DILLON CONSULTING

Case Study:

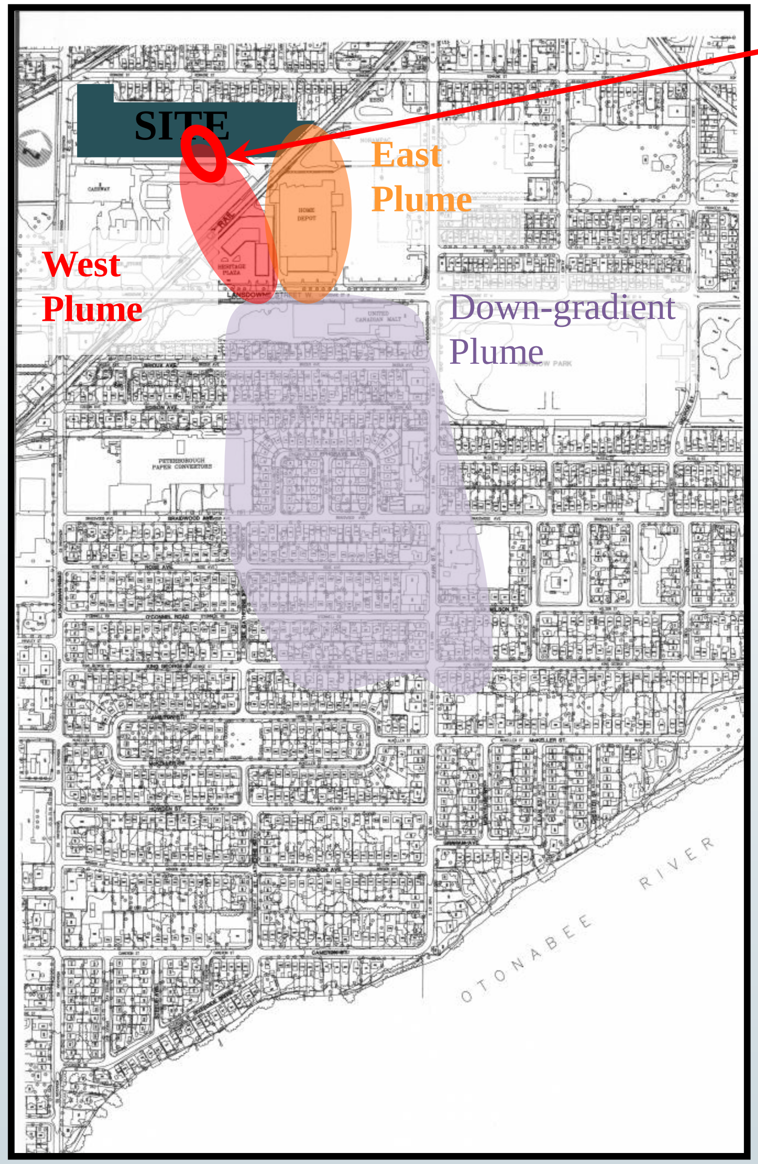
Full-Scale *in situ* Electrical Resistive Heating (ERH) Used for the Remediation of a DNAPL Source Zone

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

DILLON CONSULTING

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.

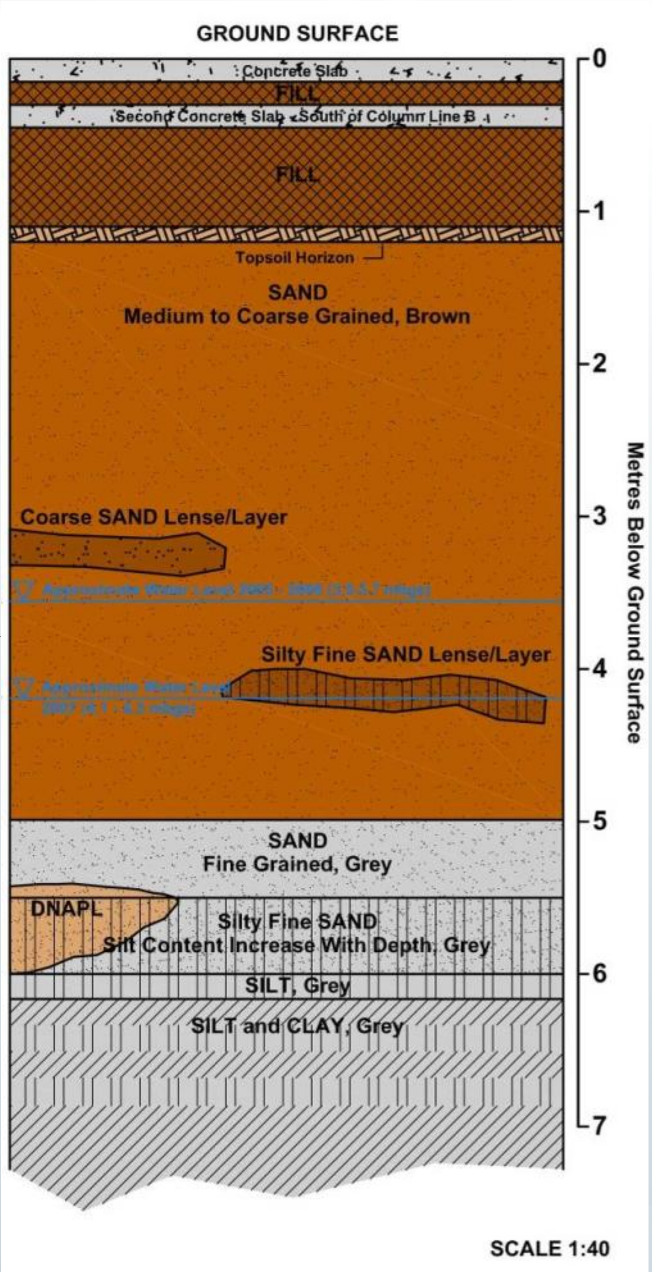
- High resolution Membrane Interface Probe (MIP) and Electrical Conductivity assessment to define DNAPL source zone boundary with more precision.

Conceptual Site Model:

PHC (F3) &
TCE (in soil)

LNAPL(?)

DNAPL

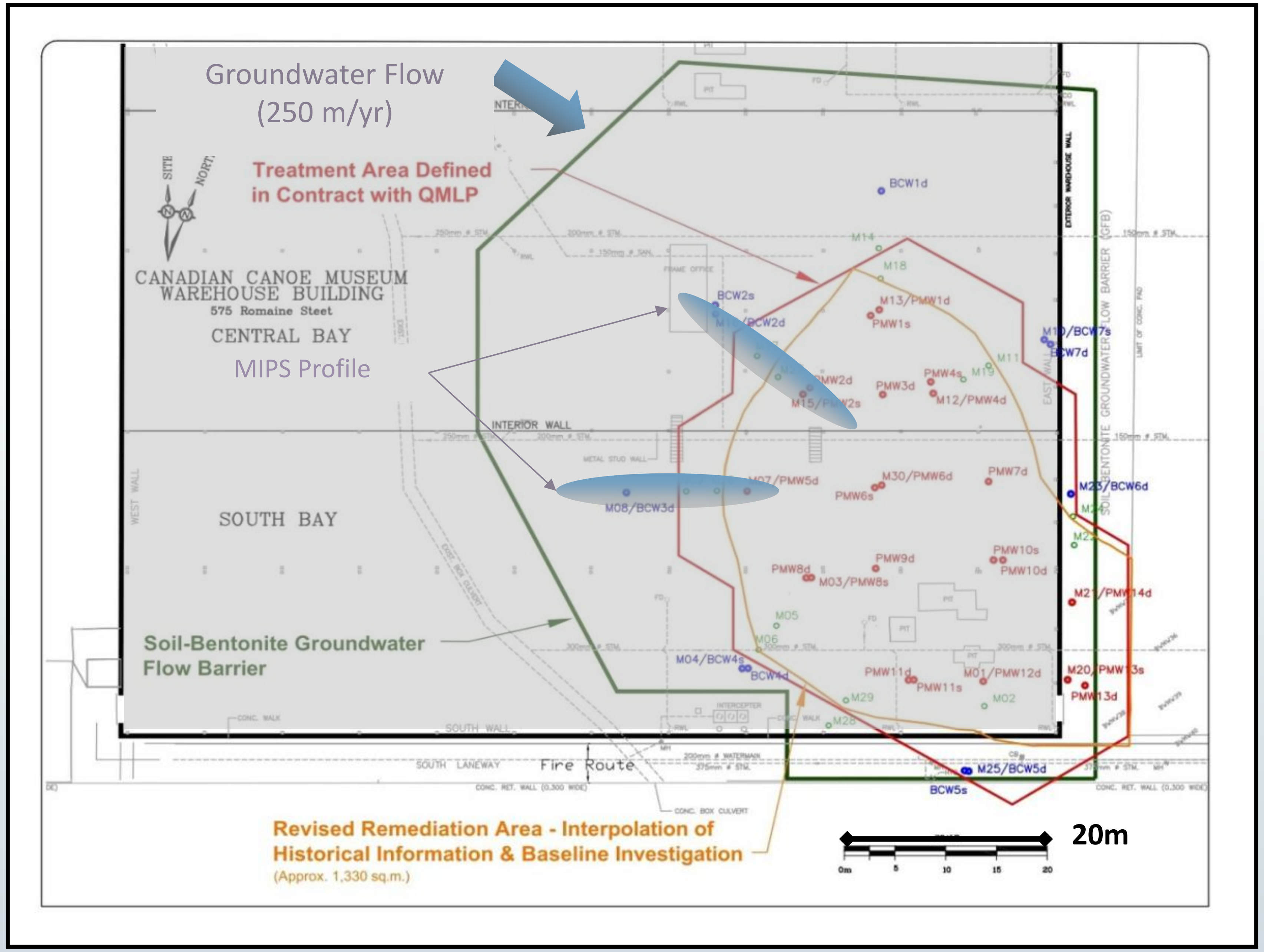


FILL

SAND

FINE SAND

SILT & CLAY



DILLON CONSULTING

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&T 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**

DILLON
CONSULTING

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.

DILLON CONSULTING

Technology Overview:

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

- 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^{o}C, Target temperature 100^{o}C.

Multiphase Vacuum Extraction

- Simultaneous extraction of NAPLs, water, and vapours from the subsurface under vacuum.

DILLON
CONSULTING

Remediation Design Summary:

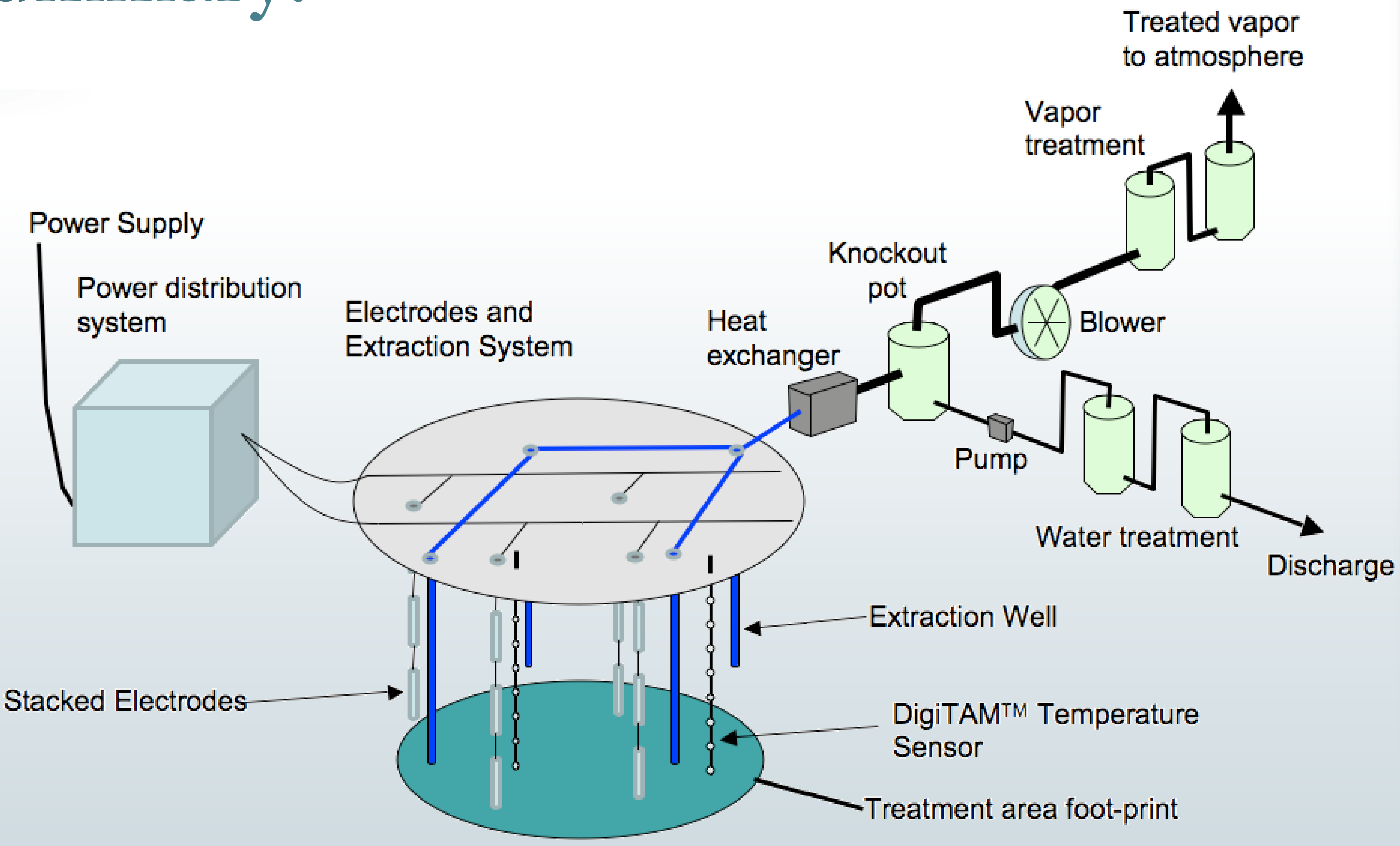
Two Main Components

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



Graphic Courtesy of TerraTherm

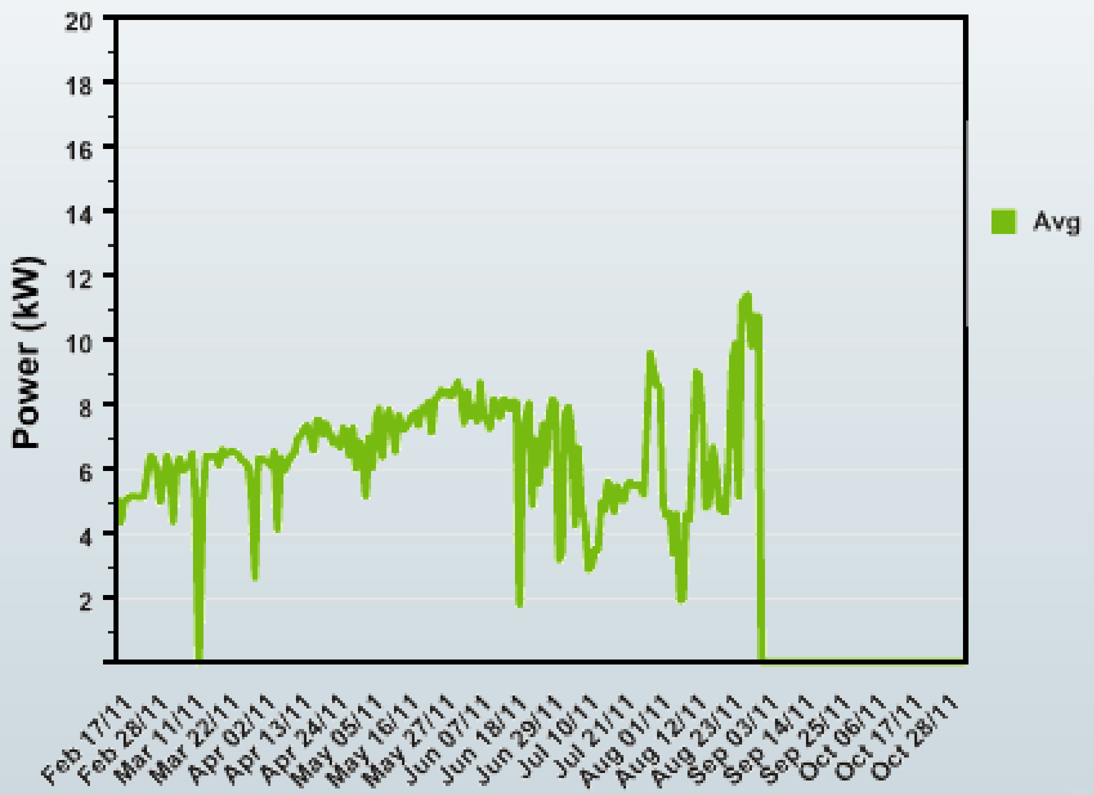
Area to be remediated

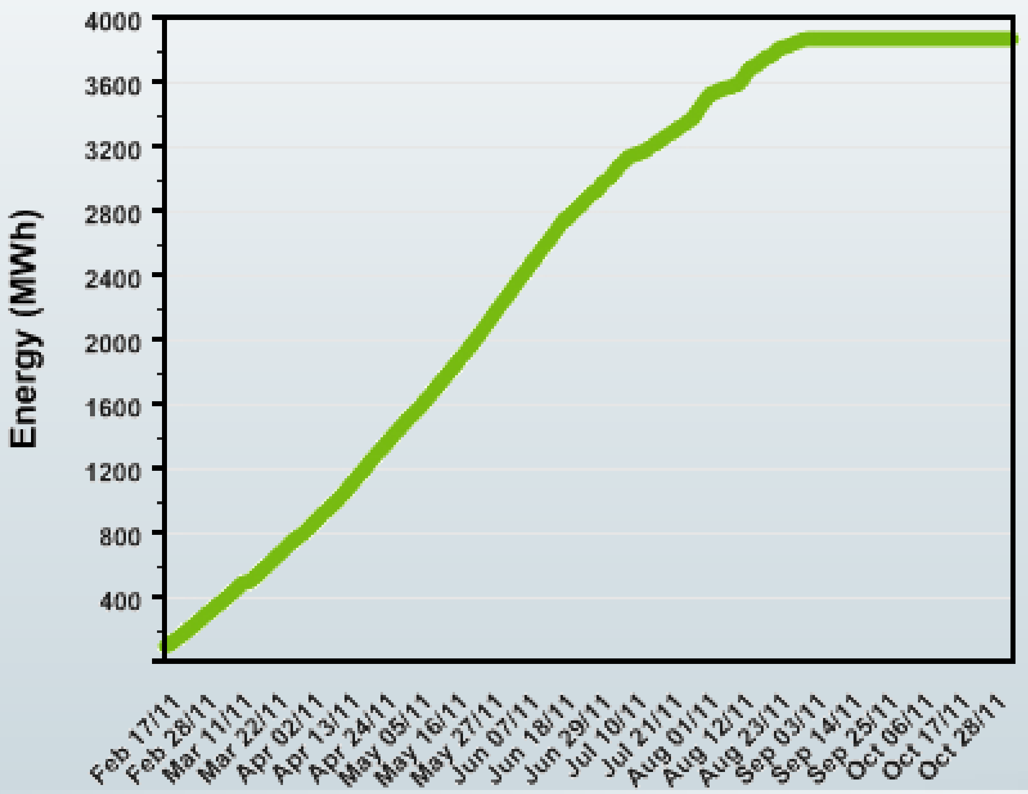
1,250m^2 by 7m deep, or 8,750m^3

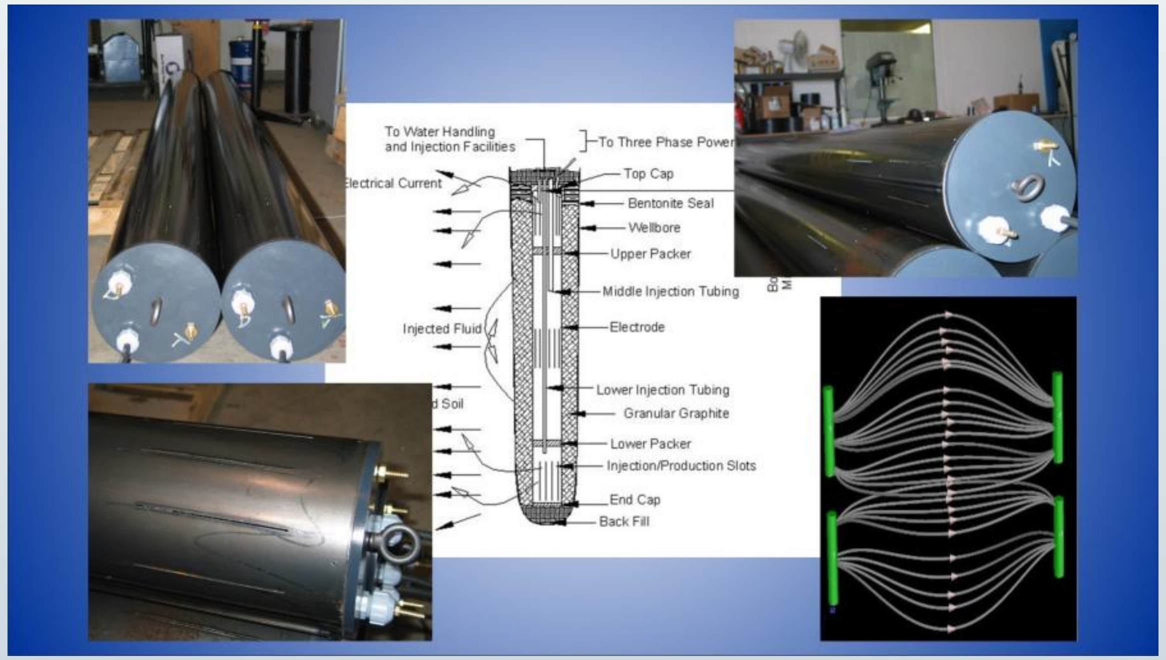
DILLON CONSULTING

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 desiccation and maintain subsurface conductivity

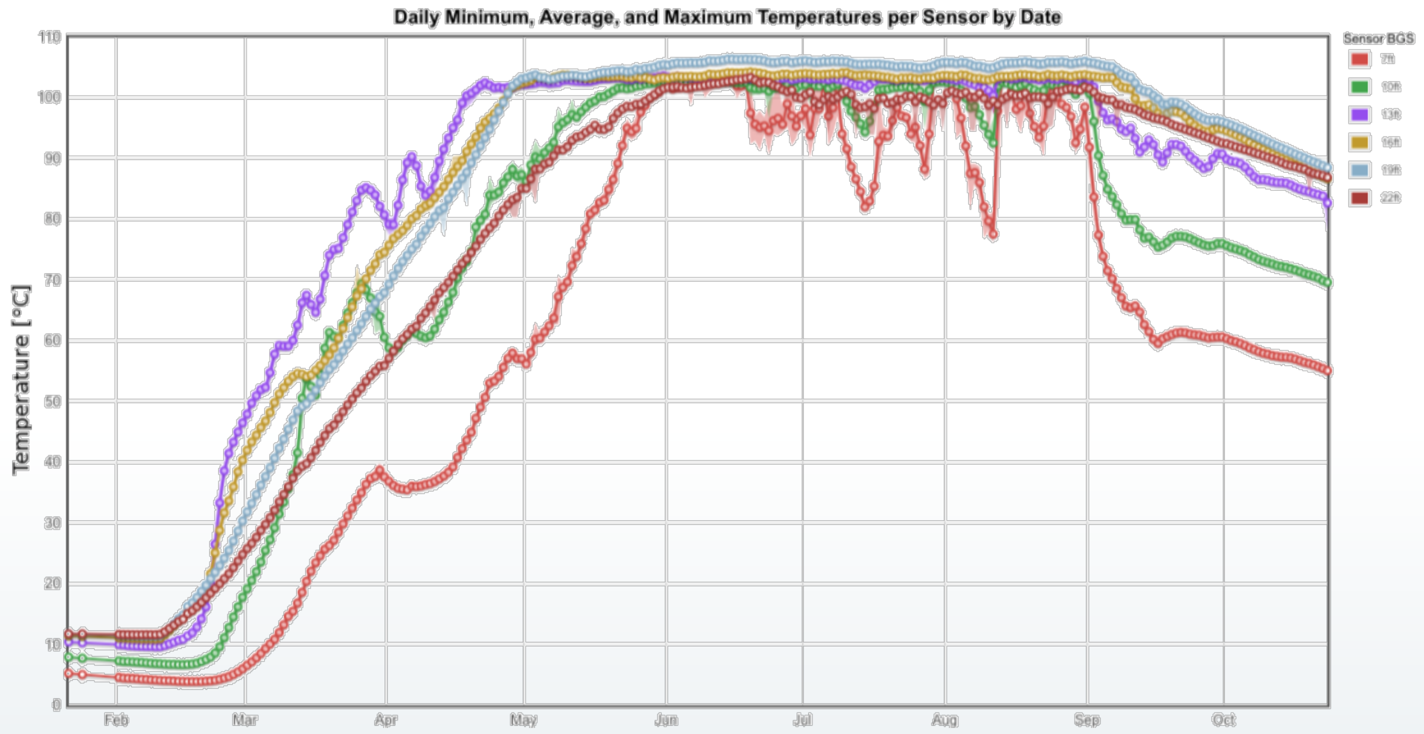


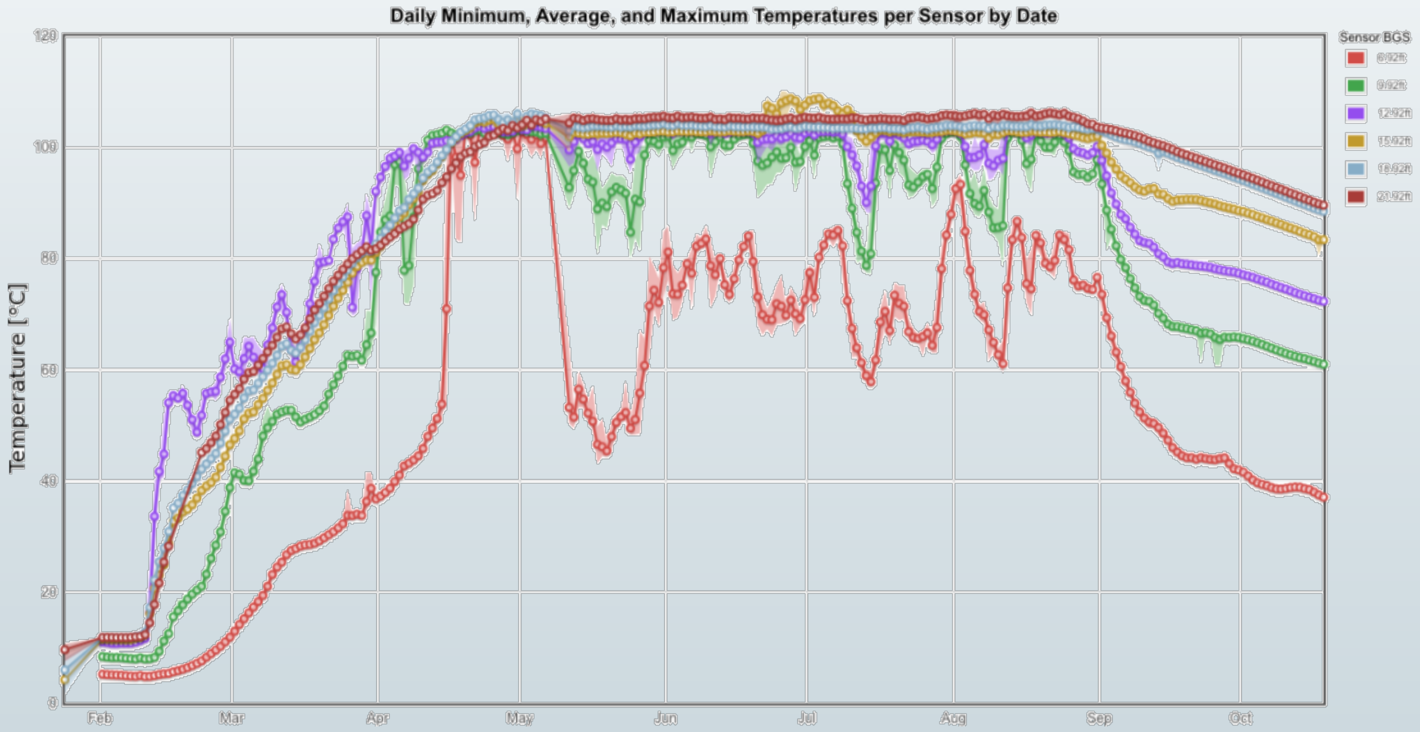


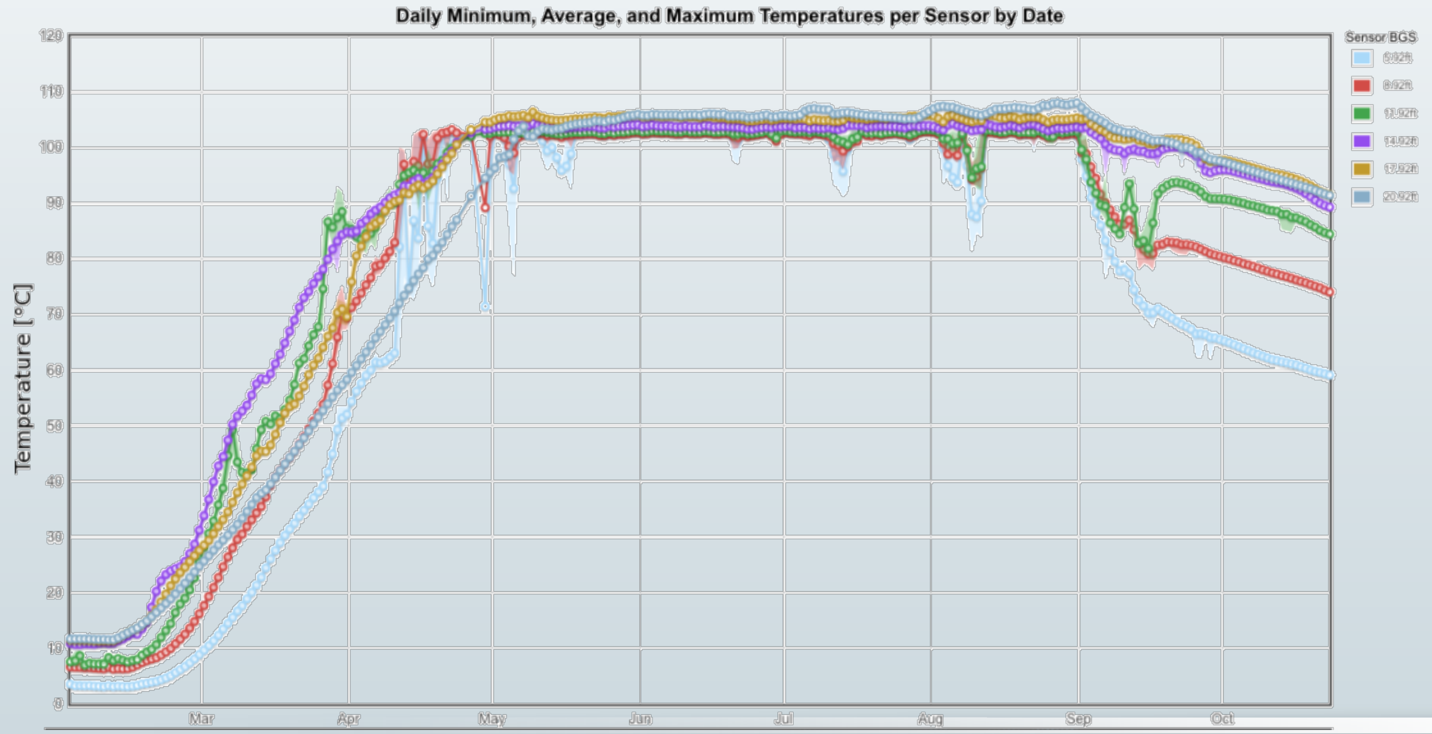


Sensors:

- 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).



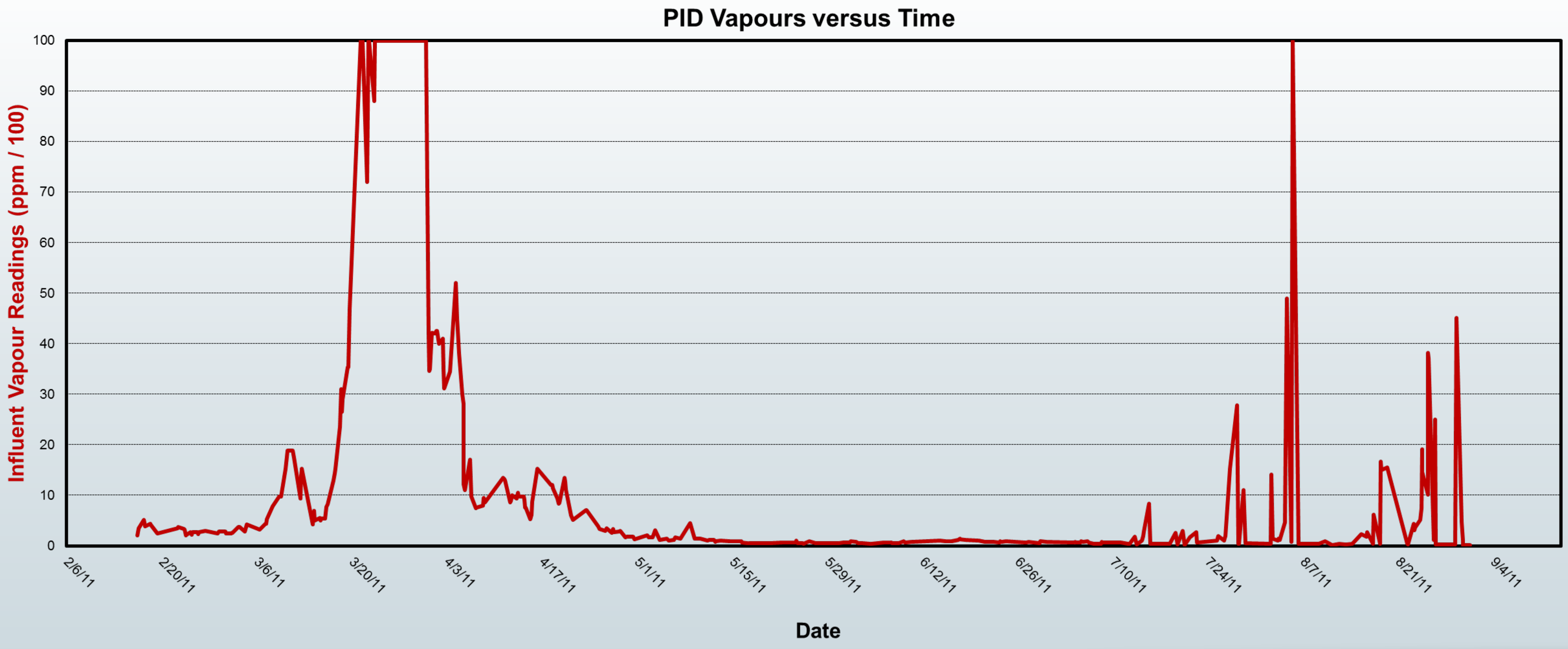




DILLON CONSULTING

Extraction Wells:

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



DILLON CONSULTING

Extraction & Treatment:

Combined Influent (Air, vapour, groundwater and NAPL)

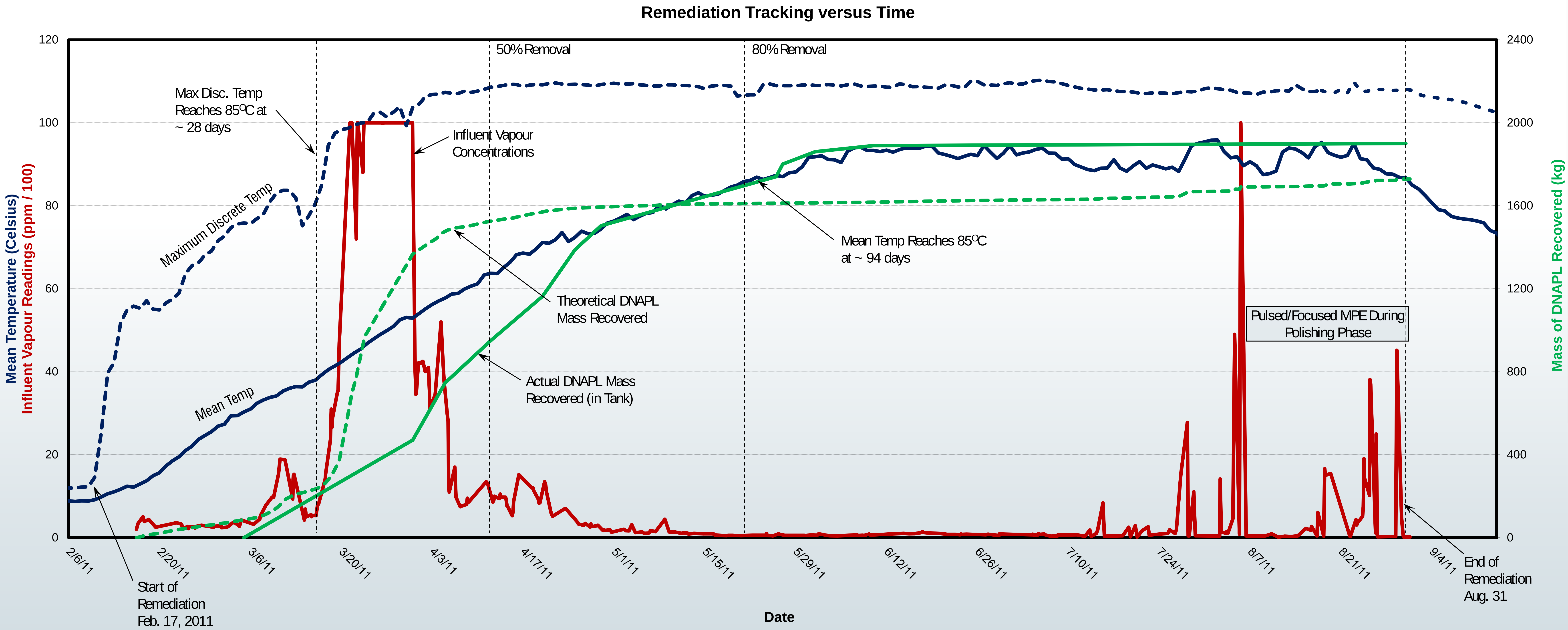
- Variable speed high vacuum extraction pump,
- Heat exchangers & vapour-liquid separators

Vapour Treatment

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

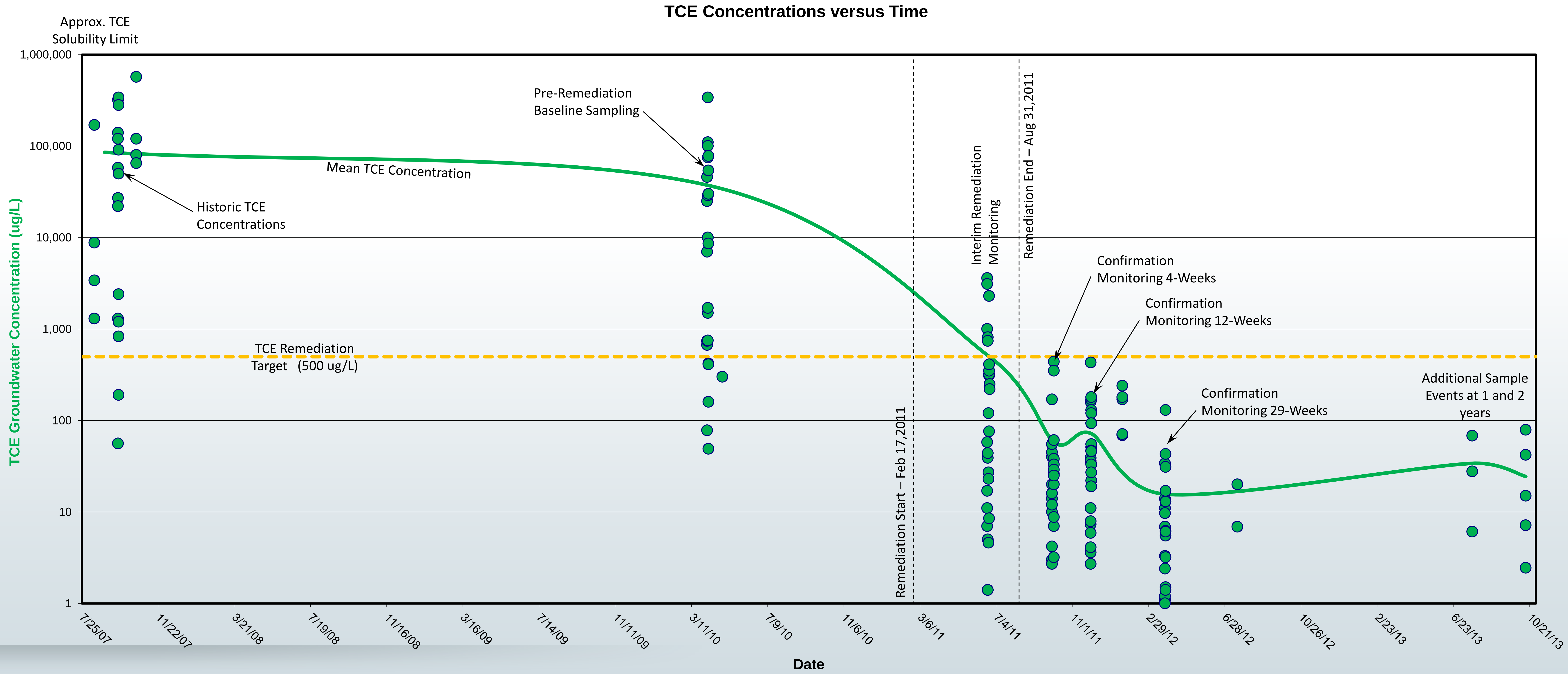
Liquid Treatment

- DNAPL/LNAPL/Water Separator, Air Stripper, GAC
- Allowing for the injection of treated water



Remediation Progress Monitoring

DILLON CONSULTING



Performance Monitoring

DILLON CONSULTING

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)

DILLON
CONSULTING

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.

DILLON CONSULTING

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., haz-waste, flowing sands, dewatering requirements, under buildings, deep impacts)

DILLON CONSULTING

Acknowledgements

Canadian Canoe Museum

The Peterborough District and Kingston Region MOE

Ontario

Quantum Murray LP
(General Contractor)

QUANTUM MURRAY

McMillan-McGee Corp.
(Technology Vendor)

McMillan-McGee Corp
thermal remediation solutions to the power of e...

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