

Sustained-Release Oxidants: Use of Remox SR+ Cylinders in Treatment for Chlorinated Solvents in Groundwater

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Outline

- Chlorinated Solvents ... Remediation
- Decision Criteria
- Technology Development
- Field Installation
- Case Studies/Examples ... 2 sites
- Summary

Chlorinated Solvents ... Remediation

We all know:

- Difficult
- Persistent
- Time has passed - migration
- Geology and Hydrogeology issues
- Breakdown products more toxic

PCE → TCE → c-DCE → vinyl chloride (VC)

Historical industrial activities using chlorinated solvents (TCE) for metal degreasing as well as past dry-cleaning (PCE) practices have created many remediation challenges.

COSTLY!

Decision Criteria

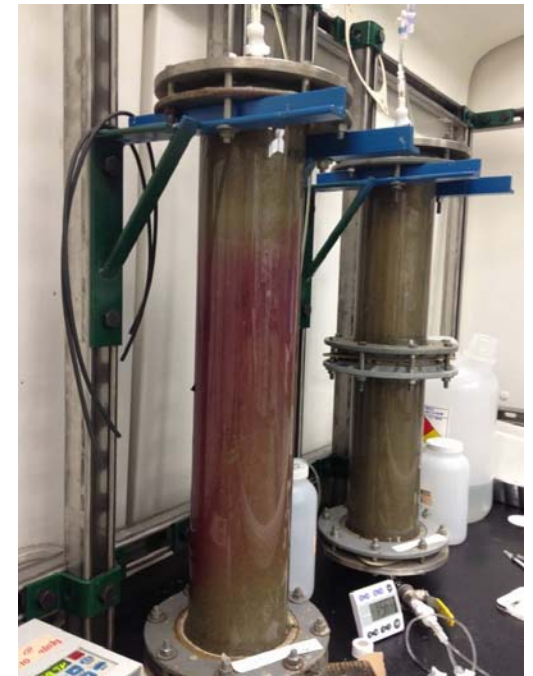
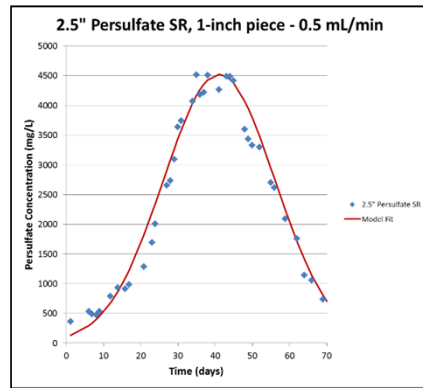
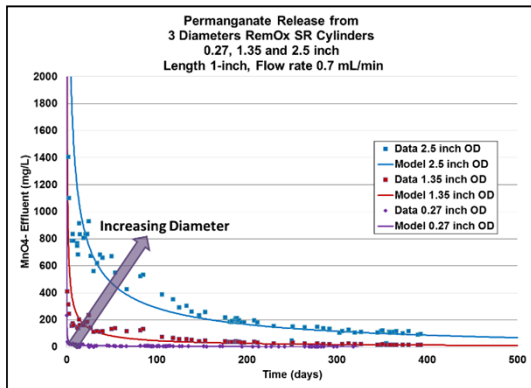
- Ease of Application – Difficult locations/situations
- Health and Safety – Workers
- Known Technology – want to be sure it works
- Low Operation & Maintenance
- Overall Cost



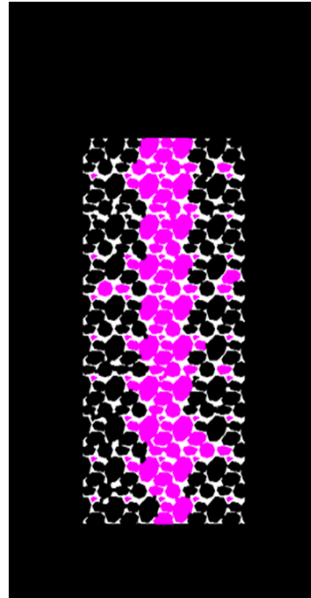
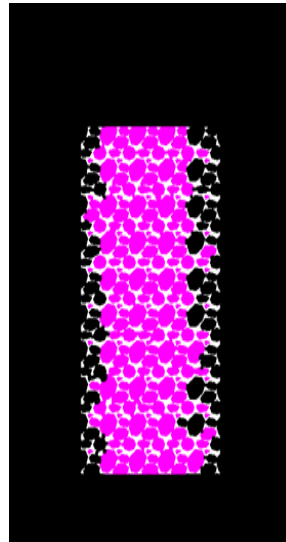
- Remtech 2012 ... RemOx SR Presentation by Dr. Pamela Dugan

Technology Development

- Sustained-Release (SR+) Oxidants
- Promising slow-release permanganate and persulfate modeling, lab, pilot-scale field studies
 - (e.g., Carus Corporation, Ohio State University, Clemson, University of Nebraska, Colorado School of Mines)



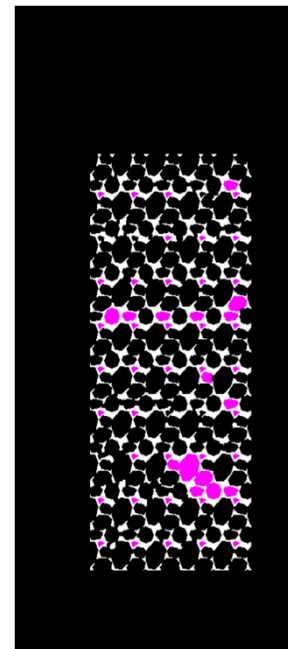
Oxidant Release from Wax



- This is why we see an initial spike of permanganate in early time...
- And a significantly slower and lower release of permanganate at later times

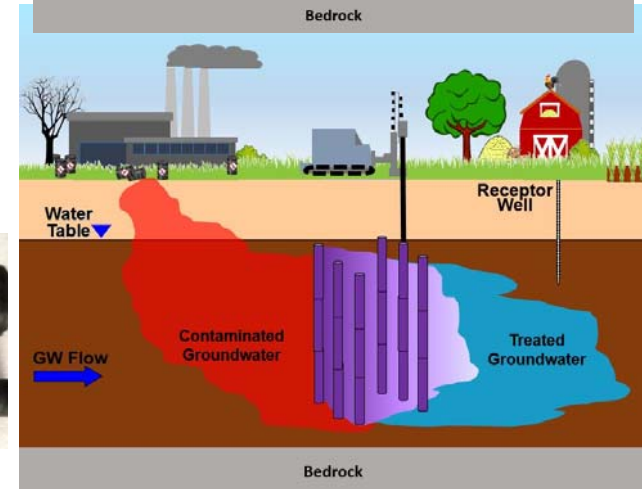
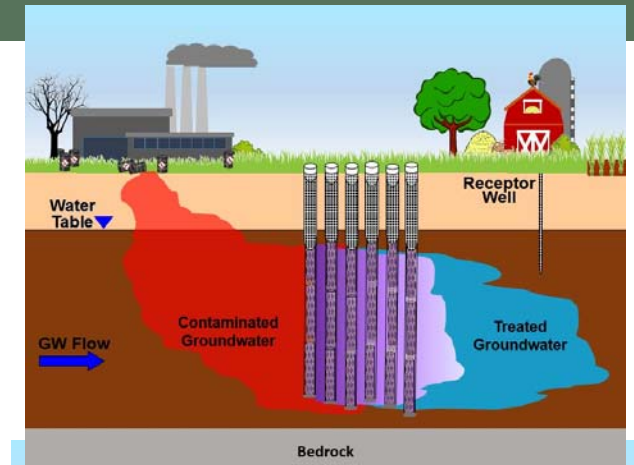


- Newly created void spaces expose permanganate solids for dissolution and diffusion
- Process occurs radially from the exterior of the cylinder to the inner core

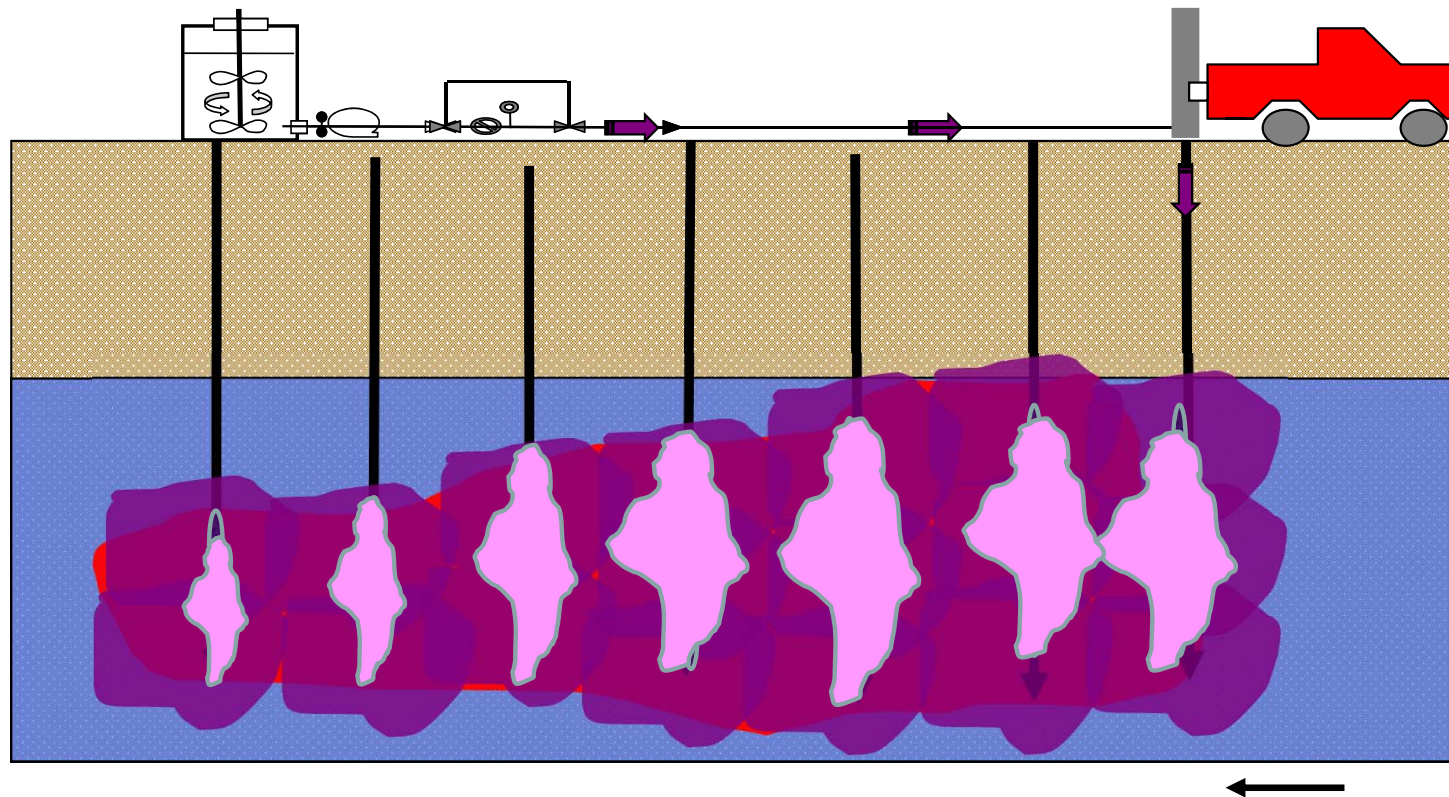


SR+ Technology - Versatility in Applications

- Cylindrical shape: 2.5" diameter x 18" long
- Application Possibilities:
 - Passive treatment- direct push, existing wells
 - Combined remedies/treatment train approaches
 - Stepped-implementation strategy
 - Minimizes above-ground infrastructure
 - Mitigate impacts of rebound, matrix diffusion, daylighting



Technology Development: SR+ Oxidants



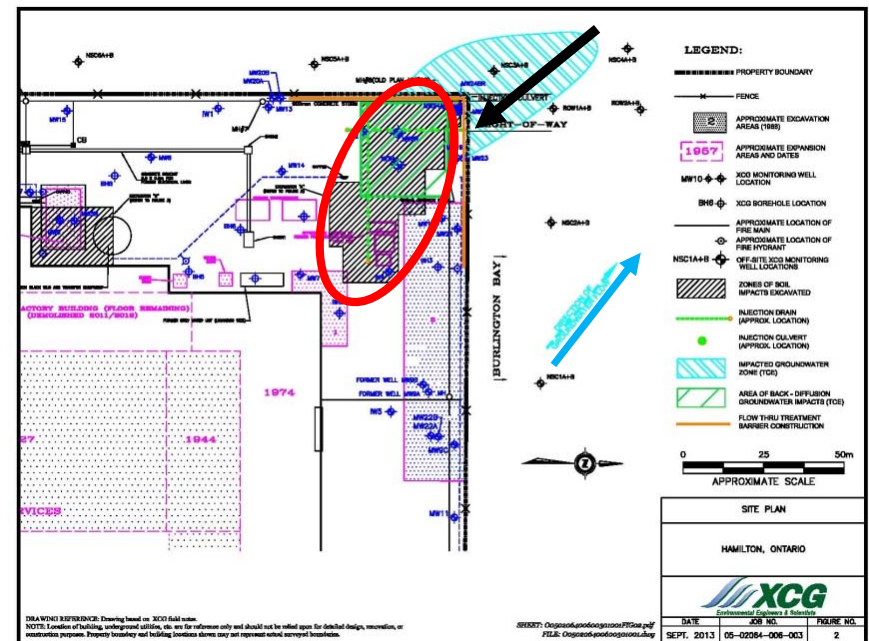
Case Study #1 – Historical Manufacturer

Case Study #1 – Historical Manufacturer

- Historical Industrial Site in Hamilton, Ontario
- Developed circa 1925
- Close to the Harbour (fresh water of Lake Ontario)
- Geology is fill over silty-clay down to clay material
- Historical use of chlorinated solvents
 - **PCE** → **TCE** → **c-DCE** → **VC** in groundwater
- Difficult Remediation – Complicated Ownership

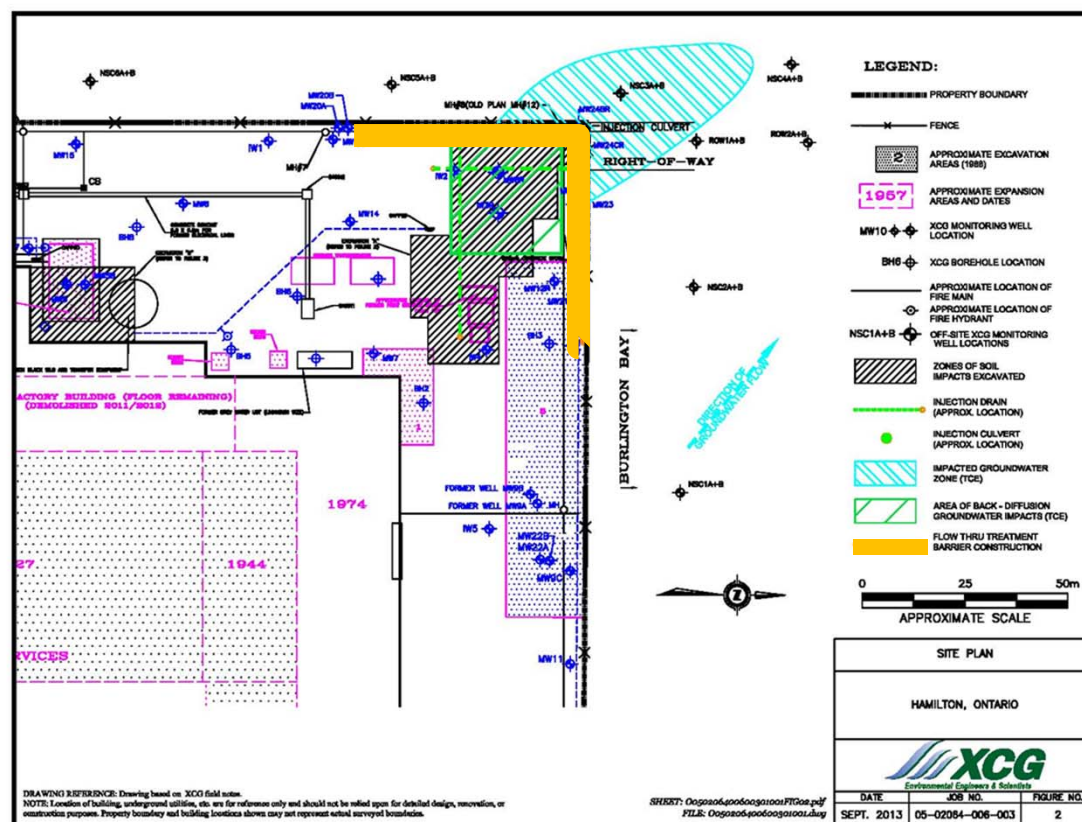
Case Study #1 – Historical Manufacturer

- Off-site Groundwater Impacts ...
 - Higher concentrations
 - Near saturation levels
- Remediation Stages ... **excavation** of soil impacts
- **Back-Diffusion** of impacted groundwater following excavation and hydraulic re-equilibration

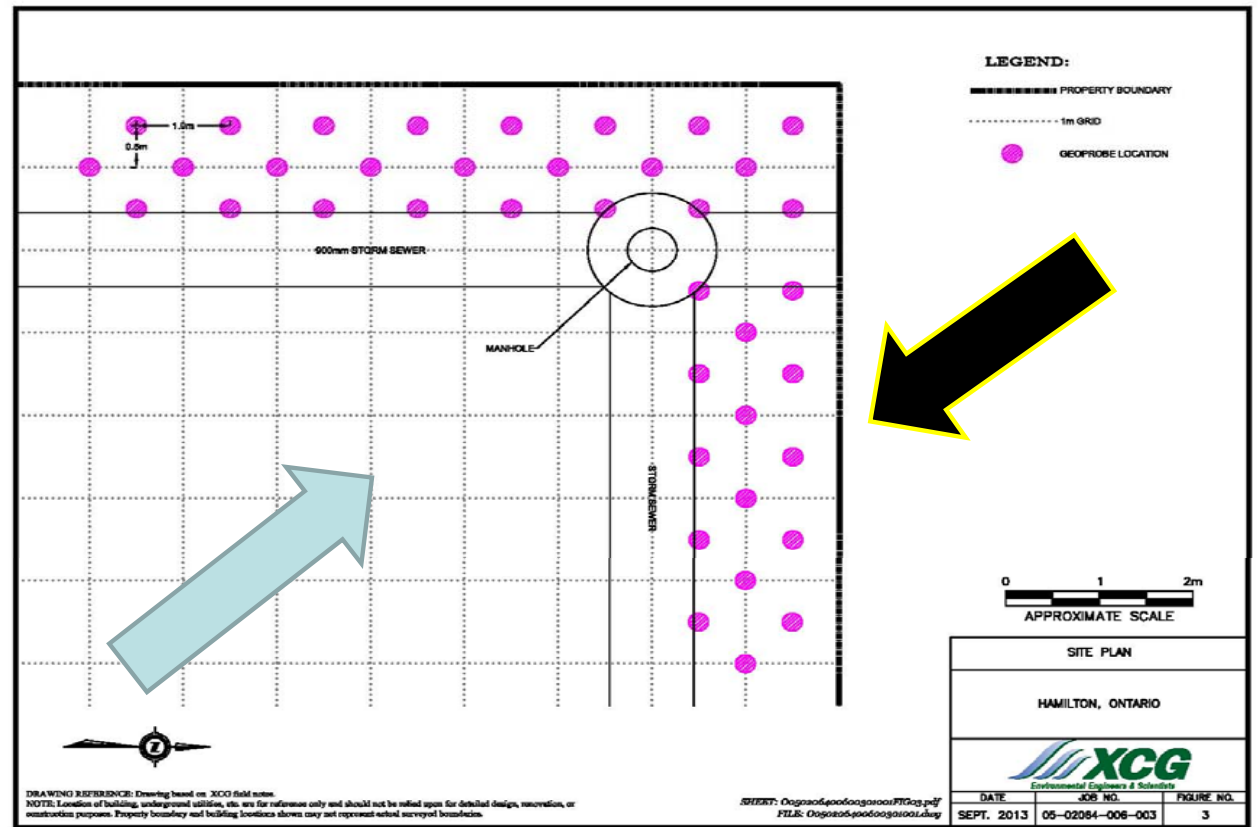
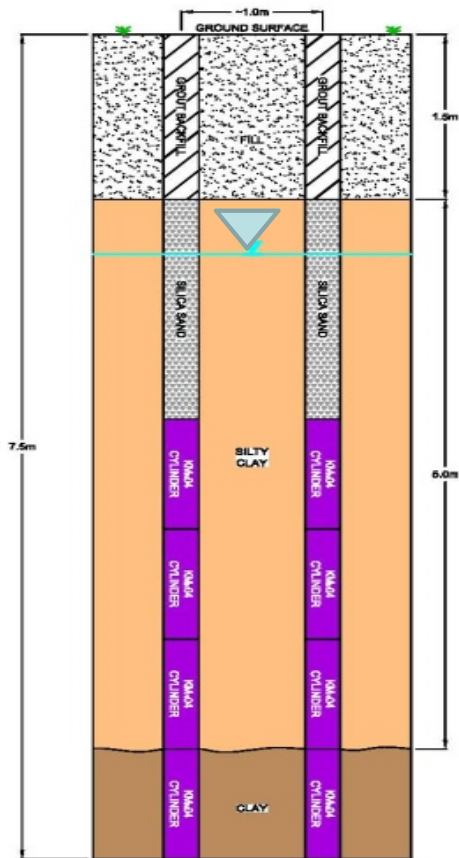


Case Study #1 – Historical Manufacturer

- First Site Application in Canada - December 2012
- Installed 476 cylinders in 119 direct-push boreholes over 8 days
- Straight-forward installation – health and safety



Case Study #1 - Barrier Design

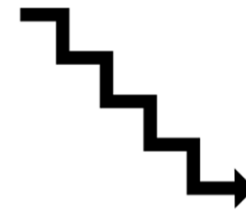
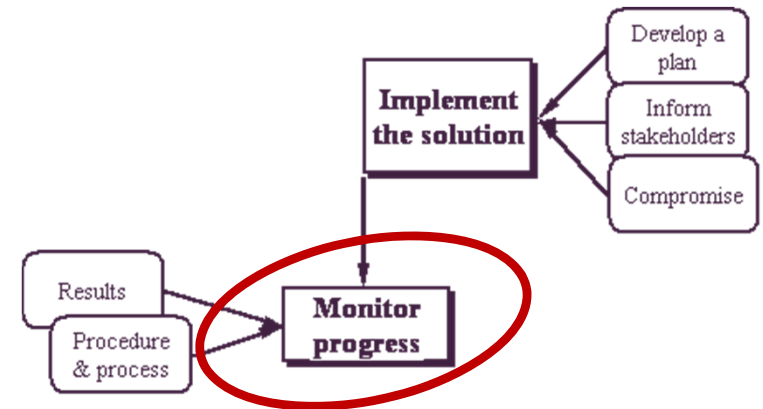


Case Study #1 - Field Installation



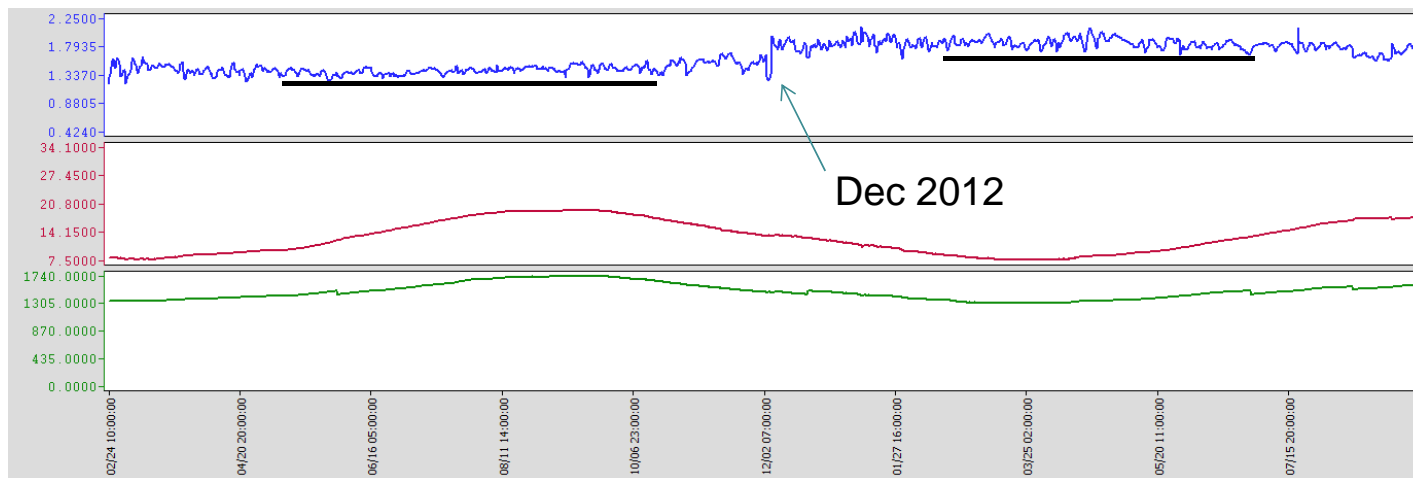
Case Study #1 - Monitoring Effectiveness

- Installed ... now what?
- Client needs assurance that effective
- Monitoring indicators in groundwater
 - **elect. conductivity, ORP, oxidant**
- Eventual cVOCs concentration decrease



Case Study #1 - Monitoring Effectiveness

- Location MW20B – observed an almost immediate increase in electrical conductivity (distance ~ 5m)



- Hydraulic conductivity is low ... 1.27×10^{-5} m/s

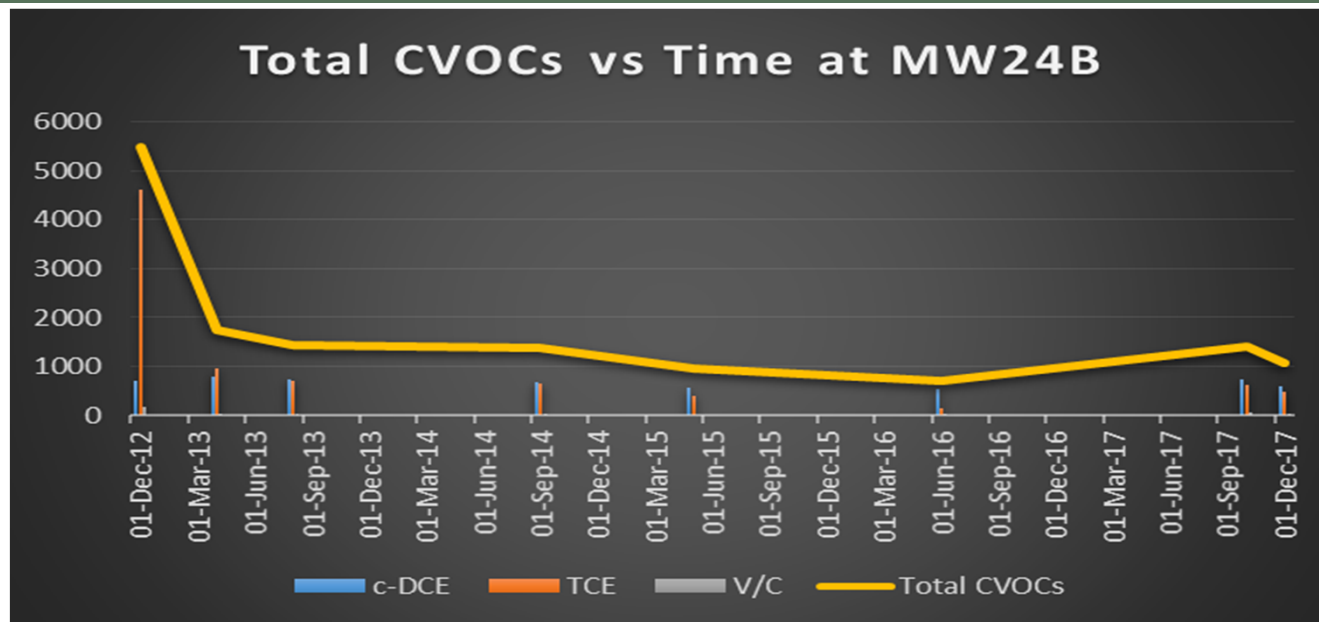
Case Study #1 - Monitoring Effectiveness

MW24B installed at 5.5 metres below ground surface, located approximately 1.5 metres from barrier

UPDATE:

From 2013, TCE concentration decreased until 2016.

Replenished Cylinders in Barrier in Nov. 2017.



MW24B	06-Dec-12	15-Apr-13	12-Aug-13	09-Sep-14	14-May-15	22-Jun-16	17-Oct-17	22-Dec-17
c-DCE	710	790	720	690	560	540	720	590
TCE	4600	950	700	660	400	150	630	480
V/C	170	5.6	19	19	0	5.2	69	0.5

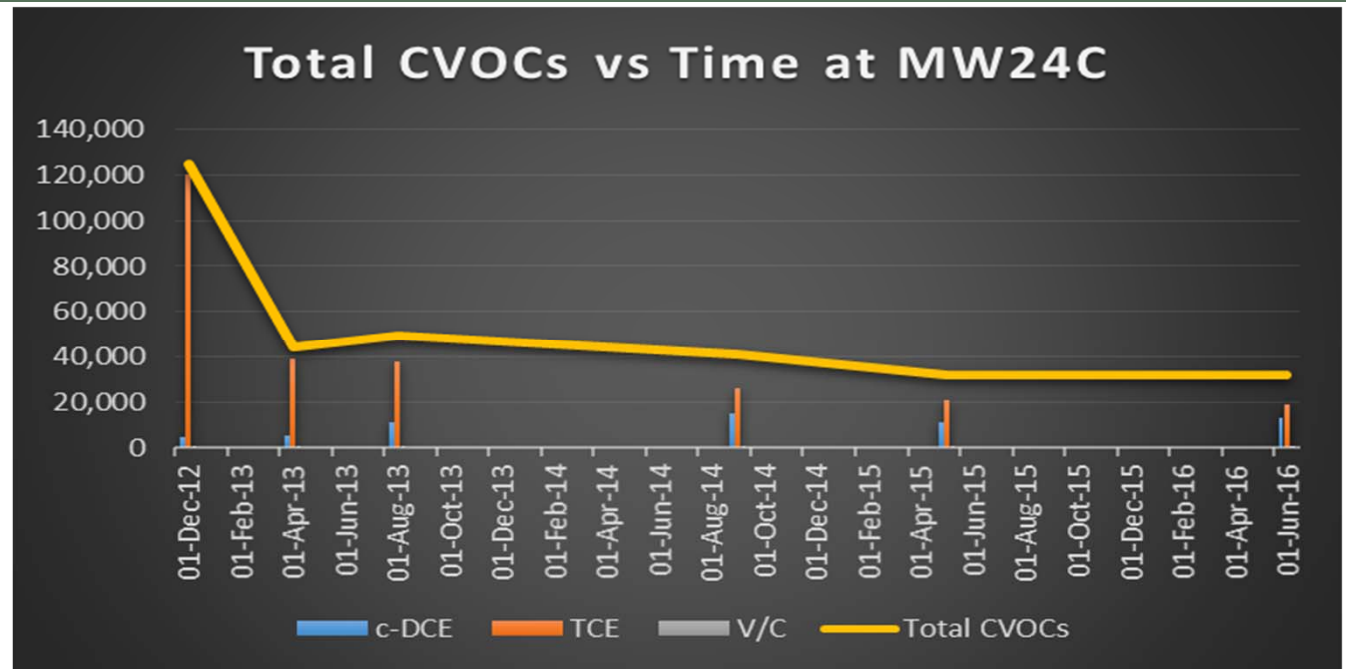
Case Study #1 - Monitoring Effectiveness

MW24C installed at 10 metres below ground surface, located approximately 1.5 metres from barrier

UPDATE:

Since 2013, TCE concentrations continue to decrease

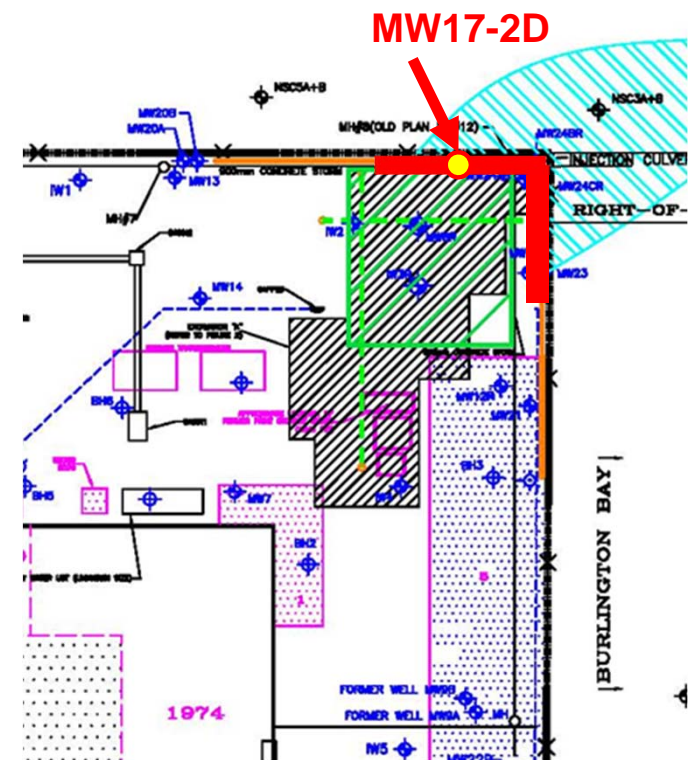
Positive outcome!



MW24C	06-Dec-12	15-Apr-13	12-Aug-13	09-Sep-14	14-May-15	22-Jun-16
c-DCE	4,400	5,100	11,000	15,000	11,000	13,000
TCE	120,000	39,000	38,000	26,000	21,000	19,000
V/C	260	9.2	270	150	10	16

Case Study #1 – Barrier Replenishment

- Initial Barrier calculated active for 4 - 5 yrs
 - Client and site owner pleased with results
- Replenished Barrier in Nov 2017
 - RemOx SR+
 - Smaller **barrier** designed due to improvements in groundwater quality in fringes of plume (depth of 5 metres)
 - 228 cylinders in 57 direct-push boreholes over 5 days



Case Study #1 – Barrier Replenishment

- Observable Changes in Indicators
 - Elec. Conductivity and ORP

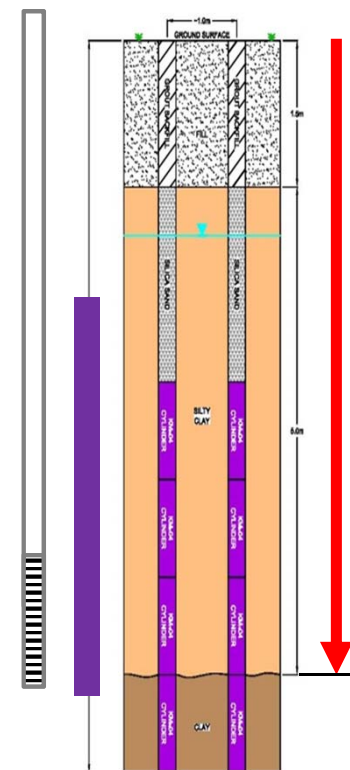
MW17-2D			
EC (mS/cm)		ORP (mV)	
13-Nov-17	22-Dec-17	13-Nov-17	22-Dec-17
3.59	3.88	131	468

- Immediate Results in total cVOCs reductions

OCT = 59,985 µg/L

DEC = 35,013 µg/L

MW17-2D	17-Oct-17	22-Dec-17
c-DCE	950	3,000
PCE	24	8.6
TCE	59,000	32,000
V/C	11	4.5

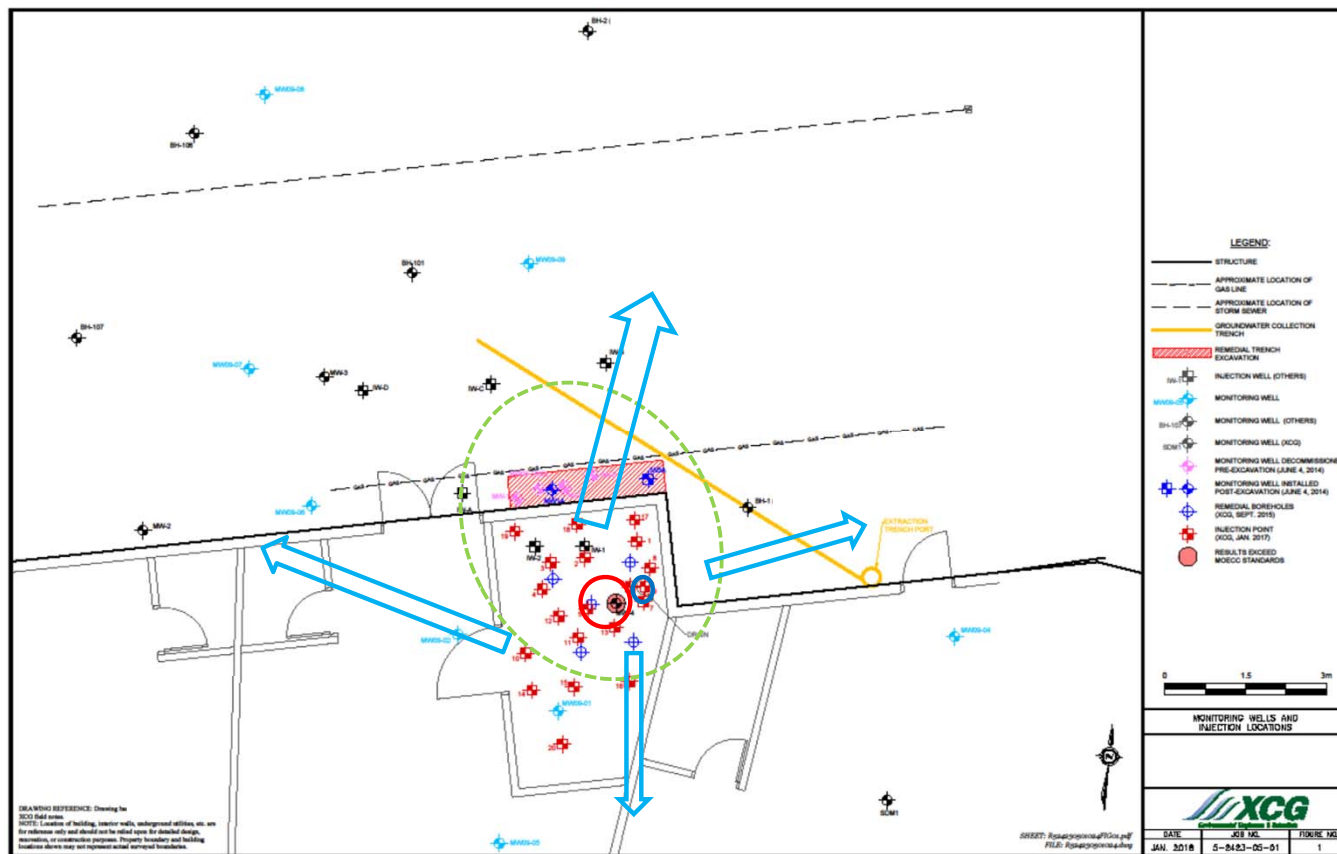


Case Study #2 – Dry-Cleaner

Case Study #2 – Dry-Cleaner

- Typical scenario – Dry-cleaner in a neighbourhood strip mall/plaza
- Established circa 1982, closed circa 2005
- Some below building, some outside bldg. footprint
- Client (owner) and current tenant relations are paramount
- Desire to meet **Generic Standards** (versus Risk Assessment)
- XCG working through the remediation since 2012
- Combined Remedies – hydraulic control, excavation, ISCO

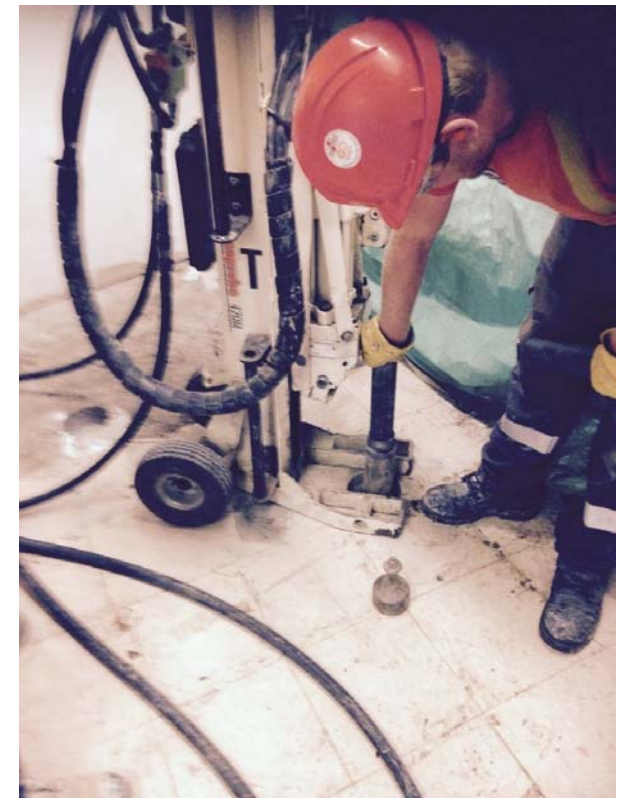
Case Study #2 – Dry-Cleaner



- One persistent well with TCE marginally above Table 3 Standard of 17 $\mu\text{g/L}$
- Limitations for active remediation
- tenant disruption

Case Study #2 – Dry-Cleaner

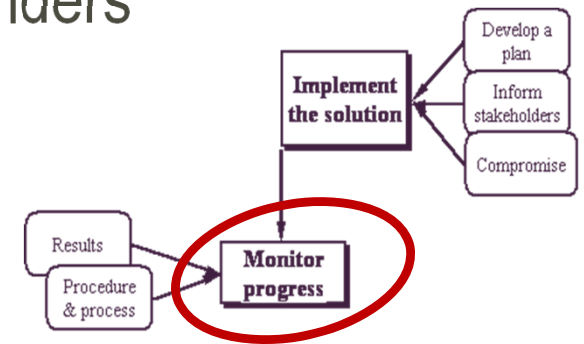
- Placement of Remox SR+ cylinders in Boreholes



5 boreholes with 2 cylinders each; depth of 2.5 m

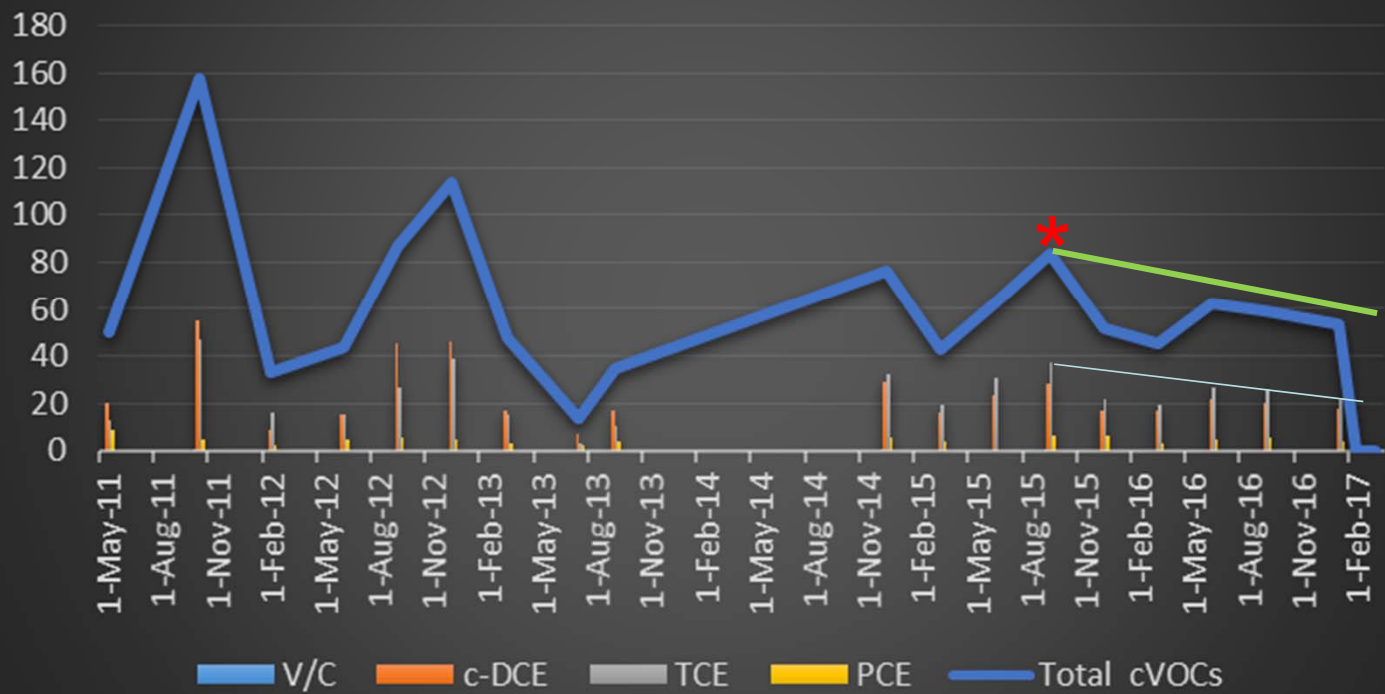
Case Study #2 – Dry-Cleaner

- Monitor the Results ... wells within 3 metres of cylinders
- **ORP** ... historic ranged from **79 to 97 mV**
- Within 3 months ranged from **154 to 202 mV**
- **EC** ... historic ranged from **0.36 to 0.90 mS/cm**
- Within 3 months ranged from **4.22 to 7.97 mS/cm**



Case Study #2 – Dry-Cleaner

Total cVOCs vs. Time at MW4



- TCE before Installation
 - **37 µg/L**
- Within 6 months
 - **19 µg/L**

MOECC
Table 3 Standard
for TCE
is 17 µg/L

- Working on site Closure
 - **4 Quarterly events**
 - **Record of Site Condition**

Summary

- New twist on a known technology – KMnO_4 & NaS_2O_8
- Application ease for difficult locations/situations
 - Health and Safety for workers
- See instant results (\uparrow ORP and electrical conductivity)
 - Clients are pleased with Cost/Benefit
 - Sustained-Release
- Technology fits well as an option for overall remediation plans and combined remedies

Thank you for Attending!

Questions?

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