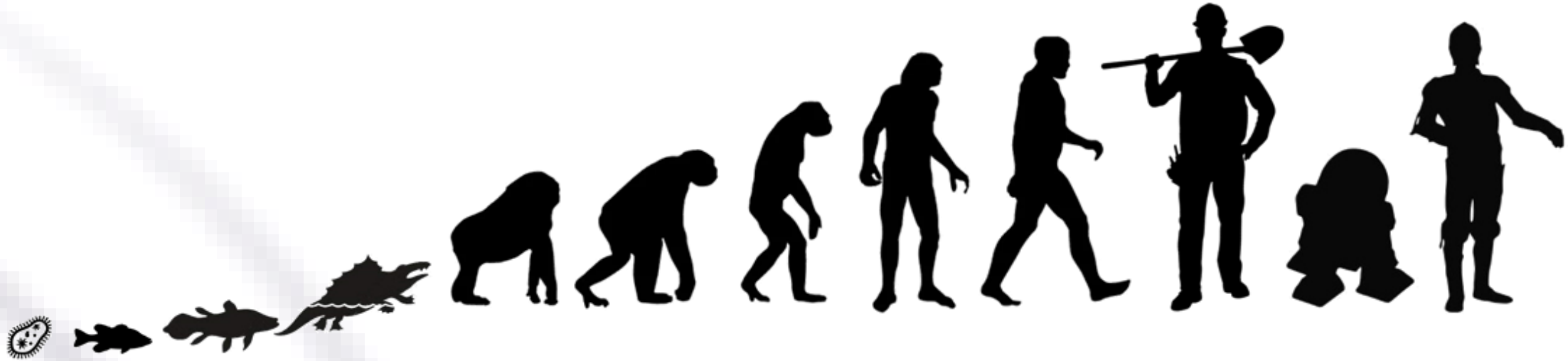
Evolution of the Contaminated Site Remediation Industry in Canada

RemTech – Banff, AB

October 15, 2021

Kevin E. French, P.Eng.

Presentation Overview



- Introduction
- Environmental Awareness
- Environmental Regulation
- 1970s & 1980s – D&D & P&T
- 1990s – Biopiles, PRBs & RAs
- 2000s – ISCO, ISCR & More Bio
- 2010s – HRSC, CBIs & B/R
- 2020s & Beyond – What's Next?
- Observations
- Questions

Introduction

Introduction – Presenter

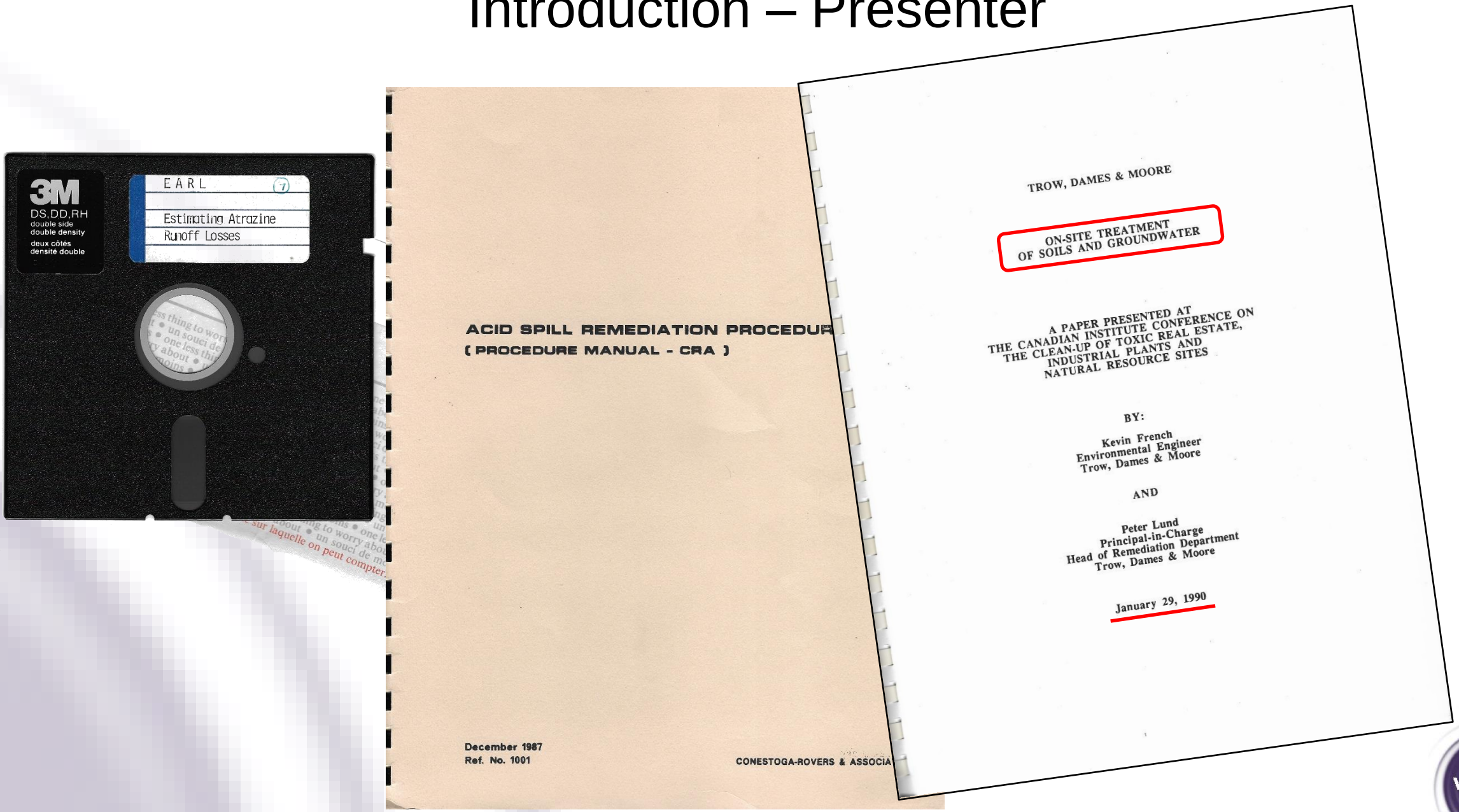
Kevin French, P.Eng

- Vice President, Vertex Environmental Inc.
- B.A.Sc., Civil/Env. Eng., U. Waterloo
- Environmental engineering (consulting and remediation contracting) since 1988

Vertex Environmental Inc.

- Founded in 2003
- Bruce Tunnicliffe, M.A.Sc., P.Eng.
- Specialized Environmental Remediation Contracting (in-situ, ex-situ, systems)
- High Resolution Site Characterization (HRSC)
- SMART Remediation learning series

Introduction – Presenter



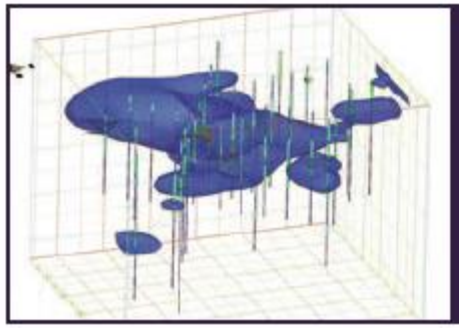
Vertex Environmental Inc.

In-Situ Remediation

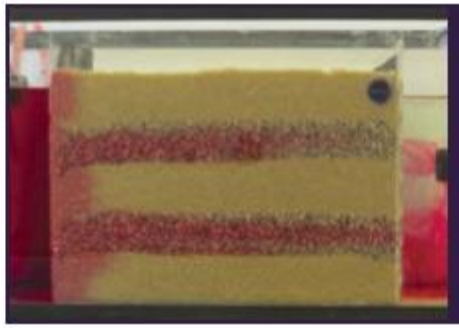
Ex-Situ Remediation

High Resolution Characterization

Treatment Systems

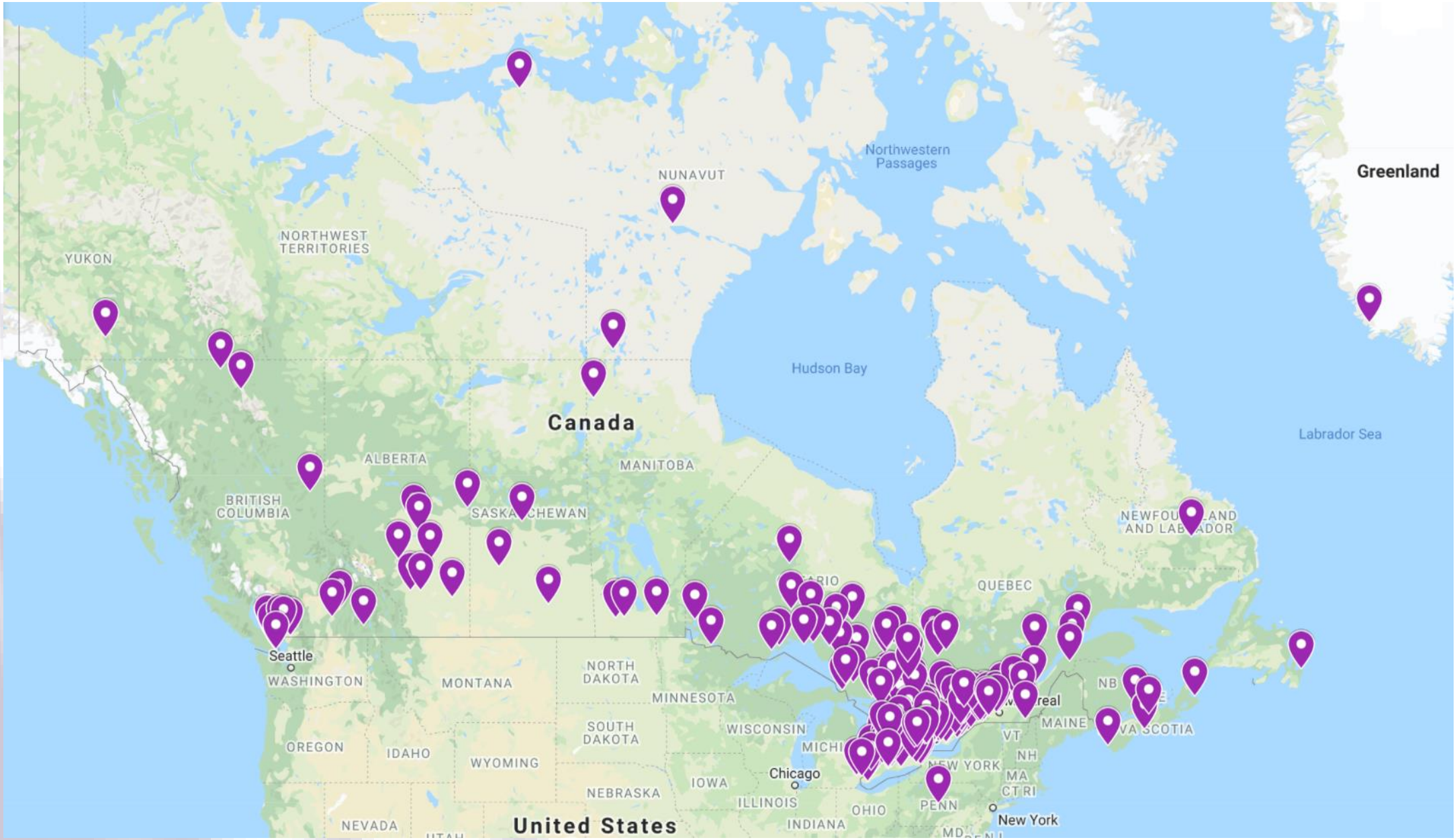


Remedial Design



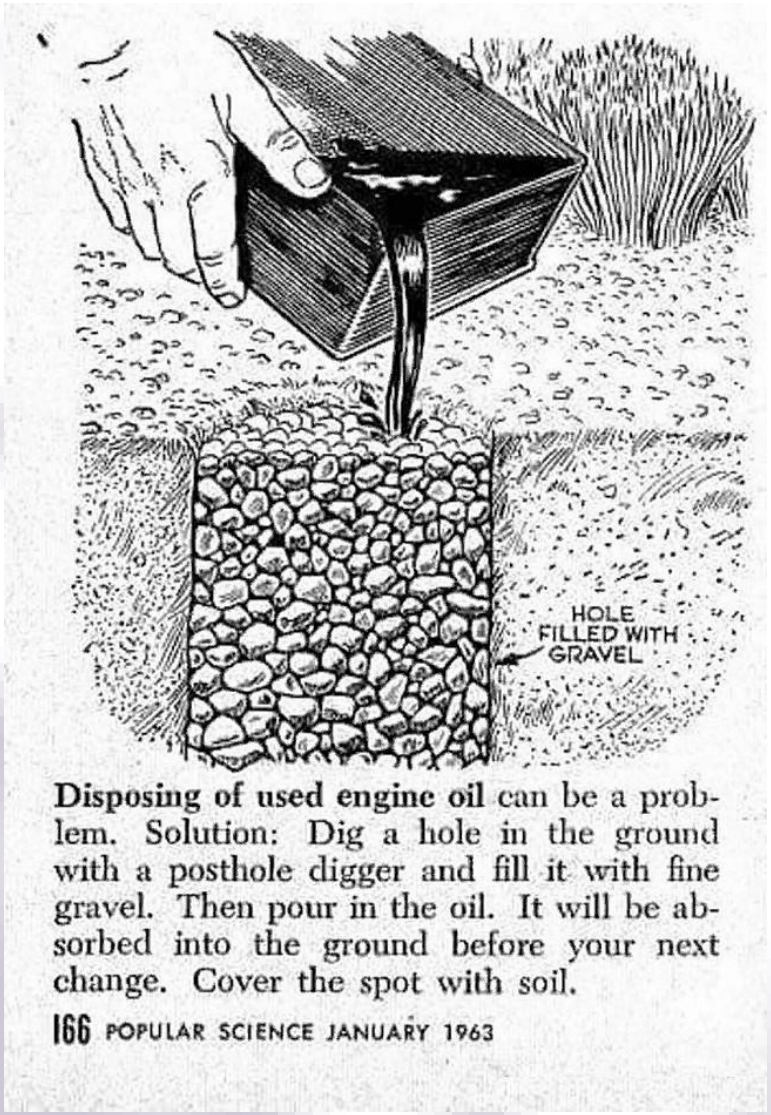
Bench-Scale Testing

Vertex Environmental Inc.



Environmental Awareness

Environmental Awareness



Disposing of used engine oil can be a problem. Solution: Dig a hole in the ground with a posthole digger and fill it with fine gravel. Then pour in the oil. It will be absorbed into the ground before your next change. Cover the spot with soil.

166 POPULAR SCIENCE JANUARY 1963

Progression of awareness of environmental contamination as an issue:

- Out of sight = out of mind
- Leaky underground tanks, back door dumping, uncontrolled fill not considered problematic and were standard practices
- Unless it injured people's health or killed them, killed plants / animals or fish, or started costing money to address (lawsuits)
- Waste disposal was seen as only a cost to the bottom line, which lead to illegal dumping
- It took environmental disasters to bring the issue to the awareness of the public and regulators

VERTEX

Environmental Awareness

Love Canal, Niagara Falls, NY

Environmental Awareness

PCB Fire, St-Basile-le-Grand, QC

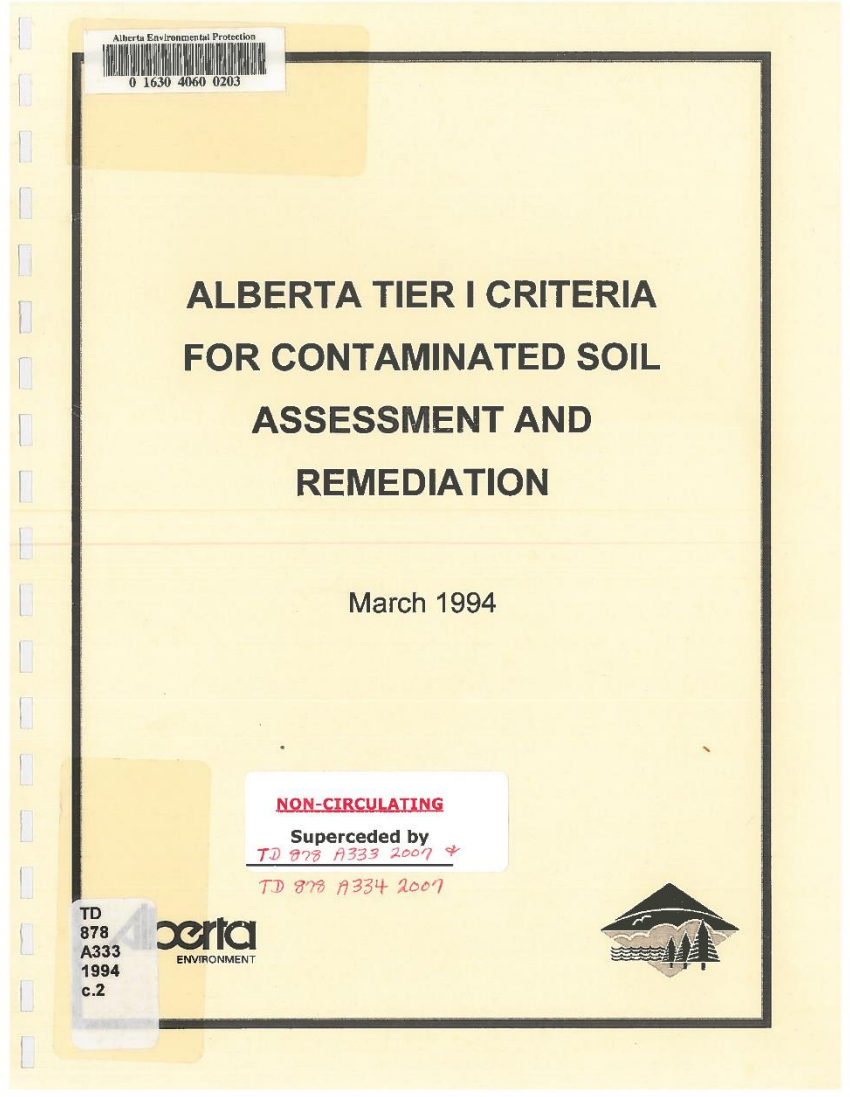
Tar Ponds, Sydney, NS

Uniroyal Chemical, Elmira, ON

Giant Mine, Yellowknife, NWT

Environmental Regulation

Environmental Regulation



History of Canadian Environmental Regulation (a sampling):

- 1968: Fisheries Act: “deleterious substance”
- 1971: Environment Canada founded
- 1971: AB Department of Environment formed
- 1989: CCME Guidelines for PCB Waste Management
- 1991: AB MUST draft remediation guidelines (7 parameters)
- 1992: AB Environmental Protection & Enhancement Act
- 1994: AB Tier I Soil Criteria released (~50 parameters)
- 2001: AB Risk Management Guidelines for Petroleum Storage Tank Sites (site-specific risk assessment)
- 2004: O.Reg. 153/04 RSC Regulation (~120 parameters)
- 2019: AB Tier I Criteria (latest) (~220 parameters)
- 2019: O.Reg. 406/19 On-Site and Excess Soil Management (focus on soil as a resource = Sustainability)
- 2021: CCME standards for PFOS in soil and groundwater
- Future: Other PFAS, emerging contaminants?

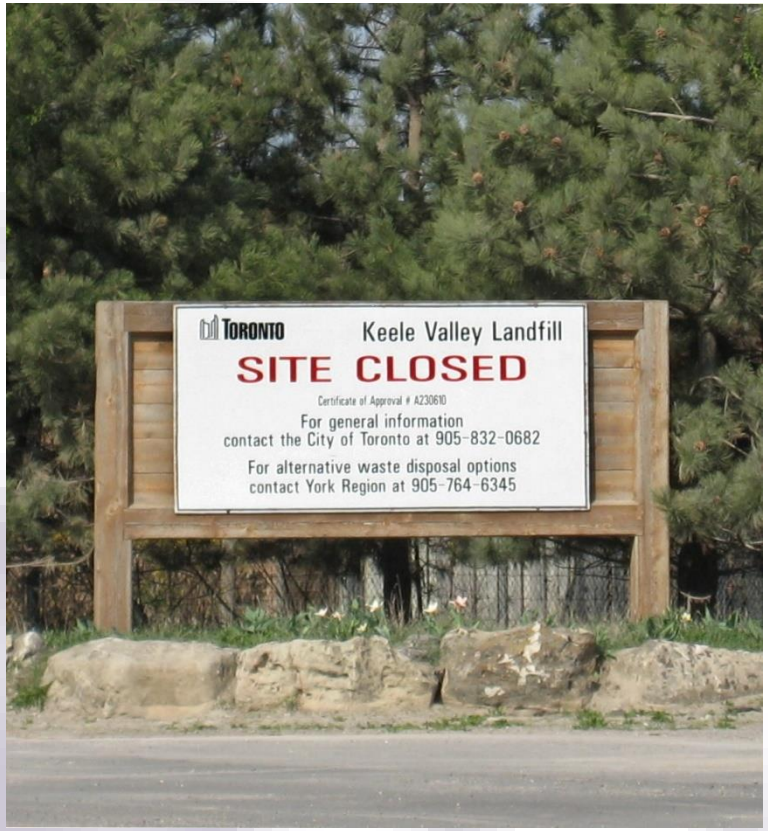
1970s & 1980s – D&D & P&T

1970s & 1980s – D&D

Excavation & Off-Site Disposal (a.k.a. "Dig & Dump"):

- <u>Only solution for dealing with soil contamination regardless of contaminant – dig until "clean" line reached</u>
- Often times also used to address groundwater only contamination due to lack of remediation solutions
- Soil taken to one of several places: lake filling site (more stringent), contaminated soil landfill, municipal landfill or hazardous waste landfill ($$)

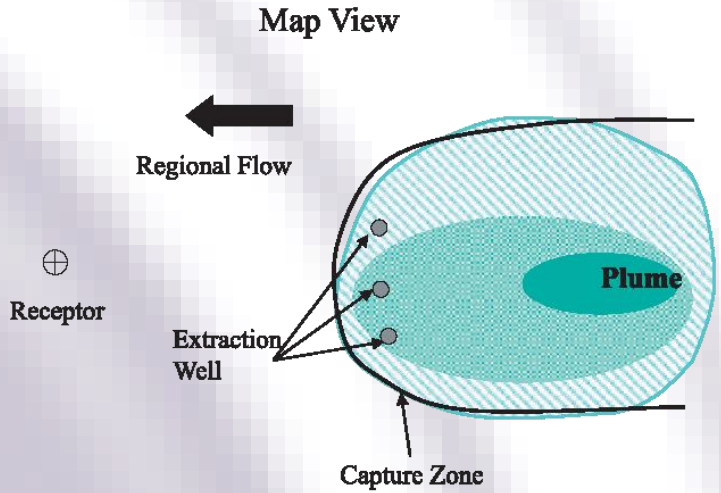
1970s & 1980s – D&D



Excavation & Off-Site Disposal (a.k.a. "Dig & Dump"):

- Landfilling originally inexpensive: landfill tipping fees in Toronto went from $18/MT in 1988 to $97/MT in 1990 to $125/MT in 1993 when space was running out (impetus for change)
- Was effective at soil remediation but revealed the idea of "rebound" or "back diffusion" in groundwater
- Soil could pass but could still contain enough residual sorbed mass of organics to fail groundwater standards
- Still has its place today for mass removal when accessible (e.g. source area extraction)

1970s & 1980s – P&T

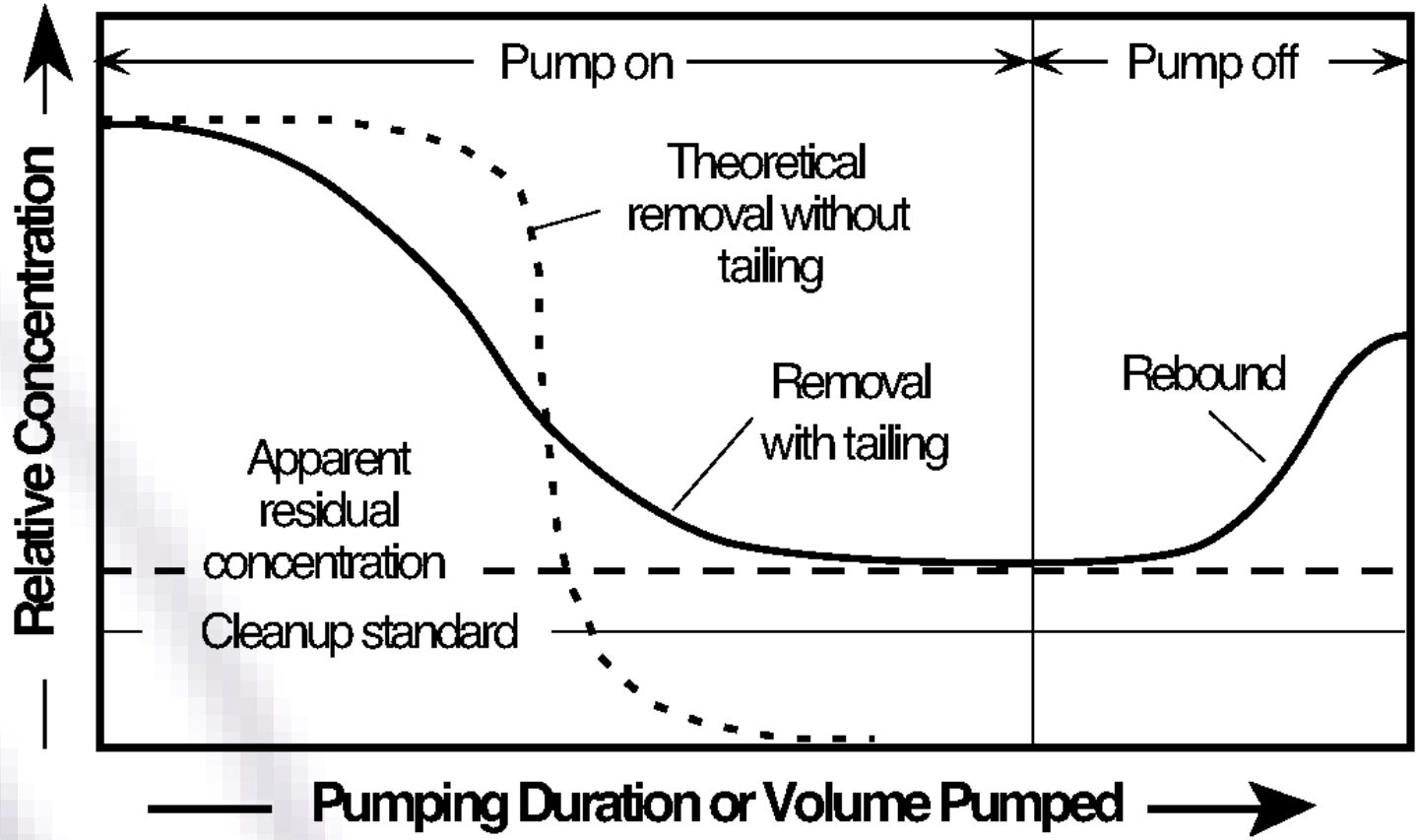


Pump & Treat Systems:

- Originally believed to be able to remediate to permanent low concentrations
- Good for removing initial high concentrations, mass and LNAPL
- Diminishing returns realized after years; sometimes plans changed to operate “into perpetuity”
- Further revealed “rebound” or “back diffusion” issue
- Concentrations reached asymptote and then rebounded to a new higher level – “fingers crossed” if steady-state was below standards
- Still has its place for mass removal and hydraulic control

VERTEX

1970s & 1980s – P&T

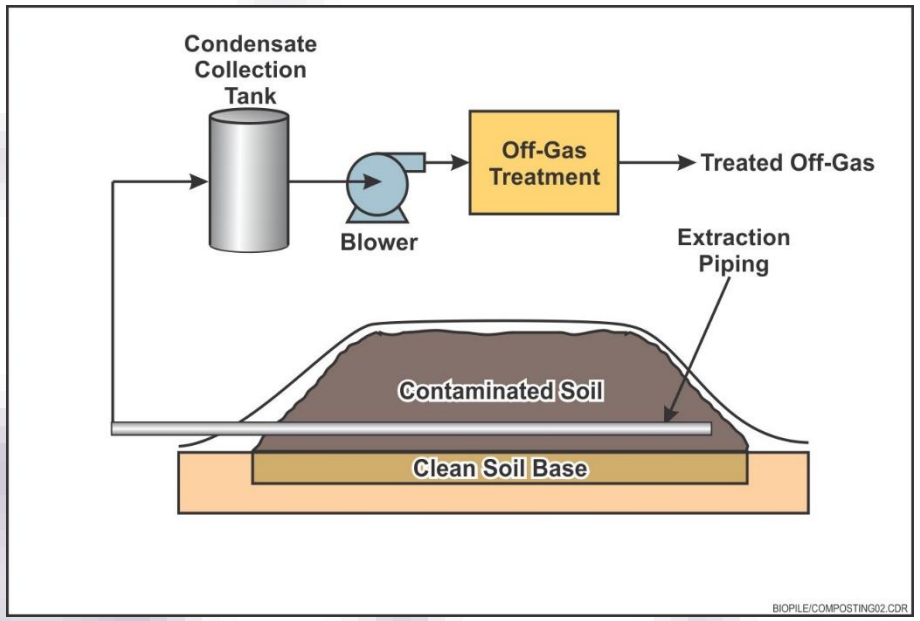


Above or below standard??

Figure 7. Concentration versus pumping duration or volume showing tailing and rebound effects (modified from Keely, 1989).

1990s – Biopiles, PRBs & RAs

1990s – Biopiles



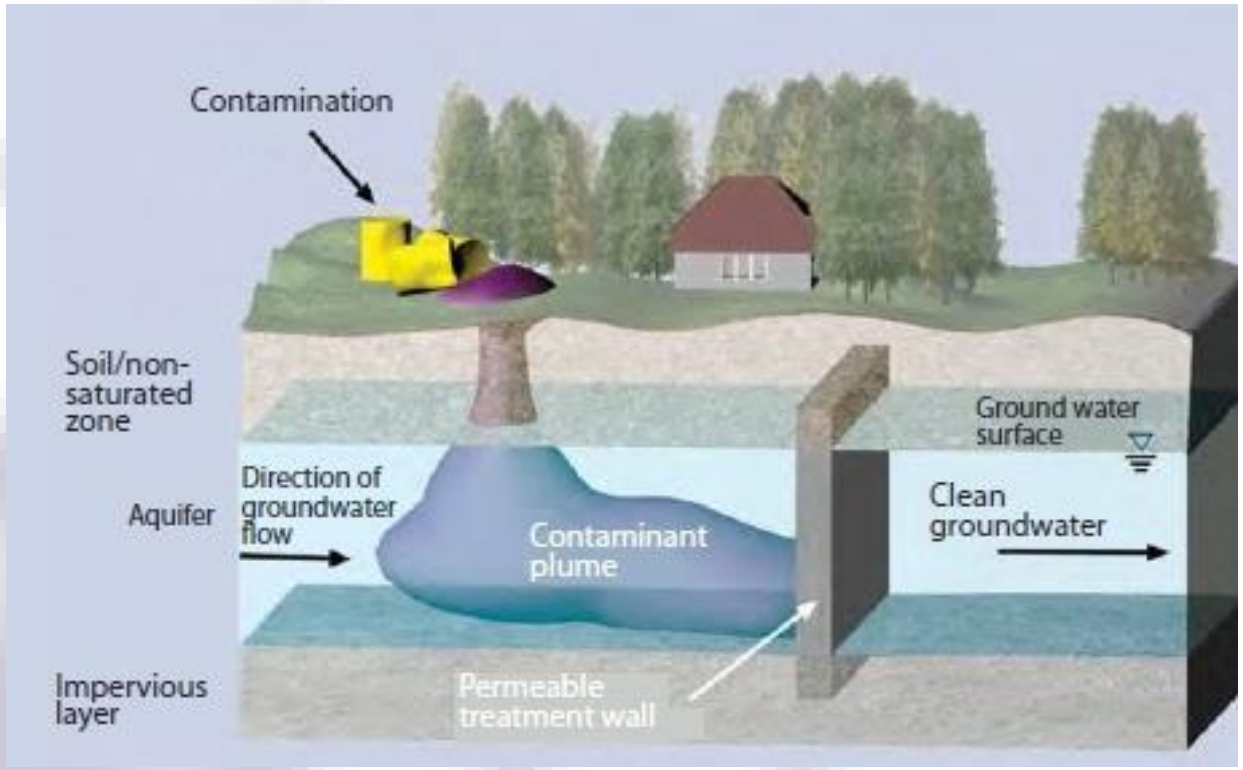
Biopiles & Landfarming:

- Some ex-situ bioremediation started in the mid-1980s
- Landfarming was done by the oil companies at owned sites, but relied mainly on aeration, volatilization and time (less scientific approach)
- US Naval Facilities Engineering Service Center (1996) and US Army Corps of Engineers (1998) guidance docs established the science behind biopiling for PHC remediation
- Continues to be used today and predict will become more popular due to sustainability

1990s – Biopiles

1990s – Biopiles

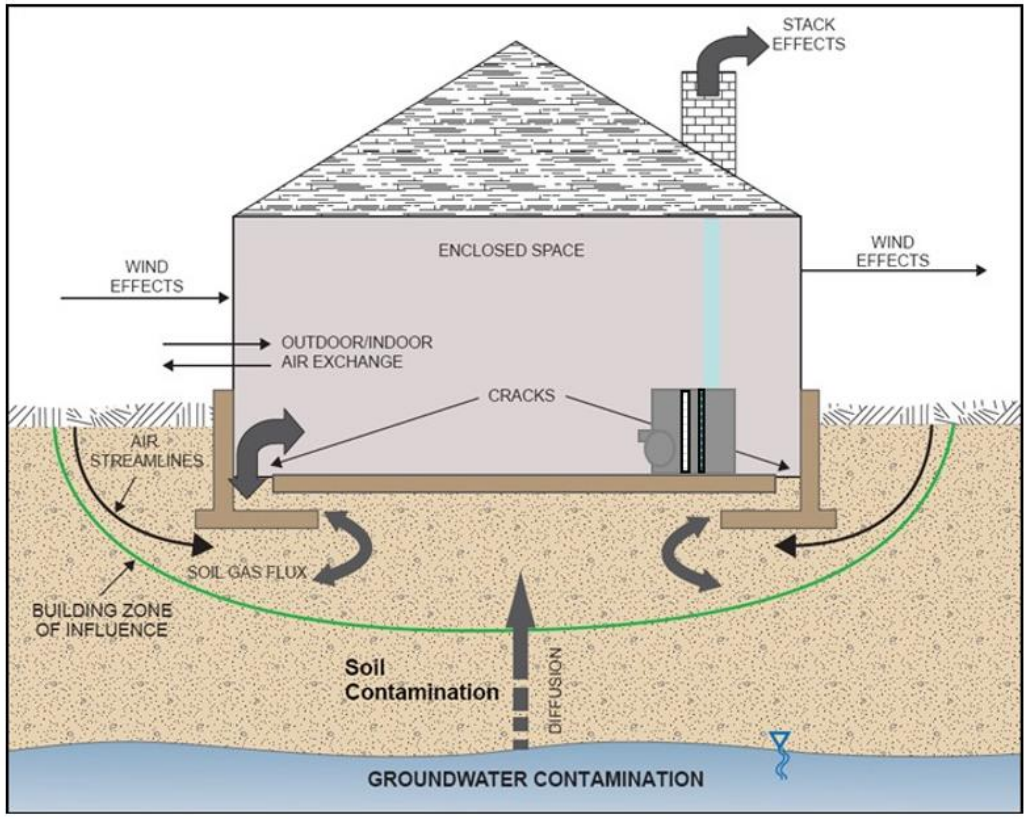
1990s – PRBs



Permeable Reactive Barriers (PRBs):

- U. Waterloo student discovery in 1980s
- Mechanism is mainly chemical reduction
- First “Iron Walls” made using zero-valent iron (ZVI) – essentially elemental iron (Fe^0)
  - Experimental: CFB Borden, ON in 1991
  - Full-scale: Sunnydale, CA in 1995
- Many ZVI PRBs installed in the mid-1990s still active and effective today!
- Since ZVI many new, long-lasting remedial amendments have been used to create PRBs for different contaminants; most recently PHCs (spoiler alert)

1990s – RAs



Risk Assessments (RAs):

- A means to derive site-specific soil and groundwater standards based on exposure routes, toxicity and receptors
- RAs established and accepted earliest in BC ~late 1980s/early 1990s
- First “unofficial” RA in Ontario approved ~1994 at the former Gooderham & Worts site with coal tar in bedrock (Distillery District site in Toronto)
- Concept written into Guidelines in AB in 2001
- RAs accepted in most jurisdictions, including Quebec (with the notable exception of PHCs)

2000s – ISCO, ISCR & Bio

2000s – ISCO

In-Situ Chemical Oxidation (ISCO):

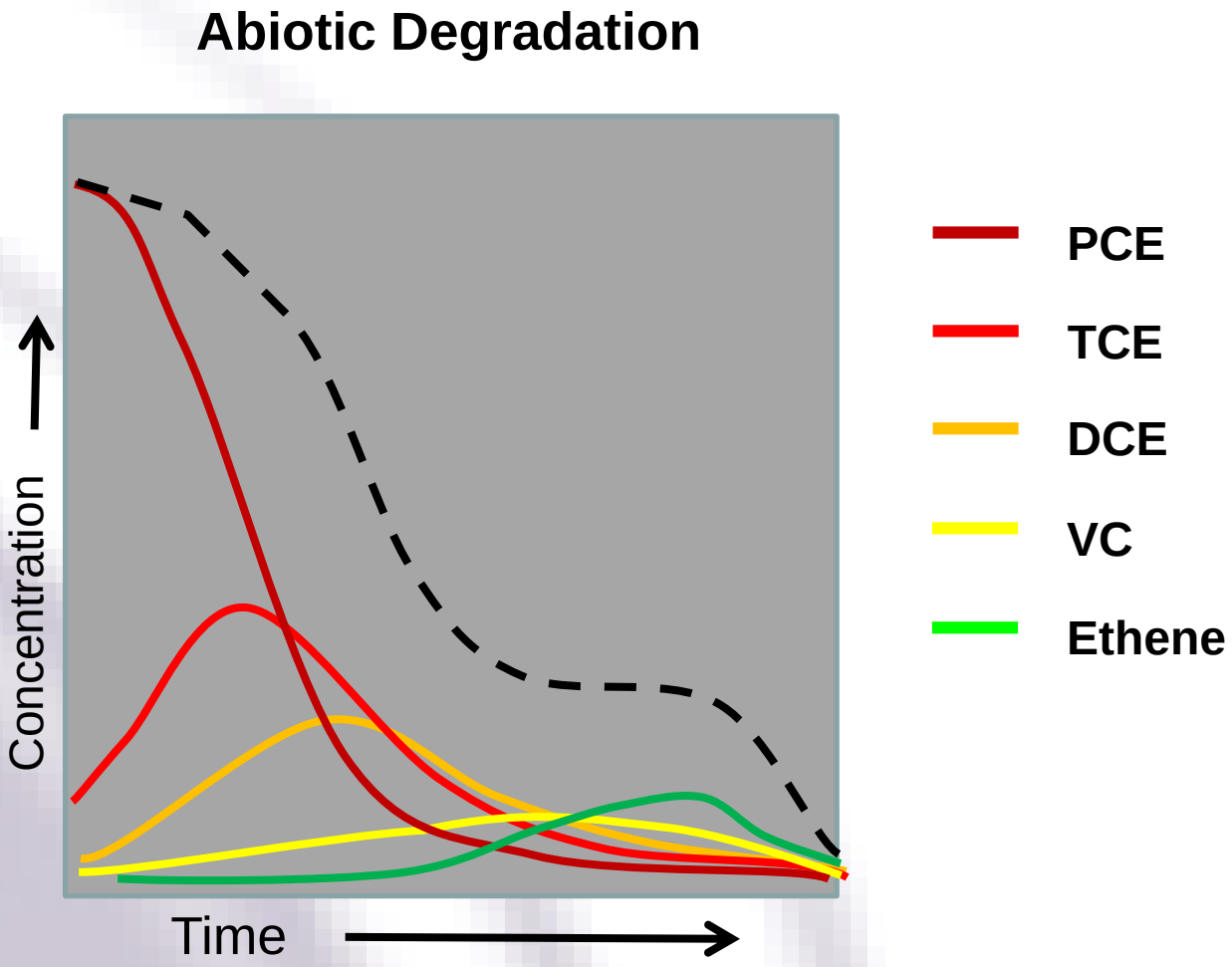
- Fenton's Reagent (1890s) modified in the mid to late 1990s / early 2000s to run at circum-neutral pH
- Early in the 2000s research was being undertaken into other chemical oxidants like permanganate for remediation purposes (Masters topic for Bruce Tunnicliffe at UW)
- Different oxidants (persulfate, percarbonate) developed over these years to focus on different oxidation potentials (strengths) and persistence
- Initially targeted CVOCs and PHCs

2000s – ISCO

In-Situ Chemical Oxidation (ISCO):

- During this time more of a focus brought to remediation in terms of reaction chemistry
- Laboratory analysis for SOD (soil oxidant demand)
- Bench-scale testing used for proof-of-concept and to refine approach & dosing
- Development of better application / delivery technologies from injection wells to injection points for better precision
- Development of better understanding of subsurface conditions that influence remediation
- My first experience with ISCO = 2007 when I hired Vertex for a former dry cleaner site in London, ON (yes – it was successful!)

2000s – ISCR



In-Situ Chemical Reduction (ISCR):

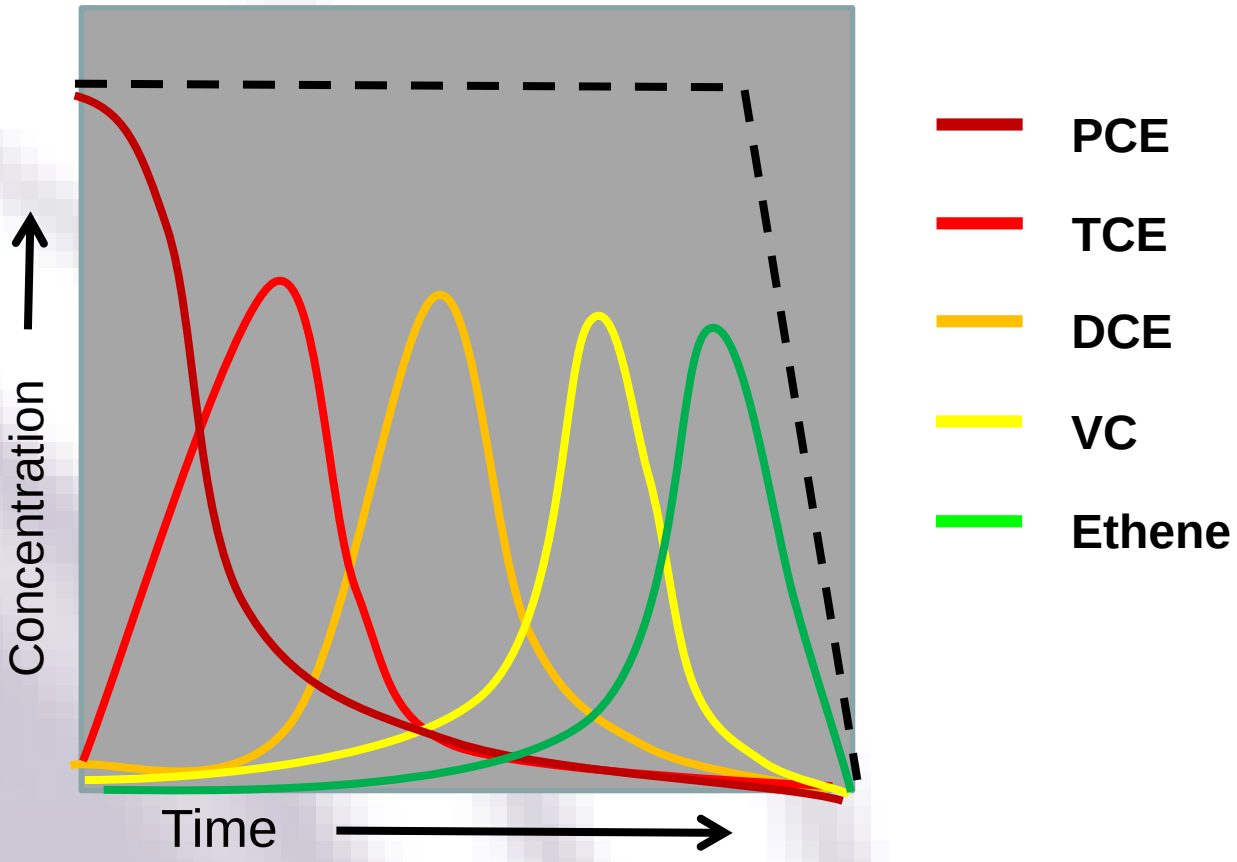
- Expanded from the initial success of the ZVI PRBs in the mid 1990s and improvements in delivery methods
- As with oxidants, different reductants developed over the years to focus on different contaminants, characteristics and persistence
- Together with amendments formulated to combine the synergies of chemical reduction and anaerobic biodegradation (SRB)
- Mainly targeted CVOCs and multi-valent heavy metals (Cr^{6+}, As, etc.)

PeroxyChem

VERTEX

2000s – More Bio

Biological Degradation (Reductive Dechlorination)



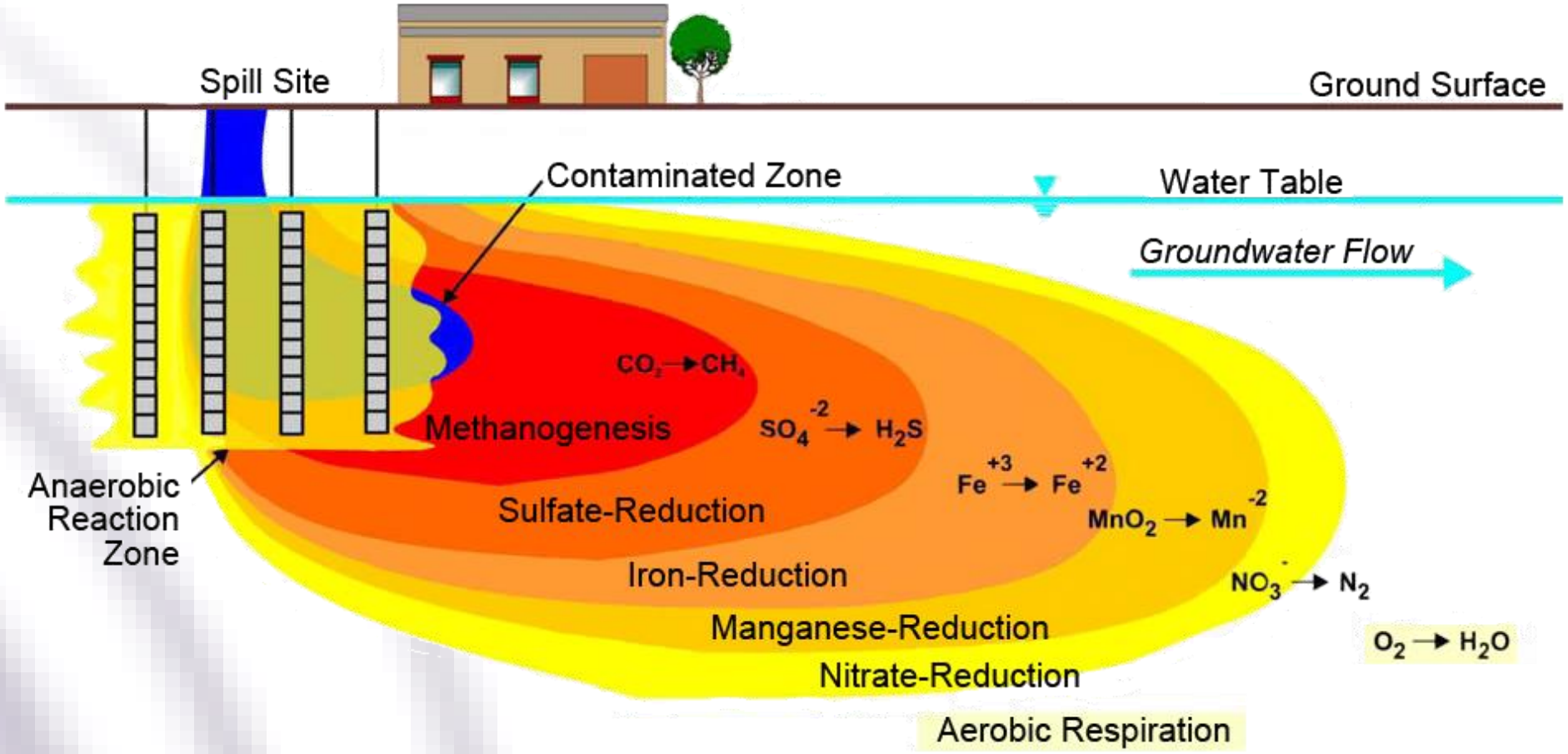
Source: PeroxyChem

In-Situ Biodegradation (Aerobic and Anaerobic):

- Initial biodegradation focus was aerobic for PHCs and anaerobic for CVOCs
- Issues identified with incomplete mineralization of CVOCs lead to the development of KB-1® (Dehalococcoides) to prevent "stall" – first used in 2008
- Oxygen sources originally air, O_2, H_2O_2, calcium peroxide, sodium percarbonate,…
- Problems with low persistence of ORC and low solubility of O_2
- Later development of anaerobic bio for PHCs using alternate, more soluble & persistent TEAs

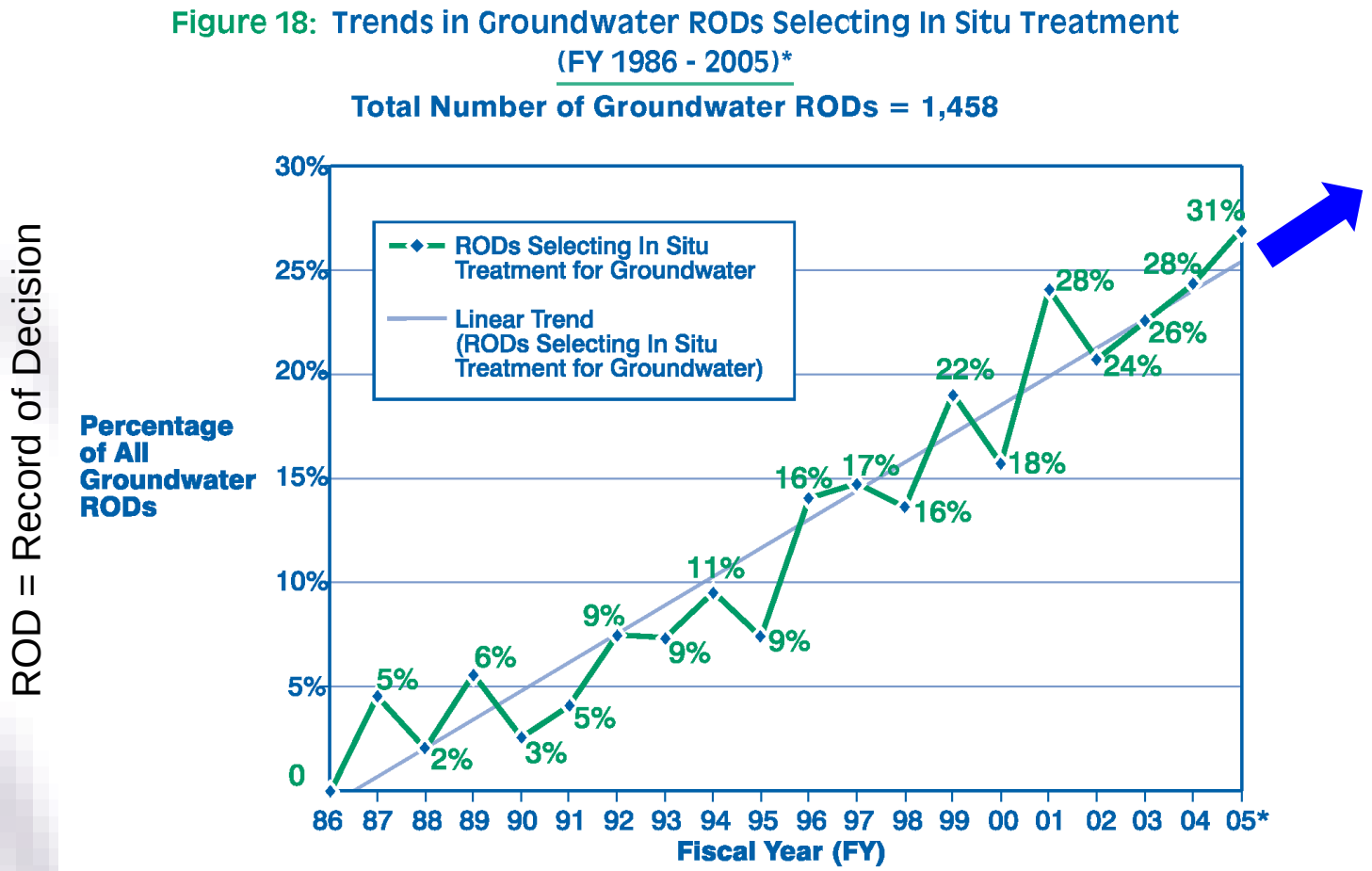
VERTEX

2000s – More Bio



2000s – In-Situ

In-Situ Market Trend



"Treatment Technologies for Site Cleanup: Annual Status Report"
US EPA Document (dated 2007)

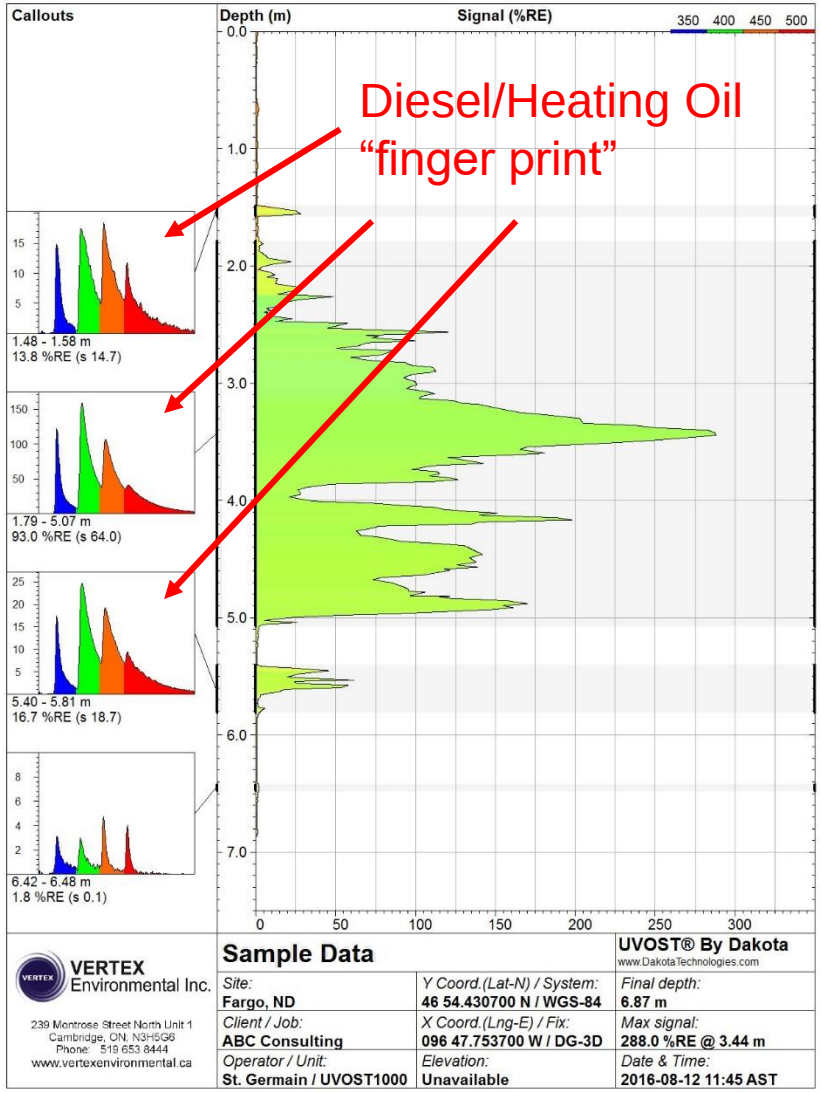
2010s – HRSC, CBIs & B/R

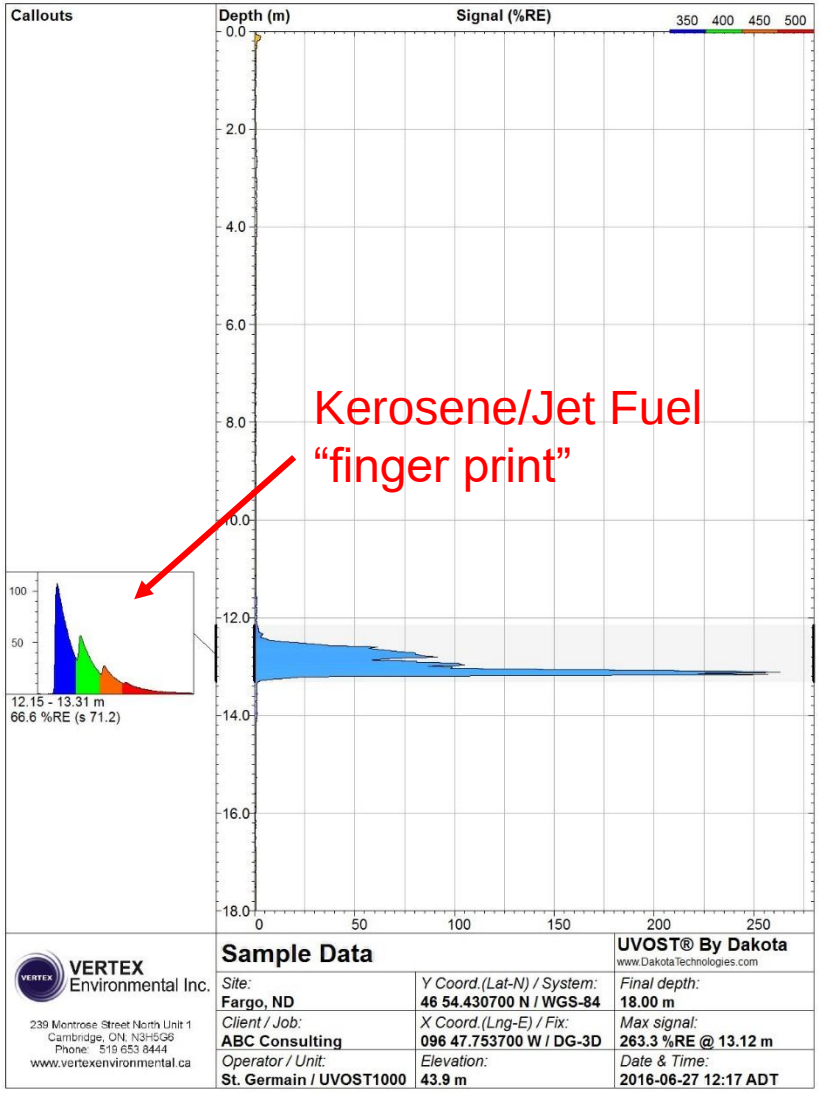
2010s – HRSC

High-Resolution Site Characterization (HRSC):

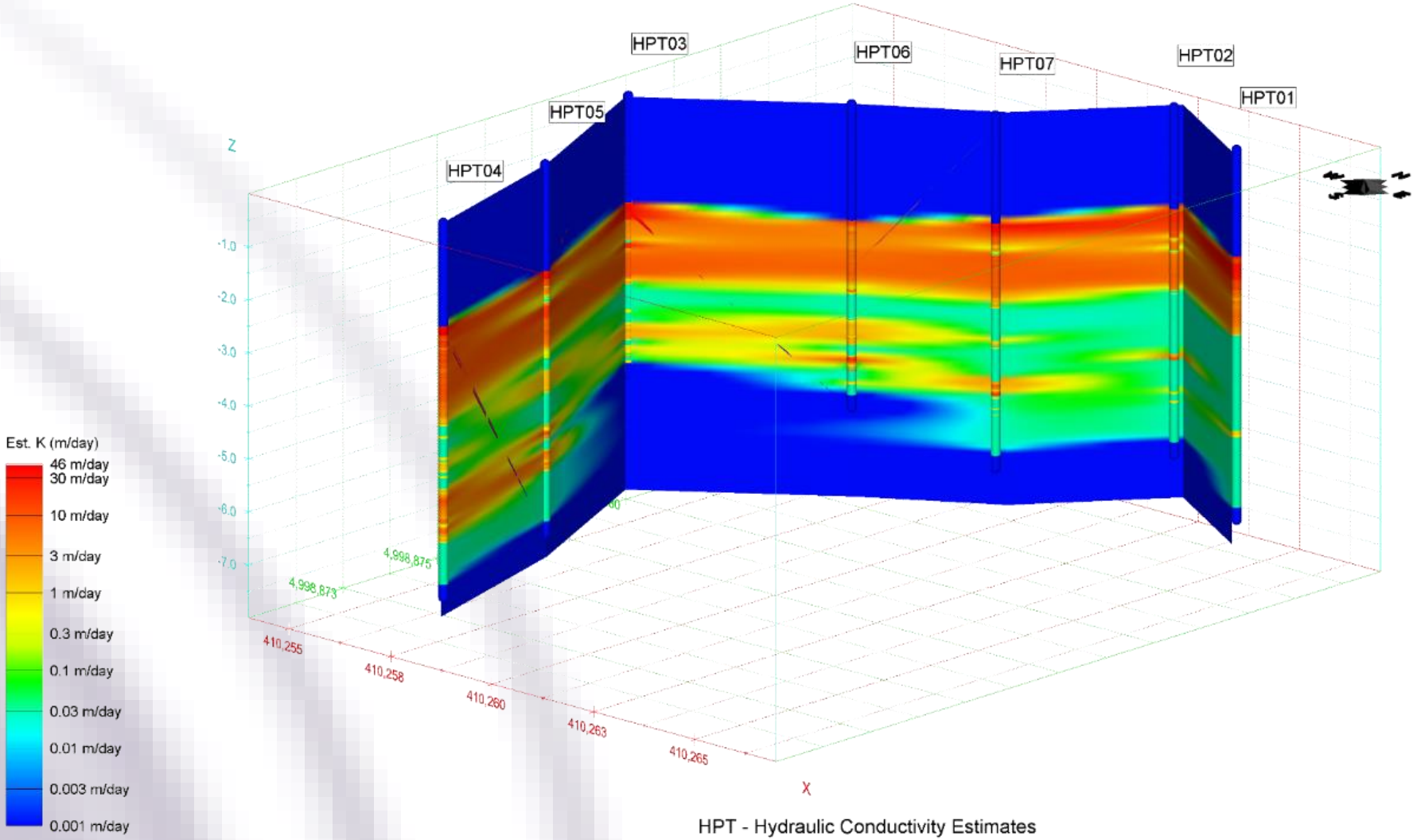
- Environmental consultants and contractors sought to better understand subsurface conditions
- Lead to the development of HRSC tools that could detect:
  - LNAPL – Laser Induced Fluorescence (LIF)
  - VOCs – Membrane Interface Probe (MIP)
  - Permeability – Hydraulic Profiling Tool (HPT)
- The MIP & LIF were first brought into Canada on a permanent basis by Vertex in 2011 – I (sadly?) left consulting in early 2012
- Since then HRSC has been used at 100s of sites across Canada with many 10s of km probed

2010s – HRSC


Callouts
Depth (m)
Signal (%RE)
350 400 450 500
Diesel/Heating Oil
"finger print"
1.48 - 1.58 m
13.8 %RE (s 14.7)
1.79 - 5.07 m
93.0 %RE (s 64.0)
5.40 - 5.81 m
16.7 %RE (s 18.7)
6.42 - 6.48 m
1.8 %RE (s 0.1)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
0 50 100 150 200 250 300
VERTEX Environmental Inc.
239 Montrose Street North Unit 1
Cambridge, ON. N3H5G6
Phone: 519 653 8444
www.vertexenvironmental.ca
Sample Data
UVOST® By Dakota
www.DakotaTechnologies.com
Site: Fargo, ND
Y Coord.(Lat-N) / System: 46 54.430700 N / WGS-84
Final depth: 6.87 m
Client / Job: ABC Consulting
X Coord.(Lng-E) / Fix: 096 47.753700 W / DG-3D
Max signal: 288.0 %RE @ 3.44 m
Operator / Unit: St. Germain / UVOST1000
Elevation: Unavailable
Date & Time: 2016-08-12 11:45 AST

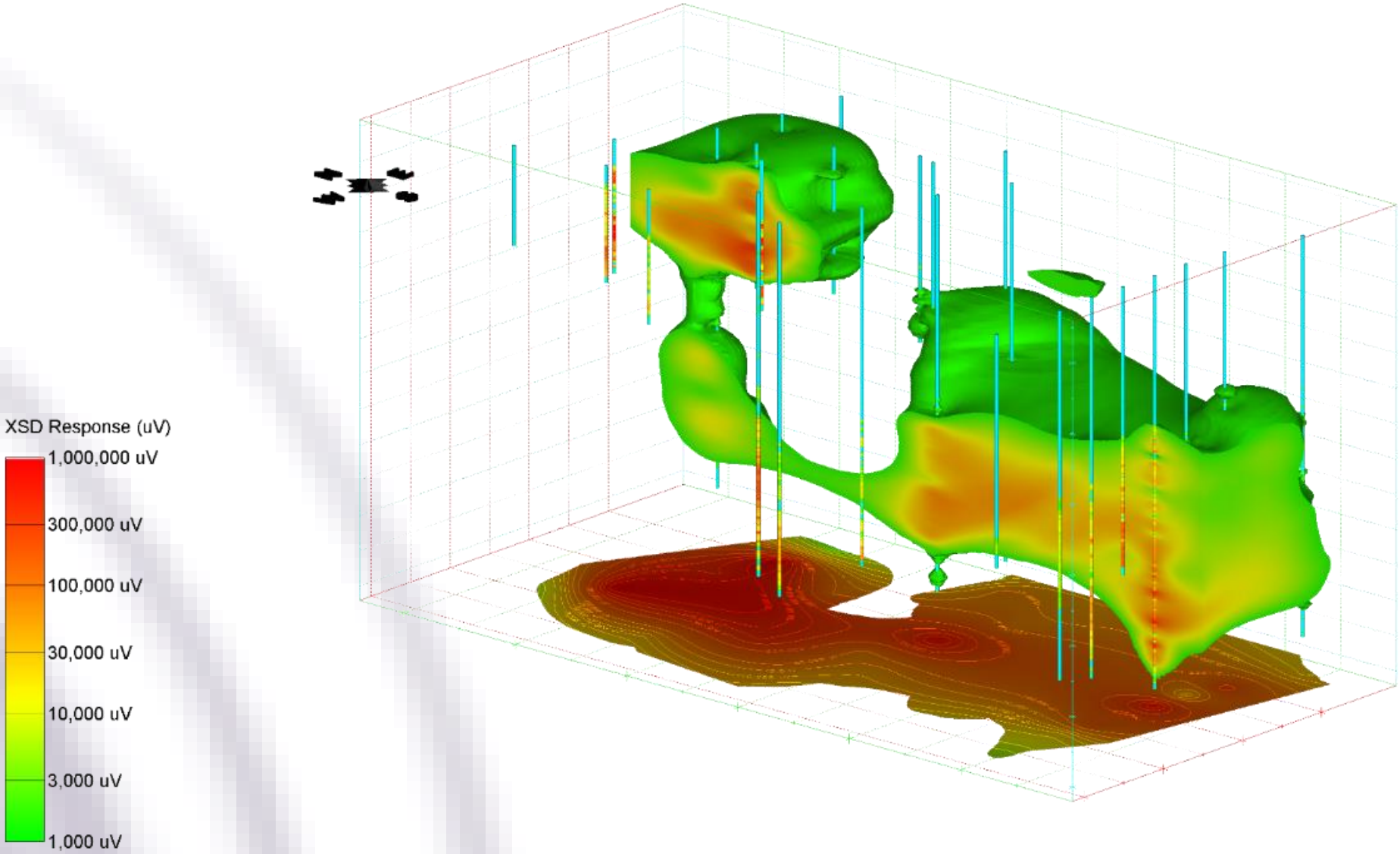

Callouts
Depth (m)
Signal (%RE)
350 400 450 500
Kerosene/Jet Fuel
"finger print"
12.15 - 13.31 m
66.6 %RE (s 71.2)
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
0 50 100 150 200 250
VERTEX Environmental Inc.
239 Montrose Street North Unit 1
Cambridge, ON. N3H5G6
Phone: 519 653 8444
www.vertexenvironmental.ca
Sample Data
UVOST® By Dakota
www.DakotaTechnologies.com
Site: Fargo, ND
Y Coord.(Lat-N) / System: 46 54.430700 N / WGS-84
Final depth: 18.00 m
Client / Job: ABC Consulting
X Coord.(Lng-E) / Fix: 096 47.753700 W / DG-3D
Max signal: 263.3 %RE @ 13.12 m
Operator / Unit: St. Germain / UVOST1000
Elevation: 43.9 m
Date & Time: 2016-06-27 12:17 ADT

2010s – HRSC

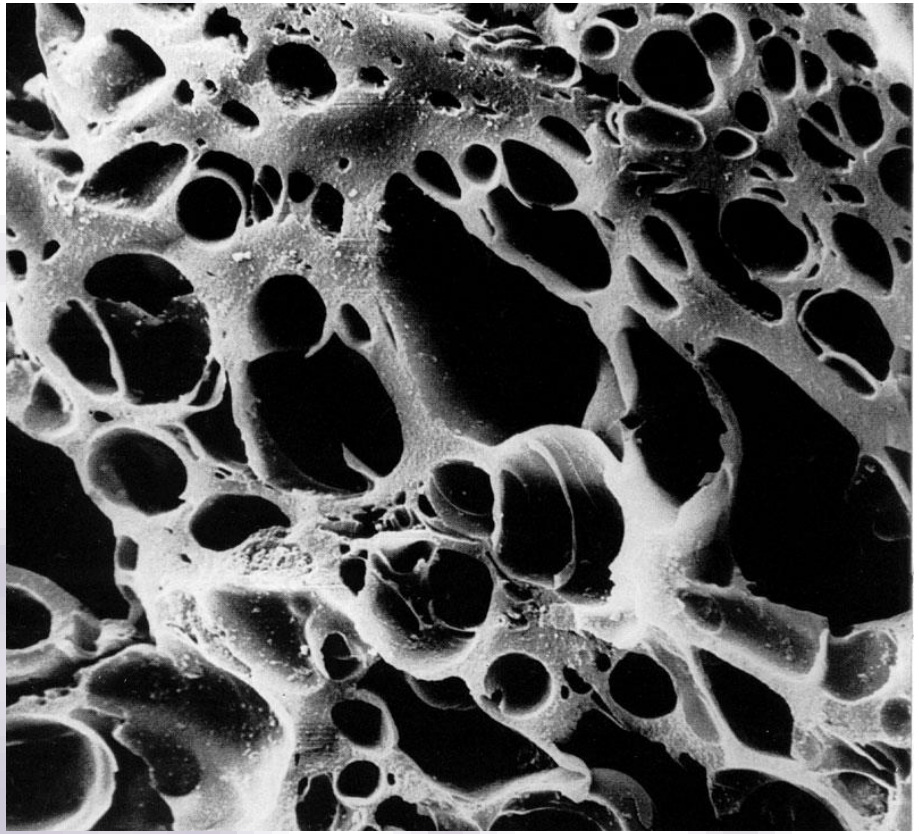


HPT - Hydraulic Conductivity Estimates

2010s – HRSC


XSD Response (uV)
1,000,000 uV
300,000 uV
100,000 uV
30,000 uV
10,000 uV
3,000 uV
1,000 uV

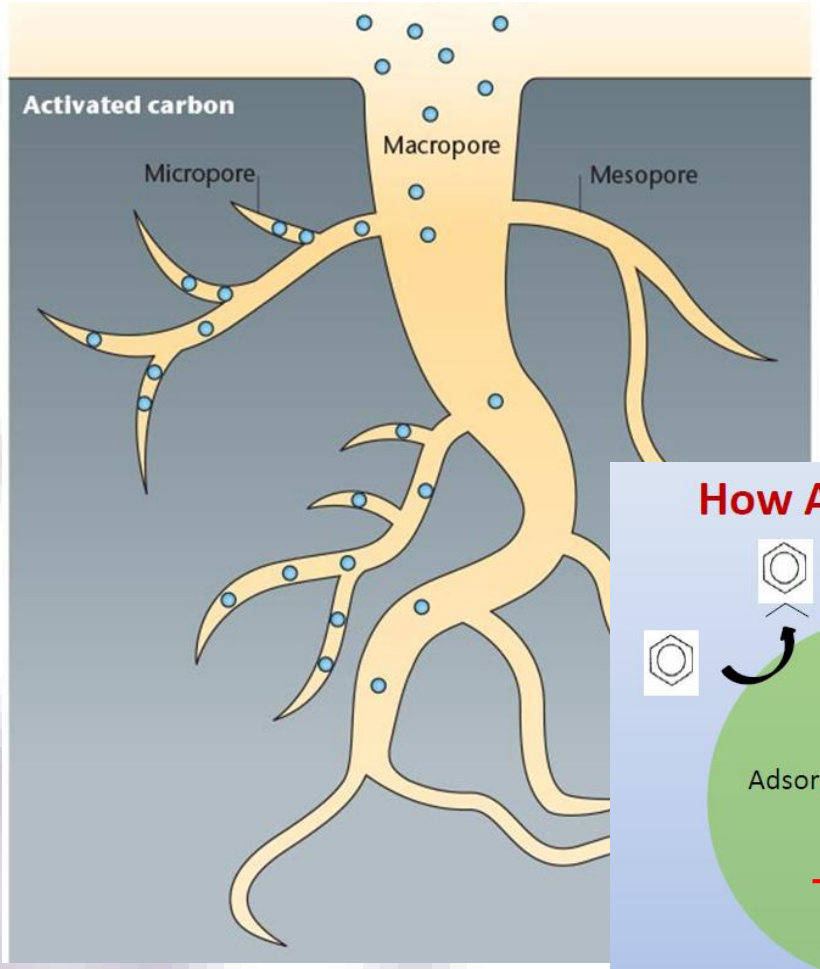
2010s – CBIs



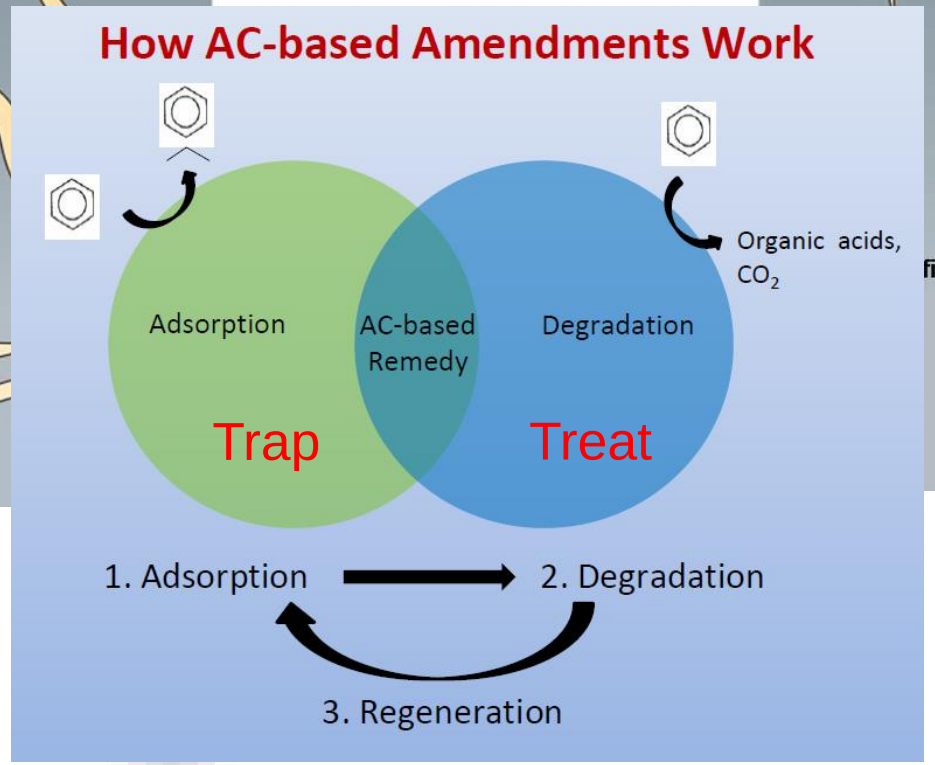
Carbon-Based Injectables (CBIs):

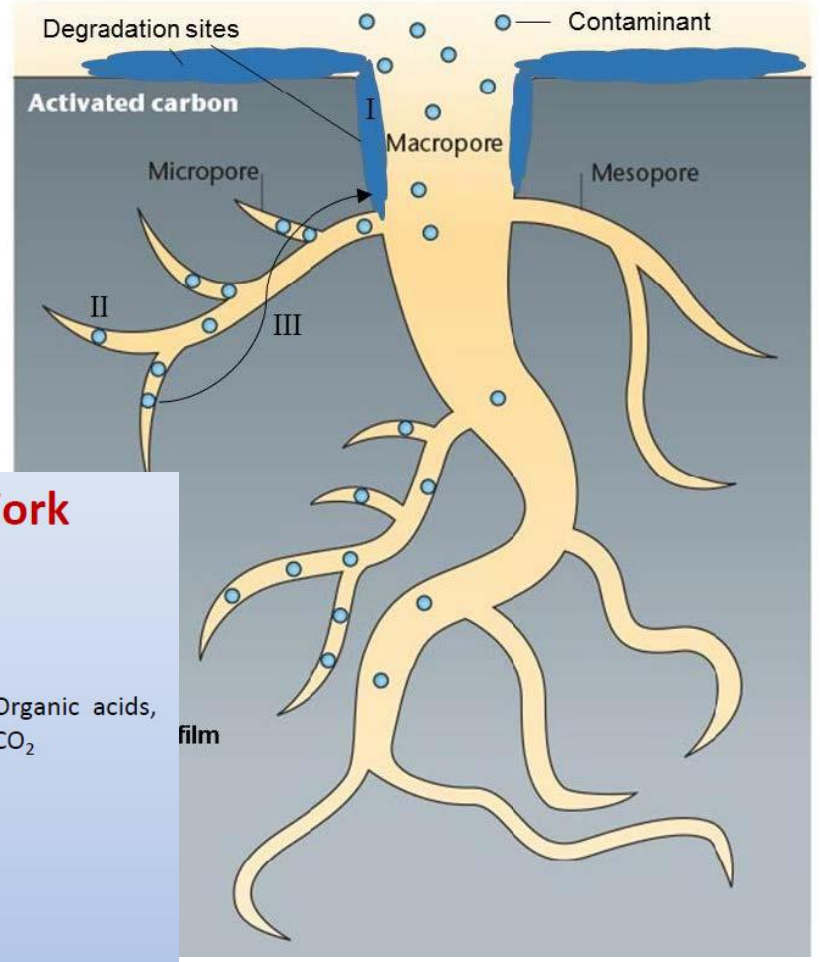
- CBIs entered Canada in 2015 (since ~2003 in US)
- First were Trap & Treat® BOS 100® and BOS 200® and PlumeStop™
- First injection job of CBIs completed by Vertex was early 2015
- Hundreds of successful CBI remediation projects completed since then
- Allowed the creation of truly passive PRBs for PHCs – a breakthrough!
- Many new versions of CBIs available now
- **This has been the biggest revolution in in-situ remediation in many years – a game changer!**

2010s – CBIs



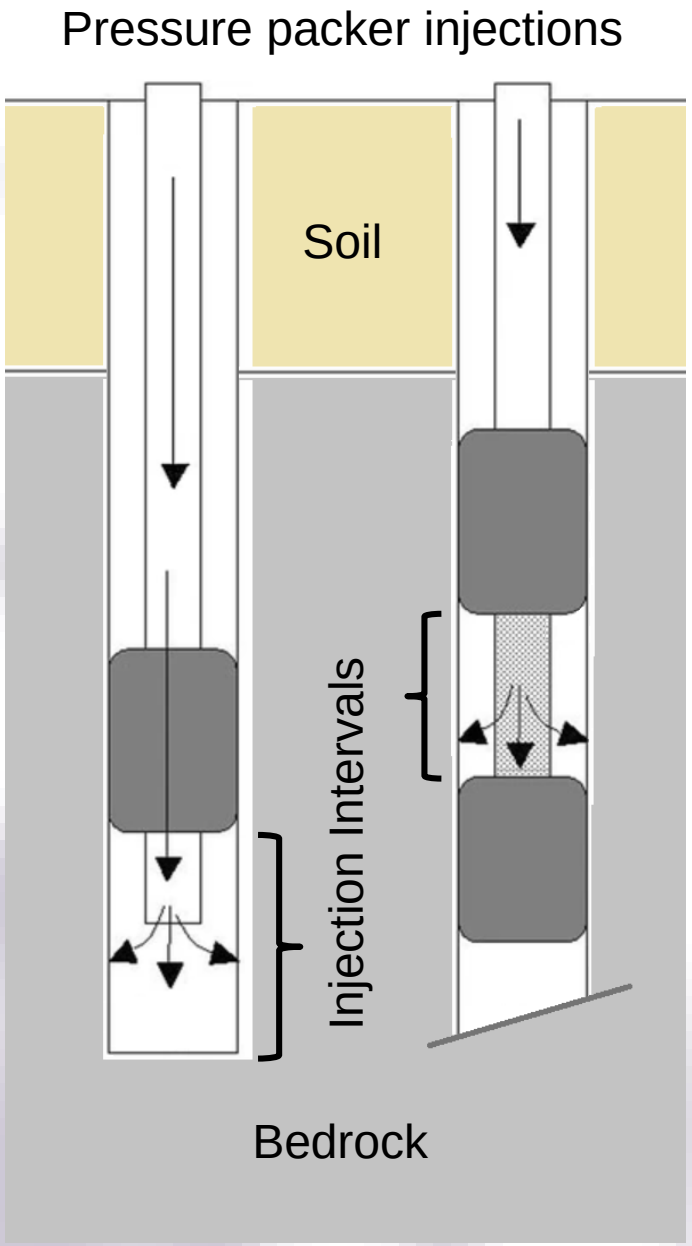
Trap





Treat

2010s – B/R



Better Bedrock Remediation:

- Advanced in-situ understandings and technologies increasingly applied to bedrock plumes
- Early attempts at bedrock remediation using systems (P&T), ISCO, etc. met with limited success due to lack of persistence and “rebound”
- Phenomenon is now better understood and addressed using more persistent (particulate) amendments: ZVI and CBIs
- Adoption of high pressure (packer) injection technologies from oil and gas industry
- Better, practical understanding of bedrock fracture networks and contaminant flow

2020s & Beyond – What's Next?

2020s & Beyond – What's Next?

Near Future Advances:

- Continued improvement and adoption of CBI-based remediations
- Societal importance – sustainability:
  - Soil as a resource; not a waste
  - Increase in on-site treatment and reuse
- Broader acceptance of In-Situ Stabilization (ISS) for LNAPL to facilitate RAs

More Distant Future Advances:

- Permanent destruction technologies for PFAS (not just sequestration) will be a high priority
- Remediation technologies for soil sterilants – ISCO, ISCR &/or Anerobic Biodegradation
- Who knows?

2020s & Beyond – What's Next?

Remaining Challenges:

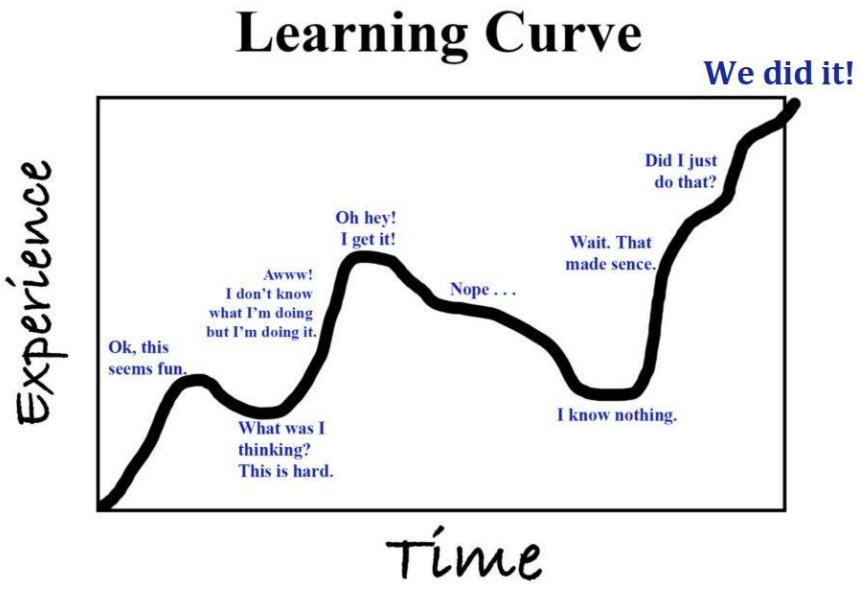
- Old organic contaminants highly sorbed in tight clay formations – 100% diffusion controlled
- Very high concentrations of non-volatile organic COCs in soil, especially above the water table, that can't be excavated
- Bulk heavy metals in soil, especially in near surface fill
- >>99.9% reductions of concentrations via in-situ
- **Industry awareness in terms of the capabilities of non-D&D remediation!**

Observations

Observations

Overall Trends in Environmental Remediation Approaches:

- “Do Nothing” / Monitored Natural Attenuation
- Excavation and Off-Site Disposal
- Systems Technologies & Phase Separation
- Soil Screening & Washing
- Chemical Oxidation
- Chemical Reduction
- Enhanced Aerobic Bioremediation
- Enhanced Anaerobic Biodegradation
- Enhanced Delivery & Recovery
- In-Situ Stabilization
- Carbon Adsorption-Based
- Permeable Reactive Barriers
- Sub-Slab Depressurization / Vapour Barriers
- Risk Assessment / Risk Management
- Many more less common as well



Observations

Overall:

- Science, engineering and technology will advance and evolve when faced with a challenge
- <u>We've come a long way since the 1970s (and we can be proud of that!):</u>
  - Dilute groundwater plumes now relatively easy to treat – even to low level ppb standards
  - Risk management and sustainability are now major driving factors
- <u>But some things never change:</u>
  - Some times D&D is still the best approach
  - Environmental professionals will never be out of work – sad but true!
- **Still many new challenges to tackle!**

Questions?

Thank You for Your Time!

Kevin French, B.A.Sc., P.Eng.
Vertex Environmental Inc.
(519) 404-5442
kevinf@vertexenvironmental.ca
www.vertexenvironmental.ca

VERTEX