Evolution of the Contaminated Site Remediation Industry in Canada

Kevin French
Vertex Environmental Inc.

SMART Remediation
Toronto, ON | March 31, 2022

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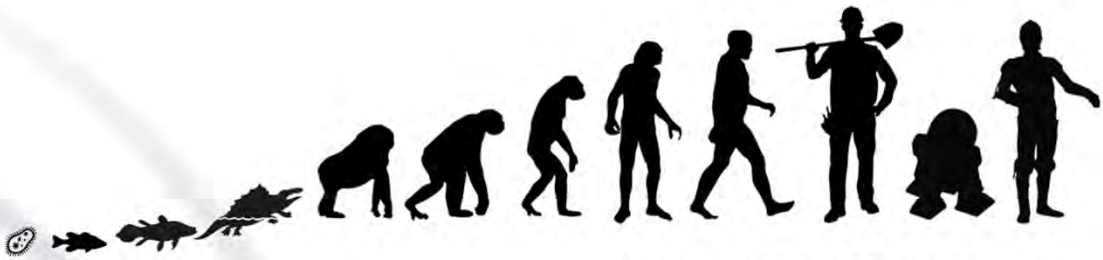
Presentation Overview



- 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

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Introduction

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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

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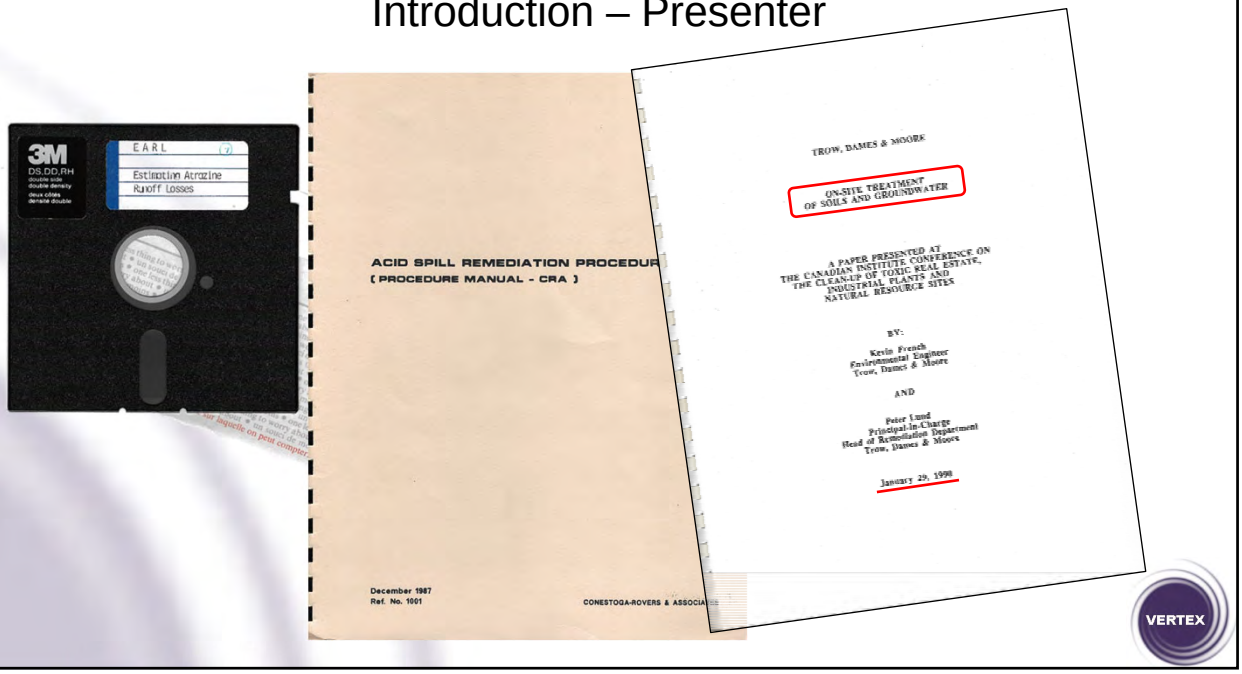
Introduction – Presenter



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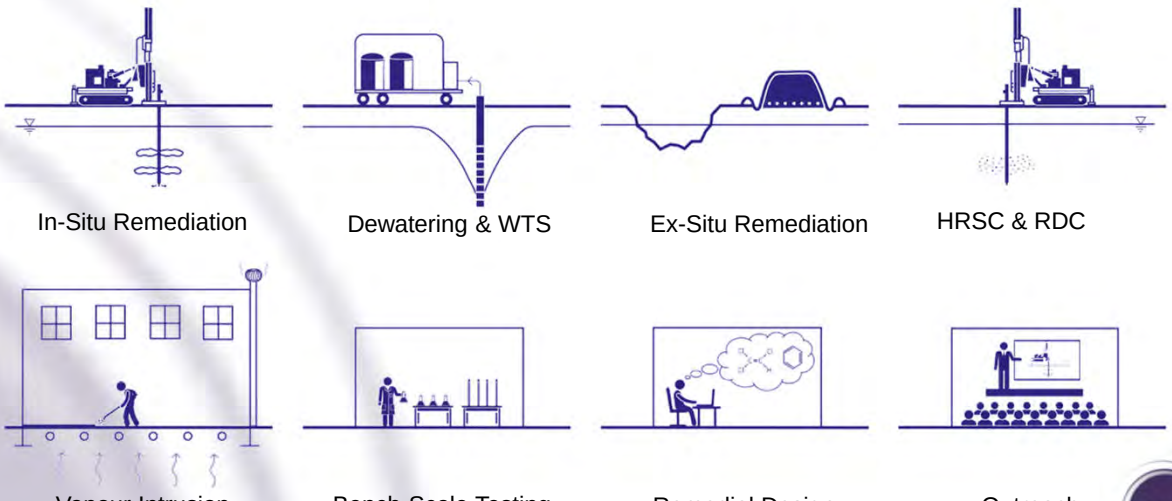
Vertex Environmental Inc.



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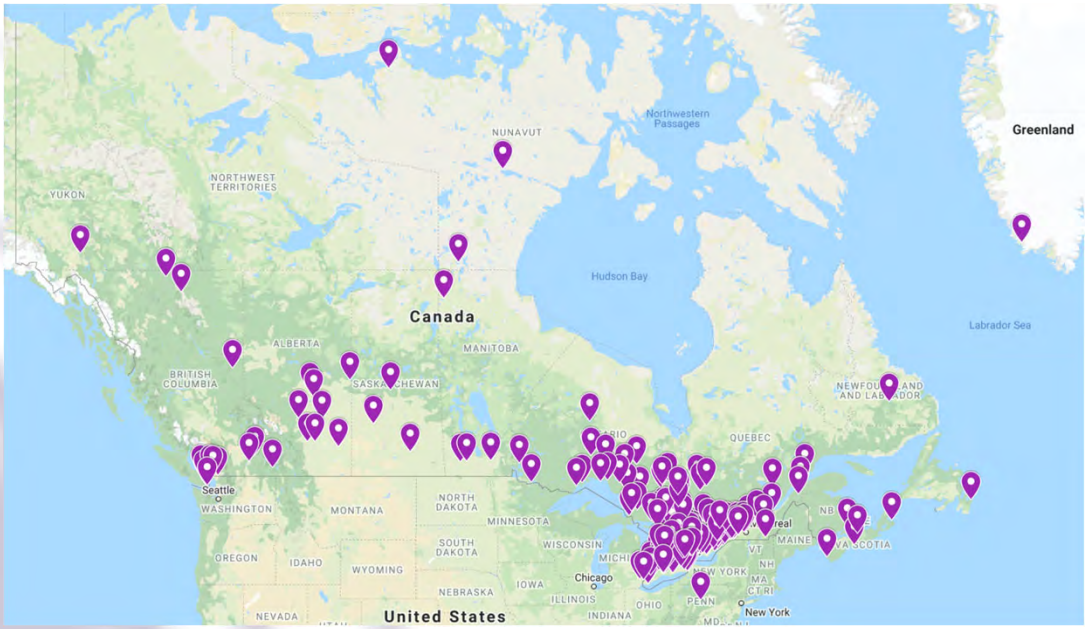
Vertex Environmental Inc.



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Environmental Awareness

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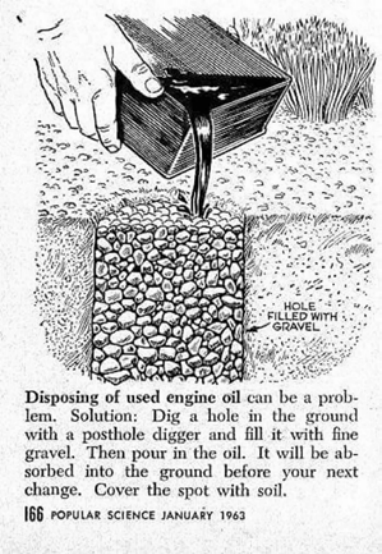
Environmental Awareness



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

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Environmental Awareness

Love Canal, Niagara Falls, NY

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Environmental Awareness

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

Tar Ponds, Sydney, NS

Uniroyal Chemical, Elmira, ON

Giant Mine, Yellowknife, NWT

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Environmental Regulation

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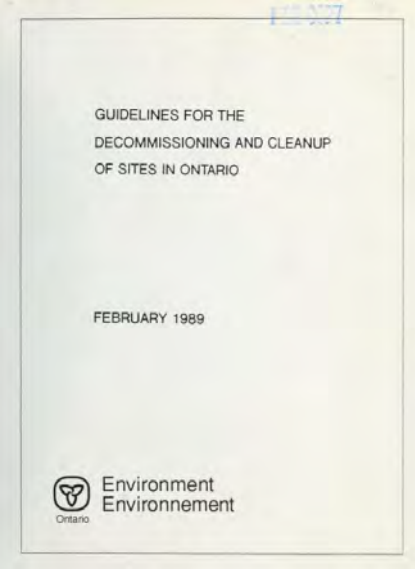
Regulation



History of Canadian Environmental Regulation:

- 1968: Fisheries Act: “deleterious substance”
- 1971: Environment Canada founded
- 1972: Ontario Ministry of Environment formed
- 1989: CCME Guidelines for PCB Waste Management
- 1989: Guidelines for the Decommissioning and Clean-up of Sites (Ontario)
- 1994/1996: Guidelines for Use at Contaminated Sites in Ontario (introduction of Risk Assessments)
- 2004/2011: O.Reg. 153/04 Records of Site Condition
- 2019: O.Reg. 406/19 On-Site and Excess Soil Management (soil as a resource = sustainability)
- 2021: CCME standards for PFOS in soil and groundwater
- Future: Other PFAS, emerging contaminants?

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1970s & 1980s – D&D & P&T

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1970s & 1980s – D&D

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

- Only solution for dealing with soil contamination regardless of contaminant – dig until "clean" line reached
- 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 ($$)

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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)

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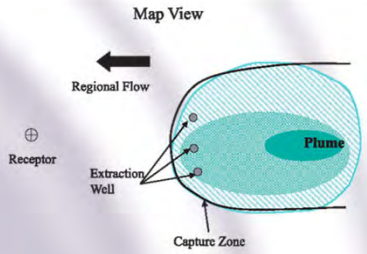
1970s & 1980s – P&T



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

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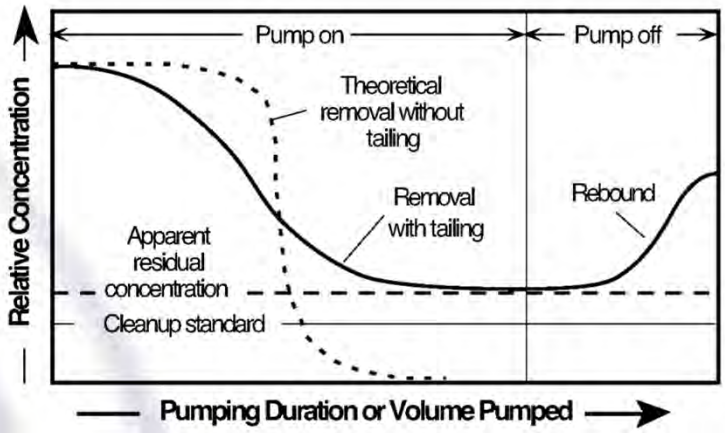
1970s & 1980s – P&T



Above or below standard??

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

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1990s – Biopiles, PRBs & RAs

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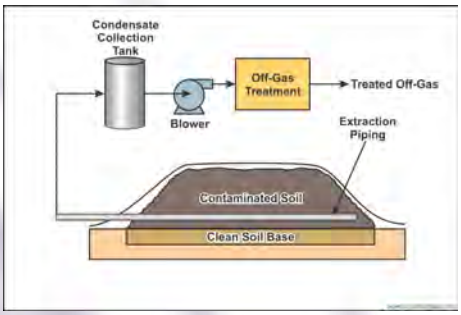
1990s – Biopiles



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

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1990s – Biopiles

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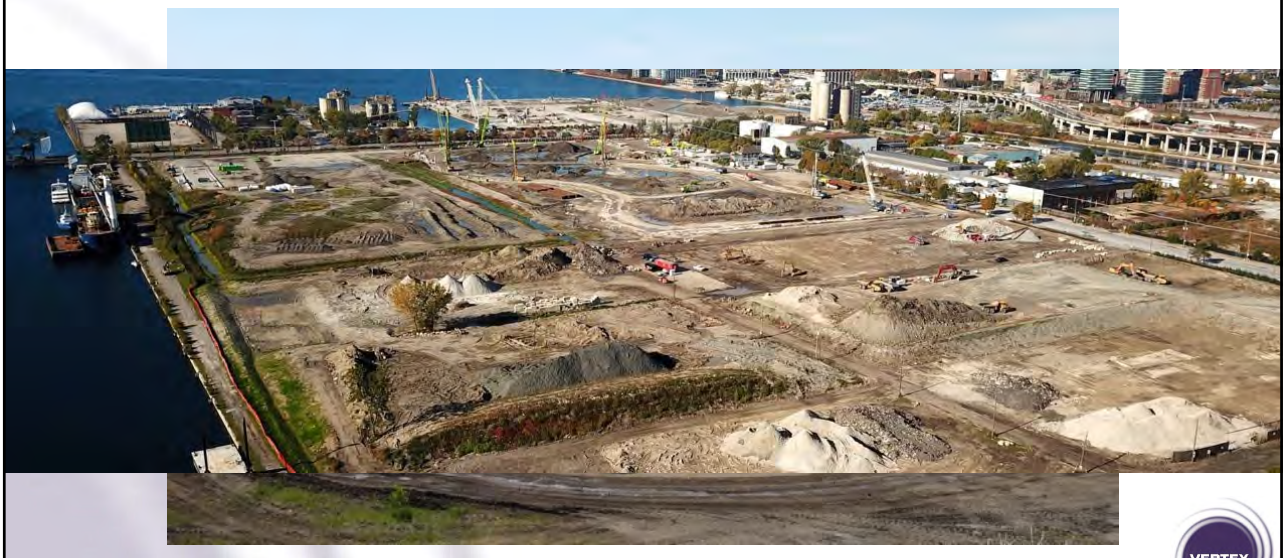
1990s – Biopiles



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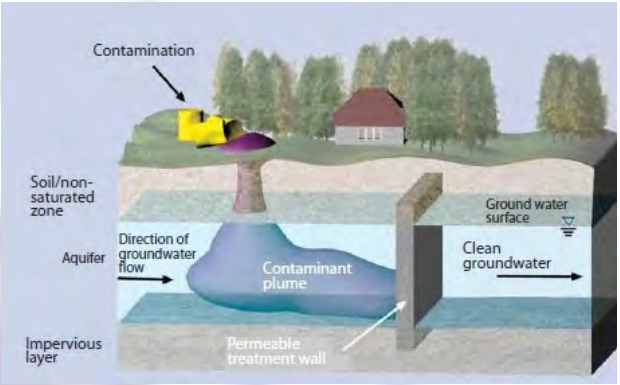
1990s – PRBs



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)

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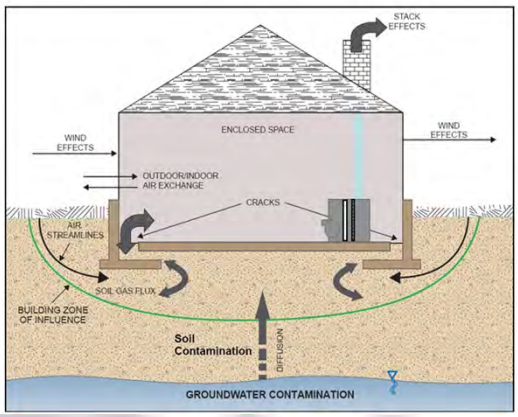
1990s – RAs



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 ON in 1996
- RAs accepted in most jurisdictions, including Quebec (with the notable exception of PHCs)

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2000s – ISCO, ISCR & Bio

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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

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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!)

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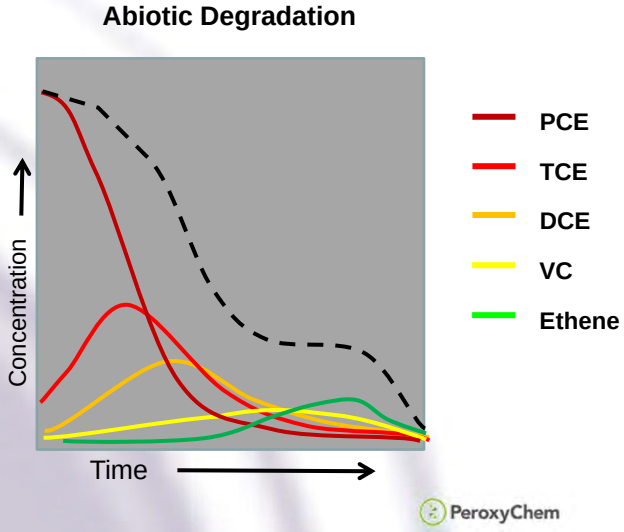
2000s – ISCR



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.)

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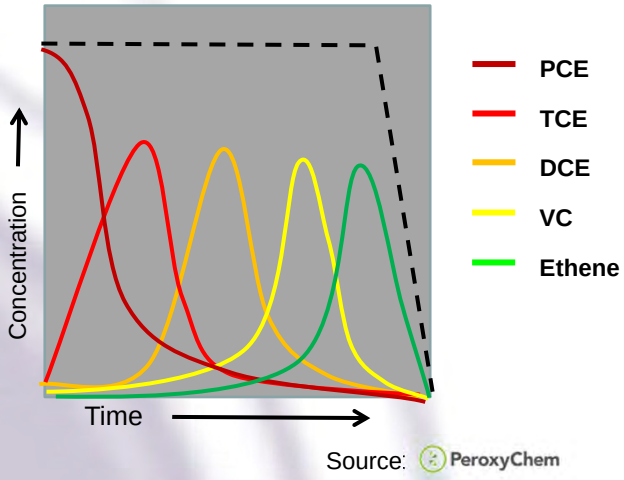
2000s – More Bio

Biological Degradation (Reductive Dechlorination)



Source: PeroxyChem

<u>In-Situ</u> Biodegradation (Aerobic and Anaerobic):

- <u>Initial biodegradation focus was aerobic for PHCs and anaerobic for CVOCs</u>
- Issues identified with incomplete mineralization of CVOCs lead to the development of <u>KB-1® (Dehalococcoides)</u> 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

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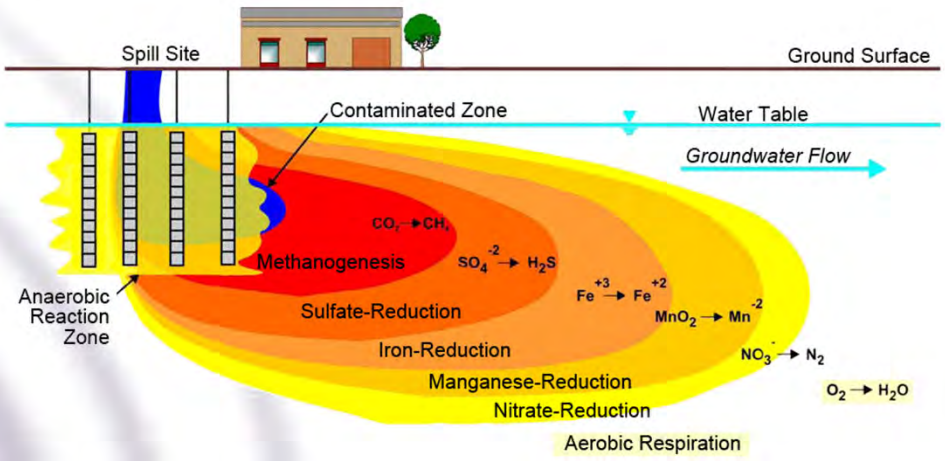
2000s – More Bio



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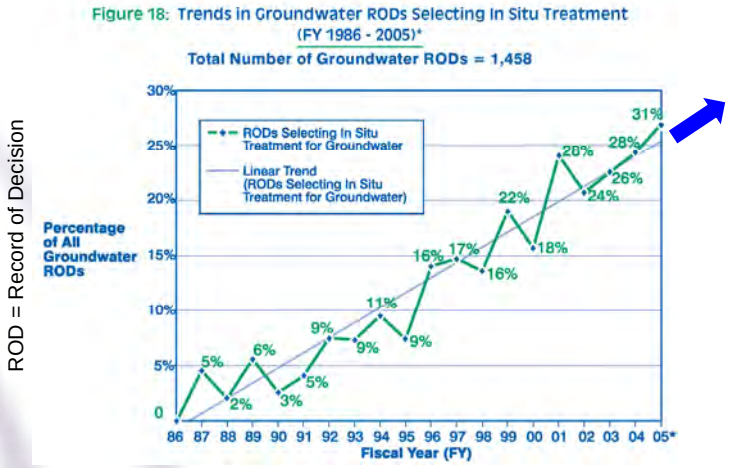
2000s – In-Situ

In-Situ Market Trend



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

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2010s – HRSC, CBIs & B/R

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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

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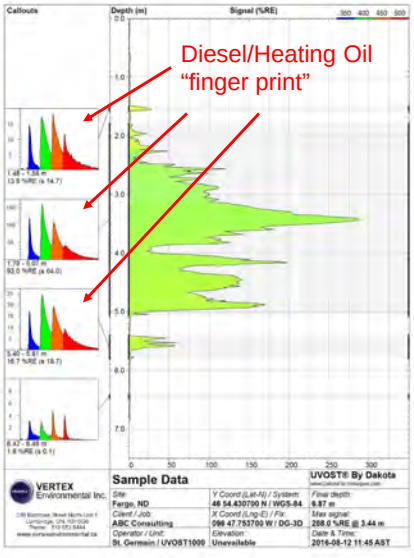
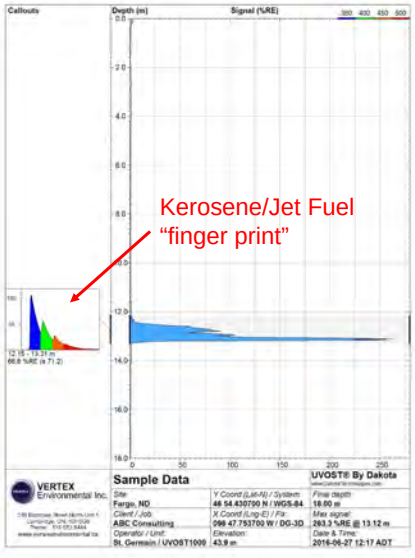
2010s – HRSC





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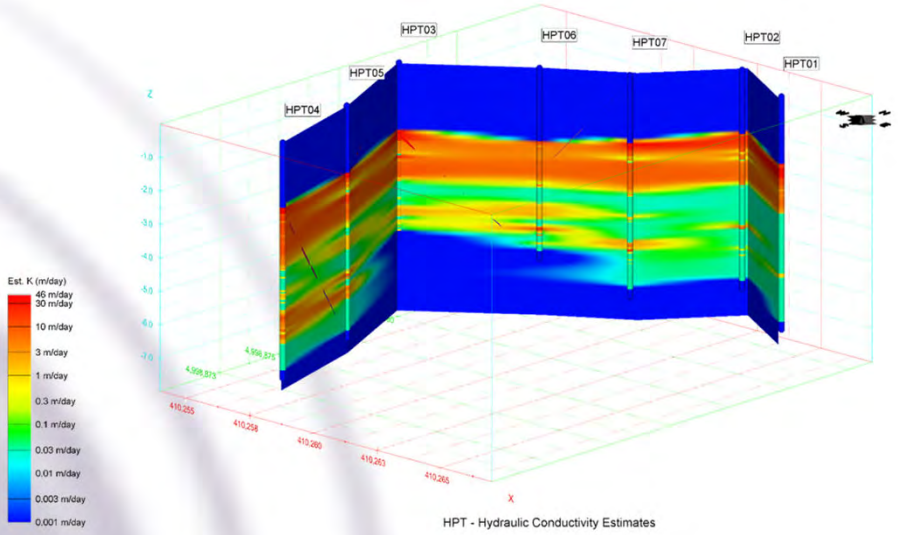
2010s – HRSC



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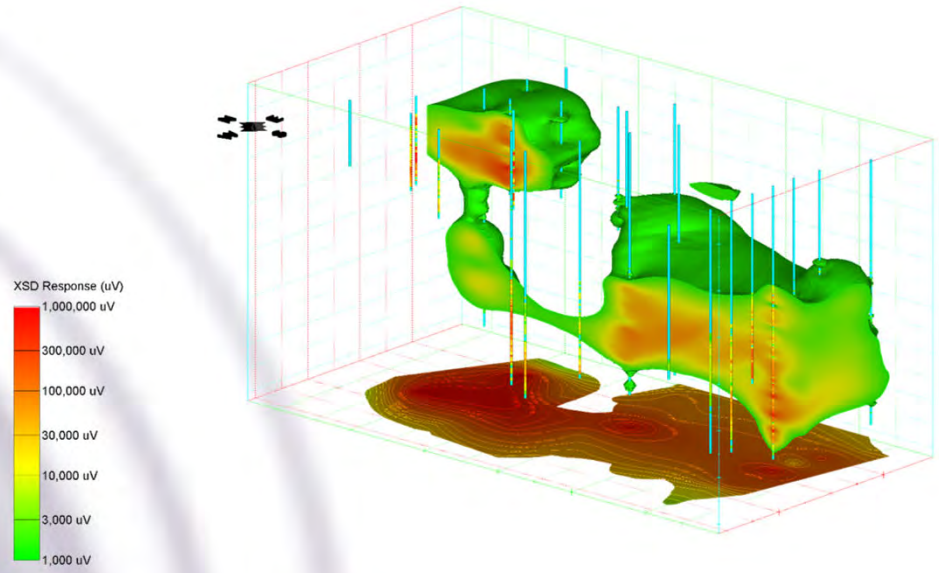
2010s – HRSC



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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!**

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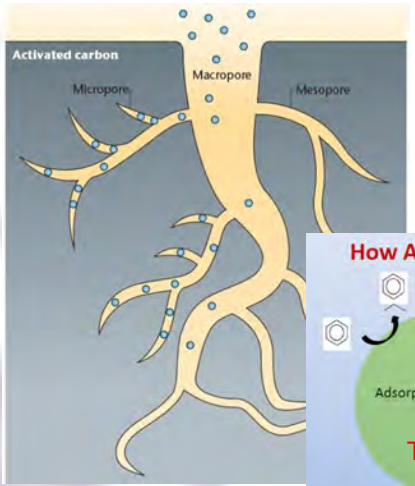
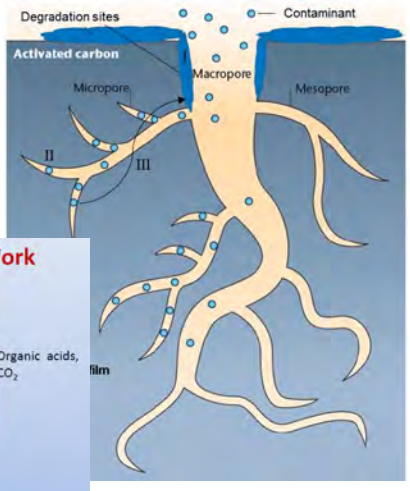
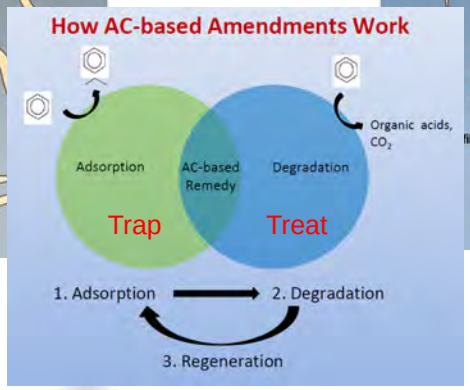
2010s – CBIs



Trap



Treat



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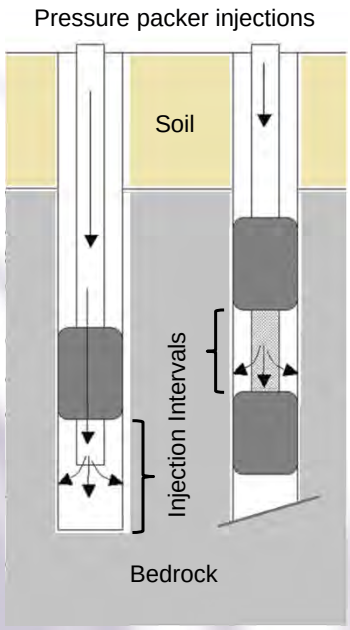

2010s – B/R

<u>Better</u> 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
- <u>Better, practical understanding of bedrock fracture networks and contaminant flow</u>

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2020s & Beyond – What's Next?

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2020s & Beyond – What's Next?

Near Future Advances:

- Continued improvement and adoption of CBI-based remediations (e.g. CAT 100)
- 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?

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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!**

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Observations

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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

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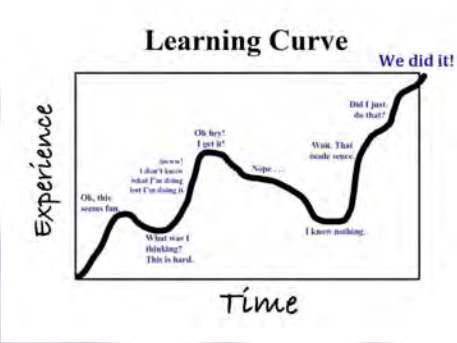

Observations

Overall:

- Science, engineering and technology will advance and evolve when faced with a challenge
- We've come a long way since the 1970s (and we can be proud of that!):
  - Dilute groundwater plumes now relatively easy to treat – even to low level ppb standards
  - Risk management and sustainability are now major driving factors
- But some things never change:
  - 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!**

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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

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