No rebound or increasing trends identified after 2 years** (Sept 2011 to Oct 2013)
- **No complaints from neighbours** (noise, traffic, smell, air)
Lessons Learned:

- Approximately 50% of chlorinated solvent mass removed between 30 and 60 days from the start of remediation.

- Approximately 80% of chlorinated solvent mass removed before halfway mark at about 94 days, but the remaining 20% required an additional 101 days.

- Communicate the migration and potential effects of heated groundwater to stakeholders early in the process.

- No rebound in total molar mass of chlorinated solvents, BUT need to account for the potential post-remediation TCE transformation/degradation to daughter products with lower remediation targets such as vinyl chloride. AND this observation maybe delayed by over 30 days.
Conclusions:

- The thermal (ET-DSP) enhancements to the MPE based remediation was very effective for:
  - Removing source zone DNAPL (in under 100 days).
  - The long term reduction of soil and groundwater concentrations of chlorinated solvents (as monitored over a 2 year period post-remediation)
  - No rebound (but possible transformation/degradation)

- This technology can be implemented quickly in comparison to other in situ remediation options with active remediation completed in under 1 year.

- This technology is cost competitive with other technologies on sites with challenging conditions (i.e., hazardous waste, flowing sands, dewatering requirements, under buildings, deep impacts)
Acknowledgements

Canadian Canoe Museum

The Peterborough District and Kingston Region MOE

Quantum Murray LP (General Contractor)

McMillan-McGee Corp. (Technology Vendor)
Presenter Biographies:

Sean Salvatori, P.Geo.
• Hydrogeologist with 20 years’ experience specializing in environmental site assessments and hydrogeological studies.
• His experience includes investigations for industrial & commercial facilities, historic landfills and emergency spill response for ground and water contamination.

Tom Grimminck, P.Eng.
• Environmental engineer with over 17 years’ experience in contaminated site investigation, remediation and environmental contracting.
• Areas of expertise include project management, environmental engineering, solid waste management, process engineering and environmental contracting.
Thank You