A TECHNOLOGY PLATFORM TO HARNESS SPEED AND CERTAINTY IN GROUNDWATER REMEDIATION

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And

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REGENESIS®

Technology-Based Solutions for the Environment

ROAD MAP

- Combined Remedies Approach
- New Technology
  - What it is
  - Key Features
  - How it works
- Case Studies
  - Proof of Concept Site
  - Large Commercial Site

Combined Remedies: Core Thesis

"All remediation technologies have strengths and weaknesses.
These are different from one technology to another.

Employing technologies in suitable combination can enable strengths to be combined and weakness overcome.

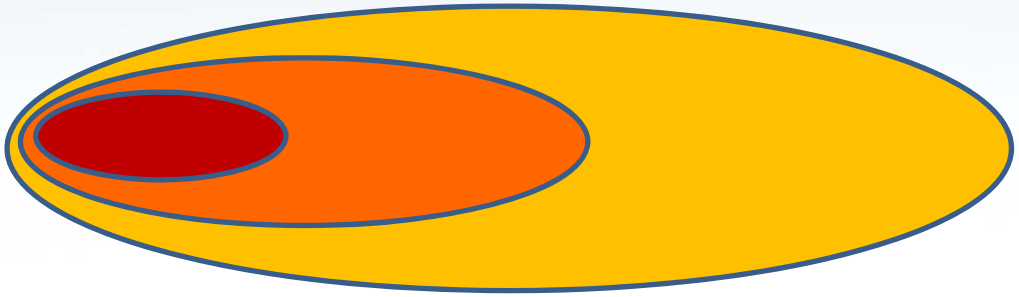
This in turn can increase efficiency, improve performance, and thereby save time, money and resources."

Combined Remedies Initiative (2014)
- **USEPA, NGWA, Industry & Academia**

EARLY COMBINED REMEDIES

- Physical Removal = Excavation
  - Large mass reduction
- ORC-Advanced = Bioremediation
  - Treat residual mass

Why Use Combined Remedies?



Source Area:
Dig & Haul
Thermal
Pump & Treat
AS/SVE
ISCO
Stabilization

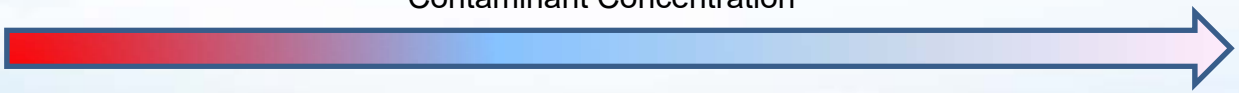
→

Core Plume Area:
ISCO
Bioremediation
Pump & Treat

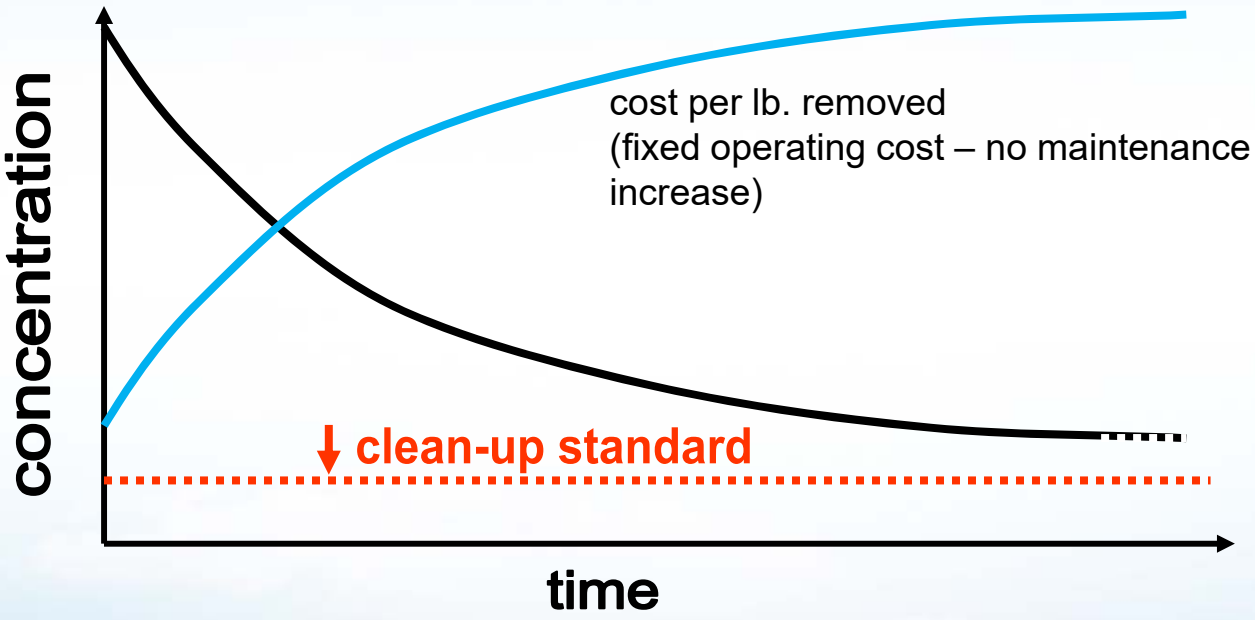
→

Dissolved Plume Area:
Bioremediation
Natural Attenuation
ISCO
Pump and Treat?

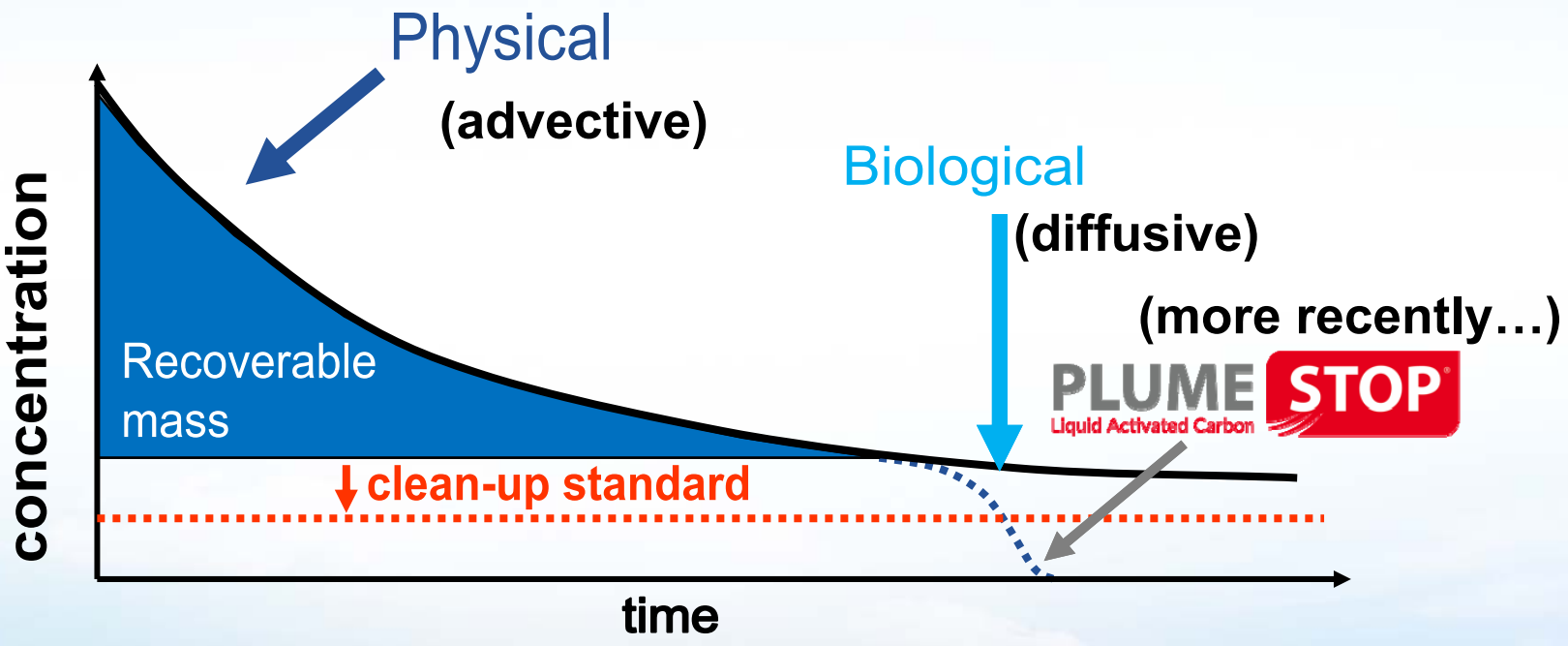
Contaminant Concentration



EXTRACTIVE REMEDIATION (P&T): ASYMPTOTE

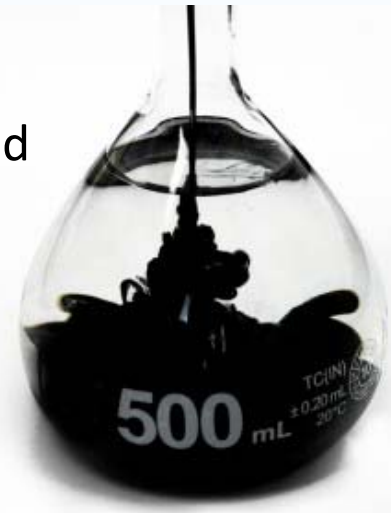


Combined Remedy: Sequential



PLUME STOP
Liquid Activated Carbon

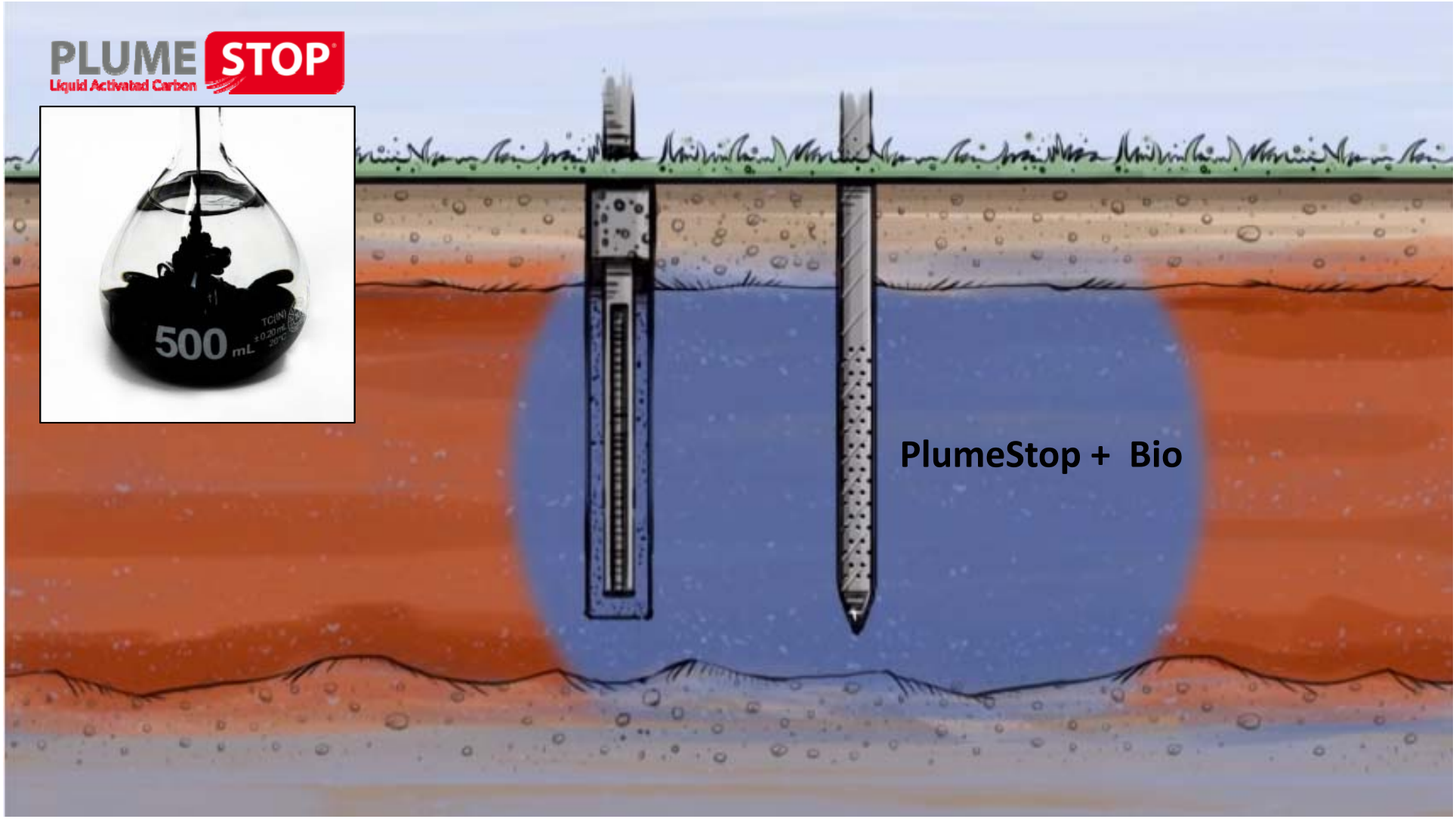
- Colloidal remediation agent
  - Polymer/sorbent/additives
  - 1-2 micron activated carbon colloid
  - Non-toxic, black “ink”
- Distributes widely in subsurface
- Sorbs contaminants rapidly
- Accelerates biodegradation

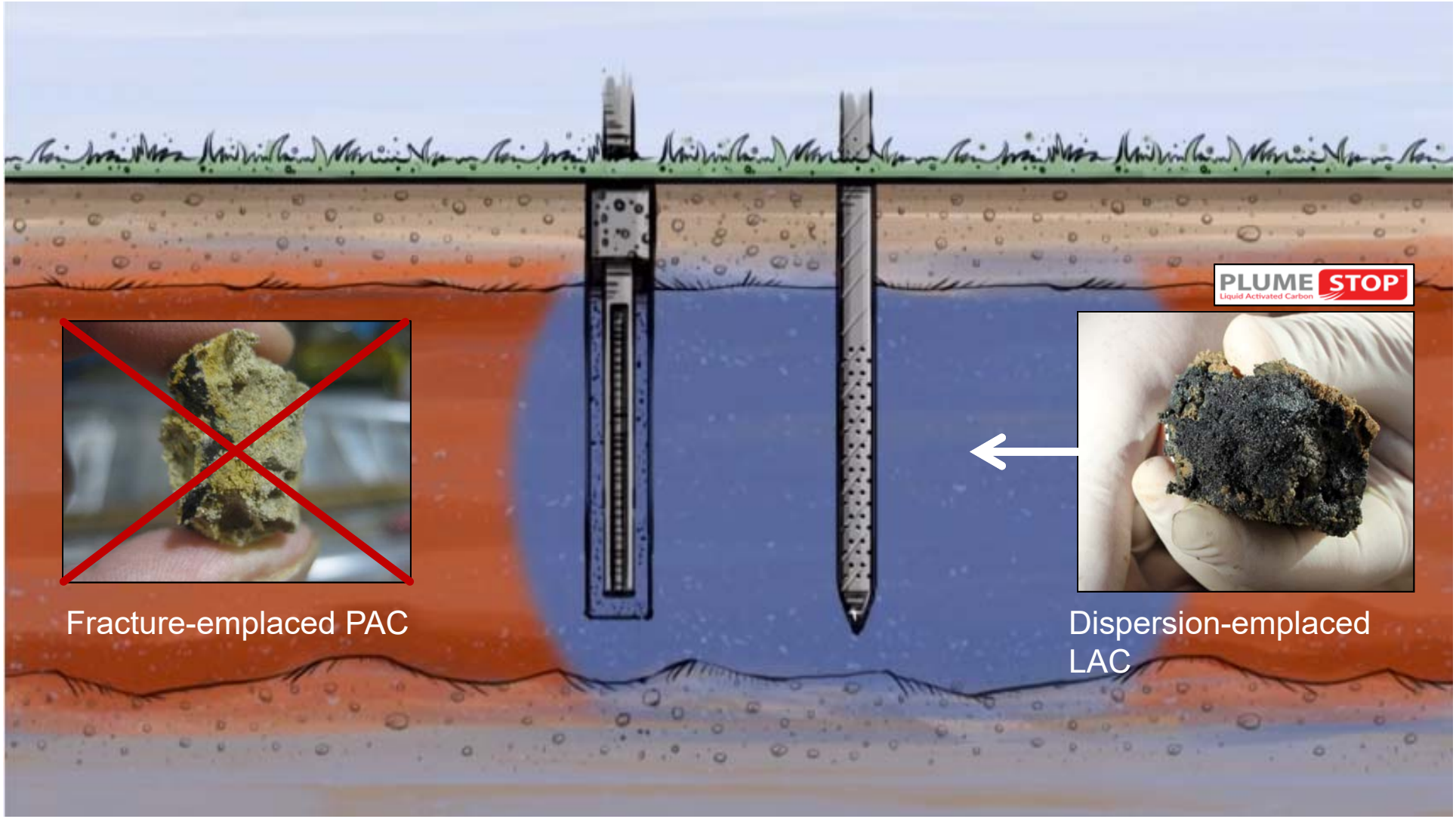


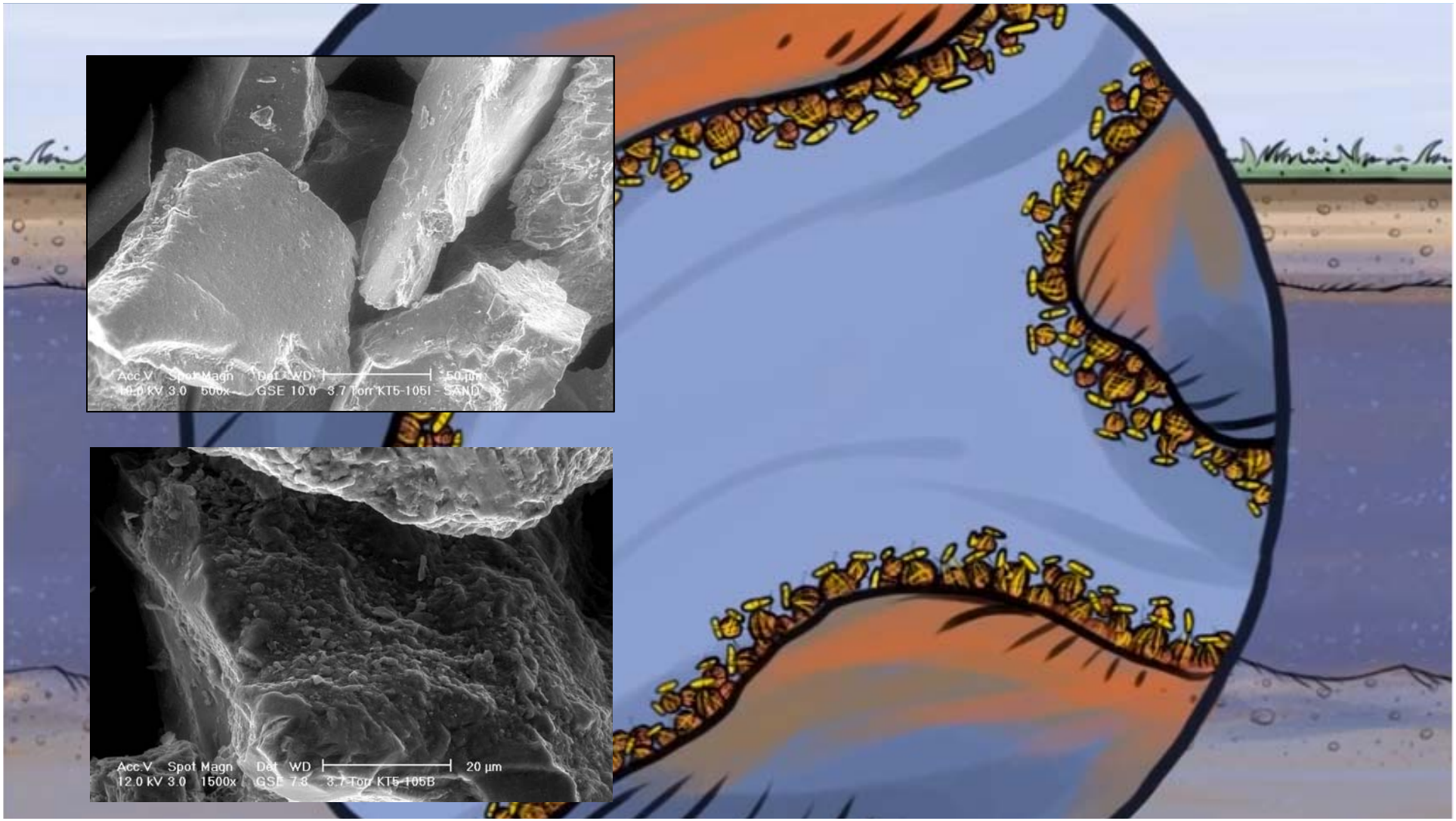
So What is It?

Principal technology features

- **Rapid reduction of groundwater concentrations**
  - Multiple order of magnitude concentration reductions in days / weeks
- **Acceleration of contaminant biodegradation**
  - Elimination of low-concentration performance tailing
  - Ability to secure stringent clean-up targets
- **Wide subsurface dispersion**
  - Efficient fieldwork
  - Ability to address areas of restricted access, deep plumes etc.
- **Long-term efficacy**
  - The reagent is not consumed – it regenerates *in situ*


PLUME STOP
Liquid Activated Carbon
500 mL
PlumeStop + Bio

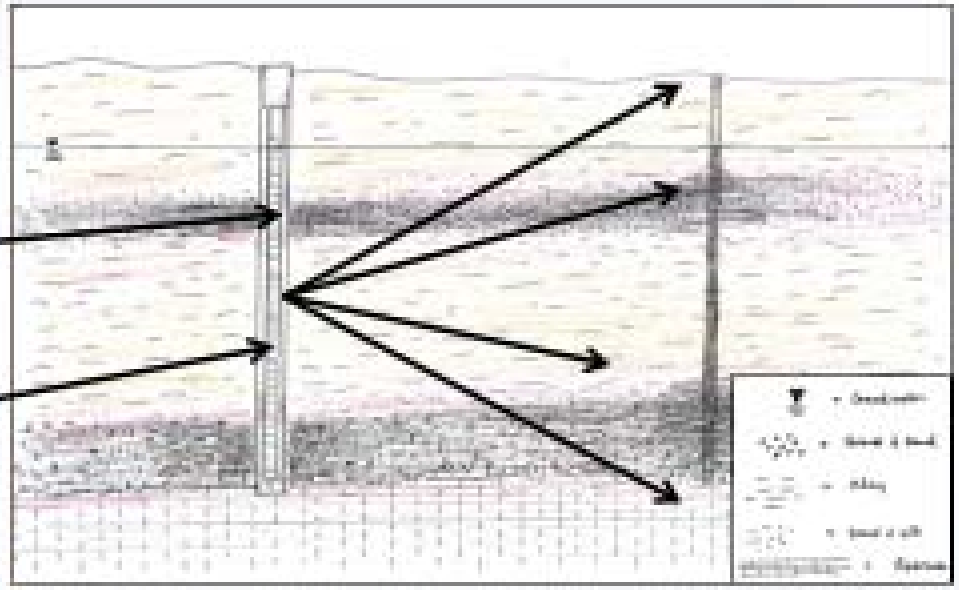

PLUME STOP
Liquid Activated Carbon
Fracture-emplaced PAC
Dispersion-emplaced LAC


Acc.V Spot Magn Det WD 50 µm
10.0 kV 3.0 500x GSE 10.0 3.7 Torr KT5-105I - SAND
Acc.V Spot Magn Det WD 20 µm
12.0 kV 3.0 1500x GSE 7.8 3.7 Torr KT5-105B

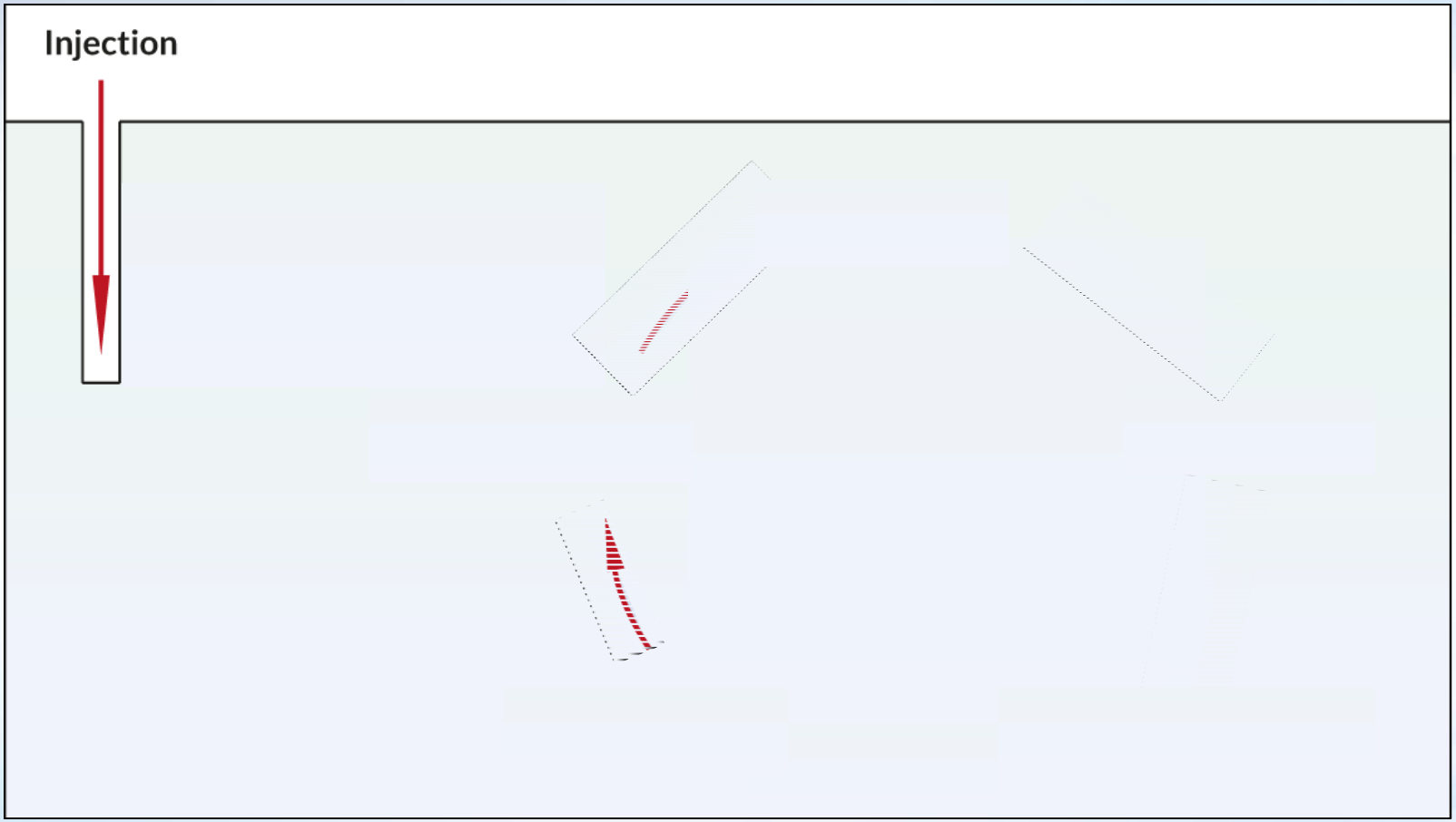
PlumeStop® Liquid Activated Carbon™ Injection

Contaminant mass back-diffusing from the low-perm zones is captured ∴ Low & high perm zones are addressed

PlumeStop® flows like water but leaves a coating ∴ Distance / radius progressed depends on volume injected



Field application ∴ all about ensuring placement in flow-zones


Injection

PLUME STOP®
Liquid Activated Carbon

- Early Proof of Concept Site-

PLUME STOP
Liquid Activated Carbon

Example in Use
- Mixed Solvents -

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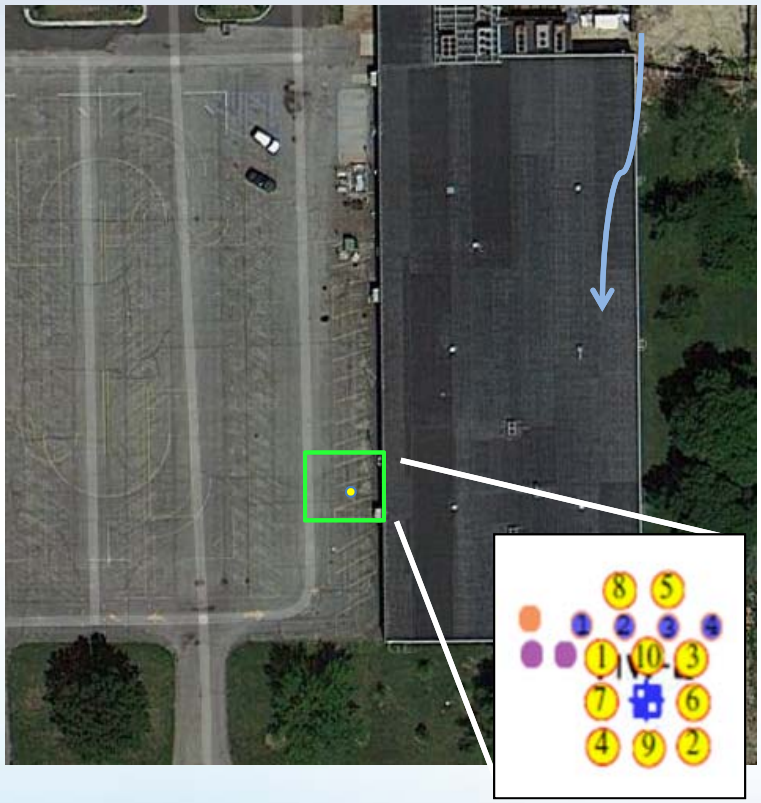
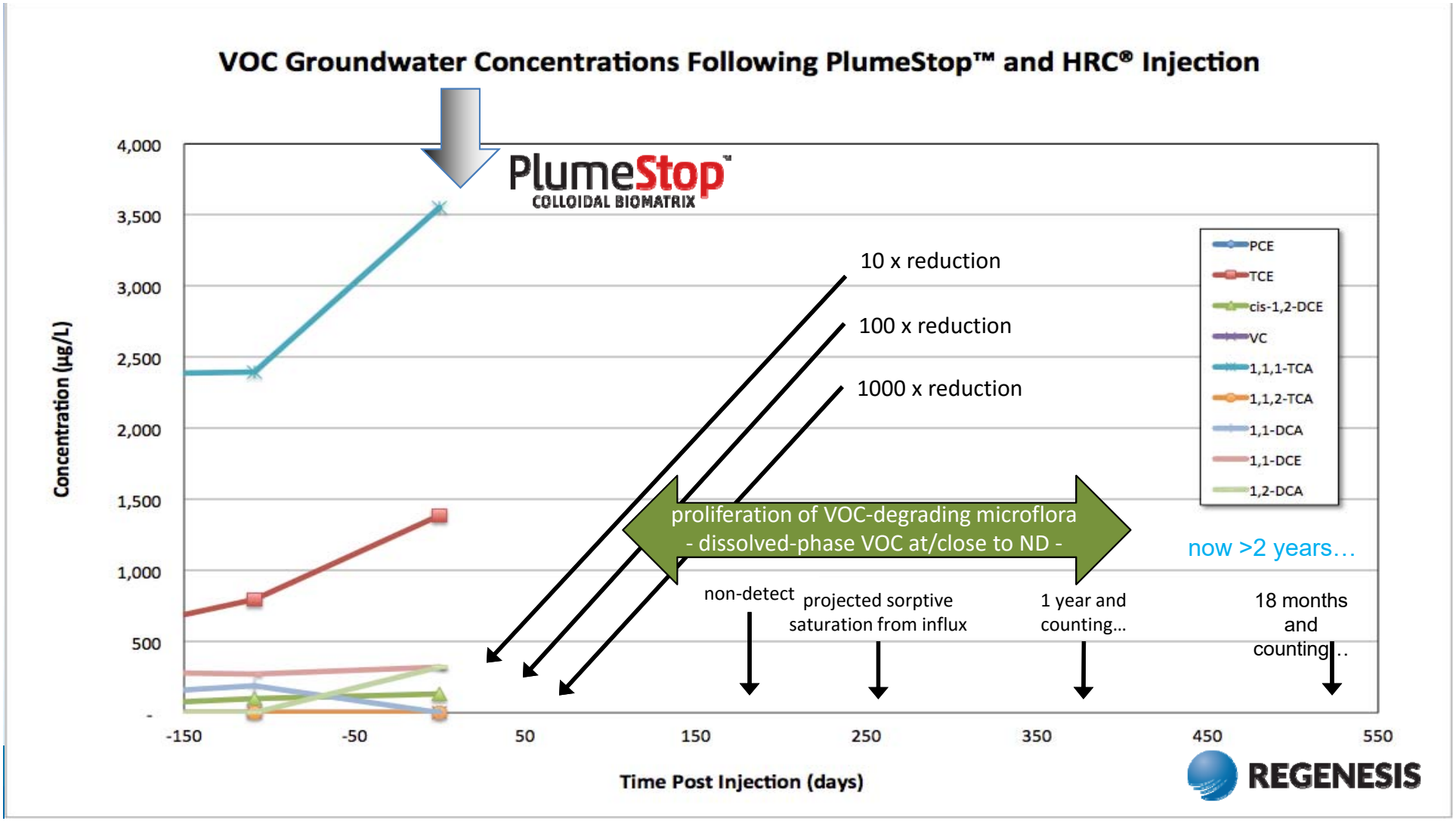
Midwest Chlorinated VOC Site



- Former electronics facility
- Contaminants: TCA, TCE, etc.
  - TCE 1,390 µg/L
  - TCA 3,550 µg/L
- Sand to silty sand
- Depth to groundwater 10-13ft bgs
- Seepage velocity 12 ft/yr toward SW

- Test site injection PlumeStop® and HRC®
  - Mitigate off-site plume migration


VOC Groundwater Concentrations Following PlumeStop™ and HRC® Injection
PlumeStop
COLLOIDAL BIOMATRIX
Concentration (µg/L)
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
-
-150
-50
50
150
250
350
450
550
Time Post Injection (days)
10 x reduction
100 x reduction
1000 x reduction
proliferation of VOC-degrading microflora
- dissolved-phase VOC at/close to ND -
now >2 years…
non-detect
projected sorptive saturation from influx
1 year and counting…
18 months and counting…
PCE
TCE
cis-1,2-DCE
VC
1,1,1-TCA
1,1,2-TCA
1,1-DCA
1,1-DCE
1,2-DCA
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PLUME STOP®
Liquid Activated Carbon

- Commercial Projects -

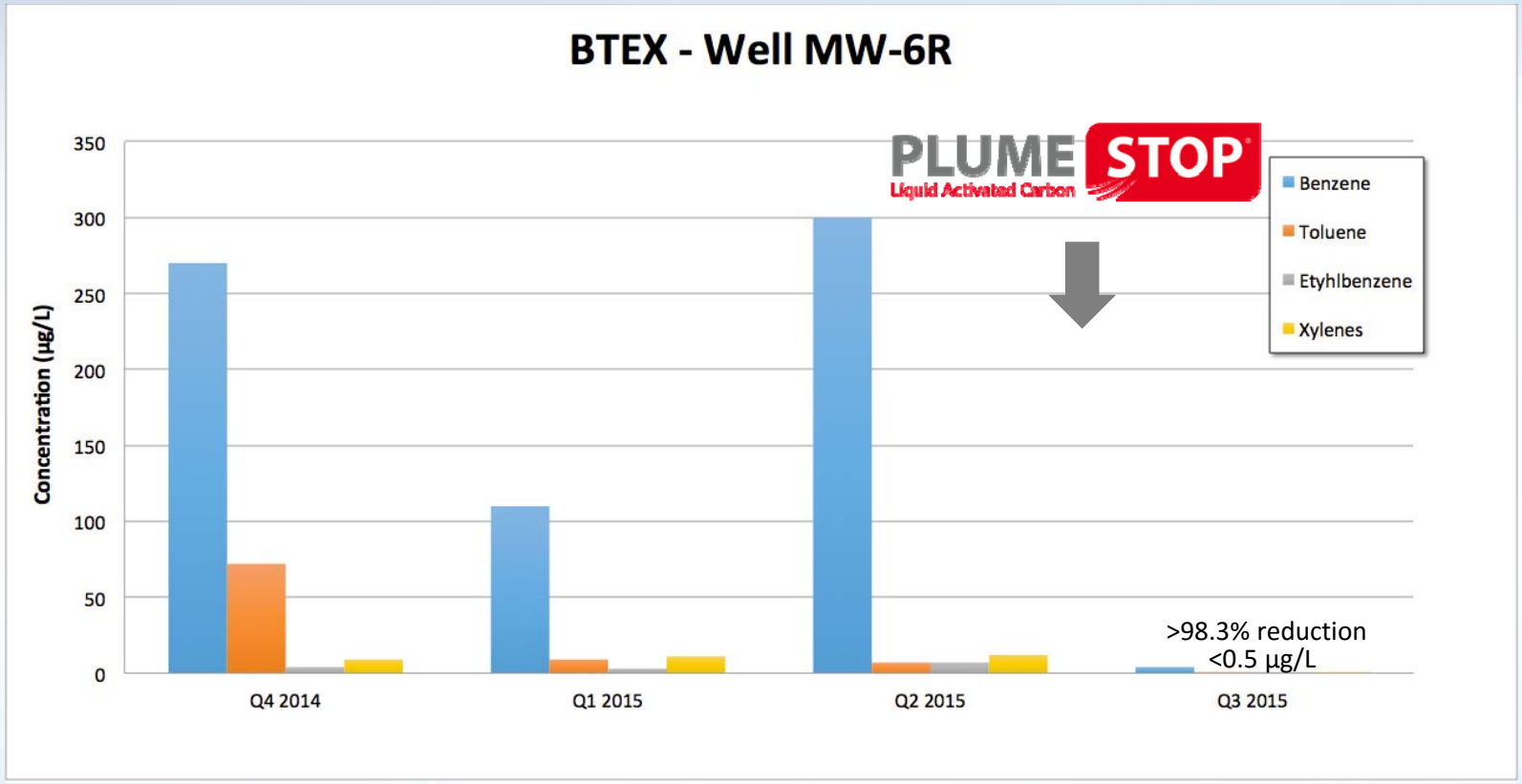
PLUME STOP
Liquid Activated Carbon

Case Study
- Filling Station – BTEX Residues -

Pennsylvania

PlumeStop® - Filling Station

- Former Filling Station
- BTEX residues
- Pilot Application - ORC-Advanced®, PlumeStop®
- Tight formation
- Clay with Sand (ca. 3.53×10^{-7} cm/sec)
- 9 – 15 ft. bgl
- Seepage Velocity Zero


BTEX - Well MW-6R
PLUME STOP
Liquid Activated Carbon
Concentration (µg/L)
350
300
250
200
150
100
50
0
Benzene
Toluene
Etyhlbenzene
Xylenes
>98.3% reduction
<0.5 µg/L
Q4 2014
Q1 2015
Q2 2015
Q3 2015

PLUME STOP
Liquid Activated Carbon

Case Study
-Inner-City Development / Time Pressure-

Downtown Chicago

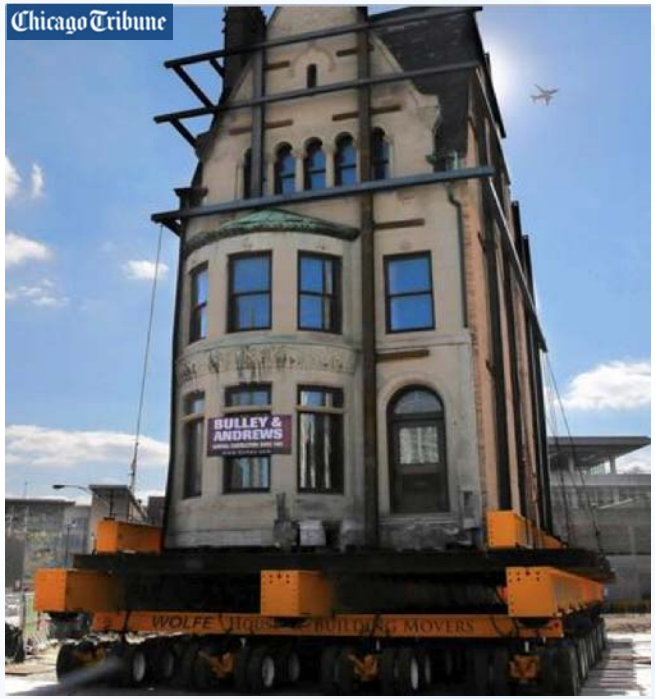
Case Study: Inner City Development – Time Pressure

- Neighborhood of McCormick Place – Central Chicago
  - New Sports Stadium
  - New Hotel Complex

- Solvent residues
- Tight time window
- High cost implications of delay
- Key remediation requirement: **FAST**

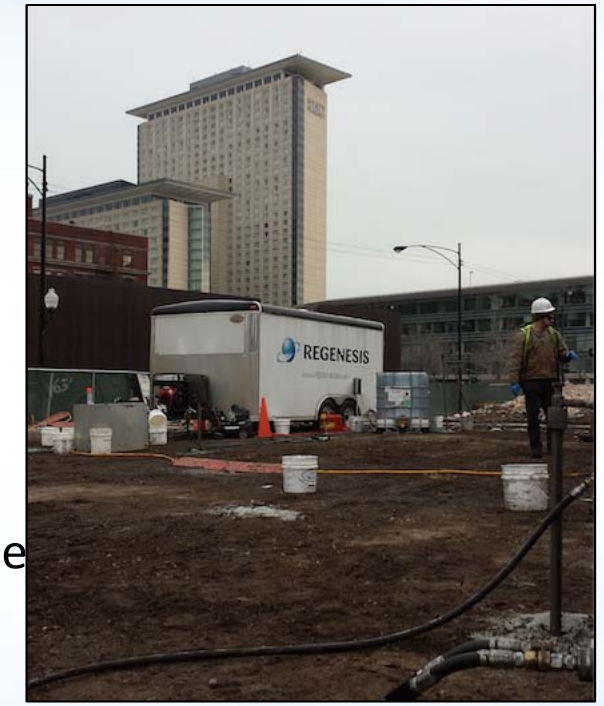
Case Study: Inner City Development – Time Pressure

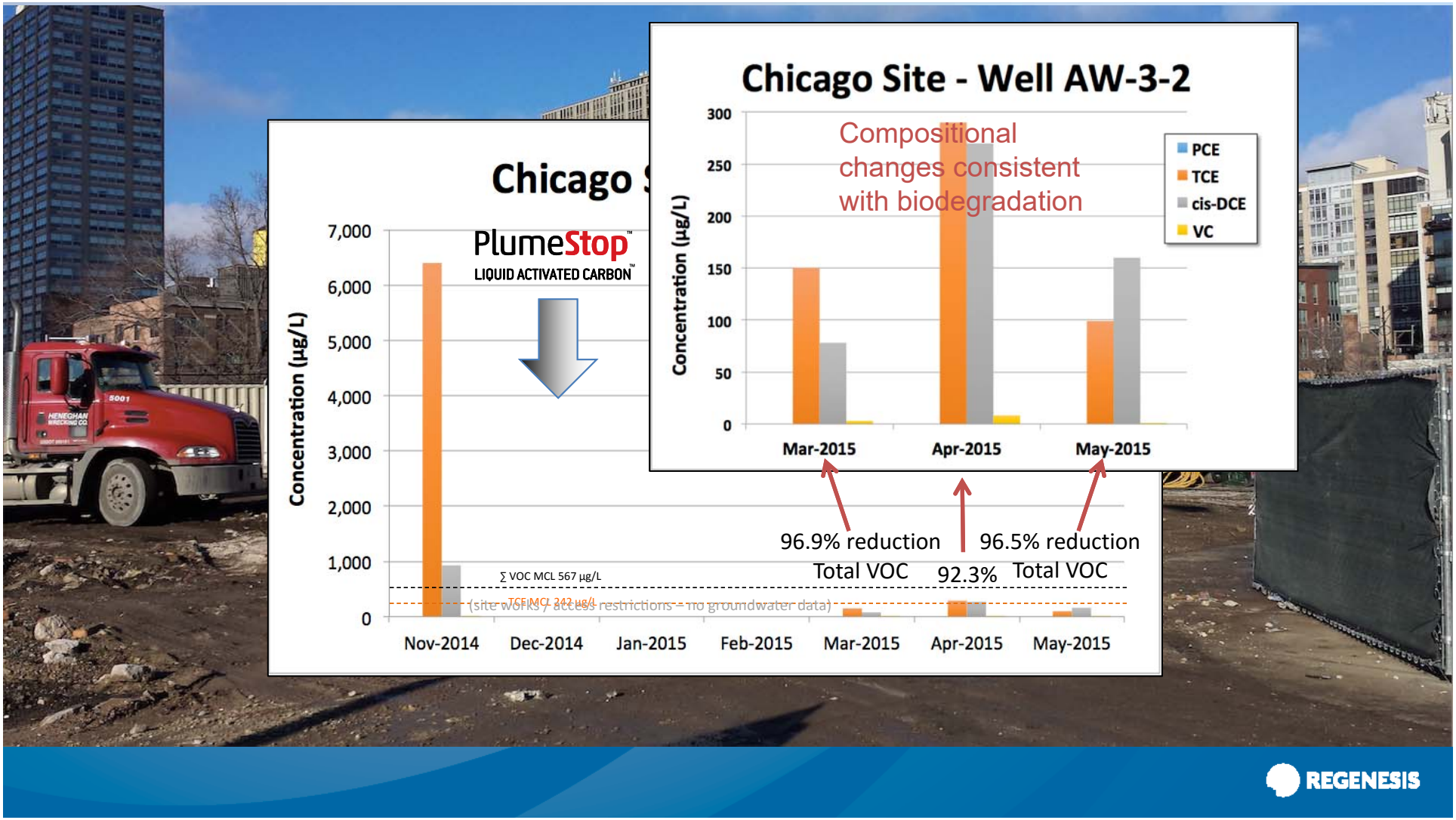
- Why the tight time window?
  - Weren't the solvent residues known?
- Access restrictions – historic buildings
  - Precluded early start
- Problem was moved aside



Case Study: Inner City Development – Time Pressure

- PCE and TCE residues – up to 7,440 µg/L
- Sand formation over clay
  - Treatment area 1,000 ft. x 1,600 ft.
  - Treatment Zone 10 – 22 ft. bgl
- Enhanced bio: HRC®, BDI®
  - Sufficient to address the contamination
- PlumeStop™
  - Rapid risk reduction and bio process acceleration
  - Take the bio process out of the groundwater phase
- 19 days' fieldwork on site (Chicago winter)
  - 138 direct-push injections – no resident equipment




Chicago Site - Well AW-3-2
Compositional changes consistent with biodegradation
PCE
TCE
cis-DCE
VC
Concentration (µg/L)
300
250
200
150
100
50
0
Mar-2015
Apr-2015
May-2015
Chicago
PlumeStop
LIQUID ACTIVATED CARBON
Concentration (µg/L)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
∑ VOC MCL 567 µg/L
TCE MCL 242 µg/L
(site works / access restrictions – no groundwater data)
Nov-2014
Dec-2014
Jan-2015
Feb-2015
Mar-2015
Apr-2015
May-2015
96.9% reduction Total VOC
92.3%
96.5% reduction Total VOC

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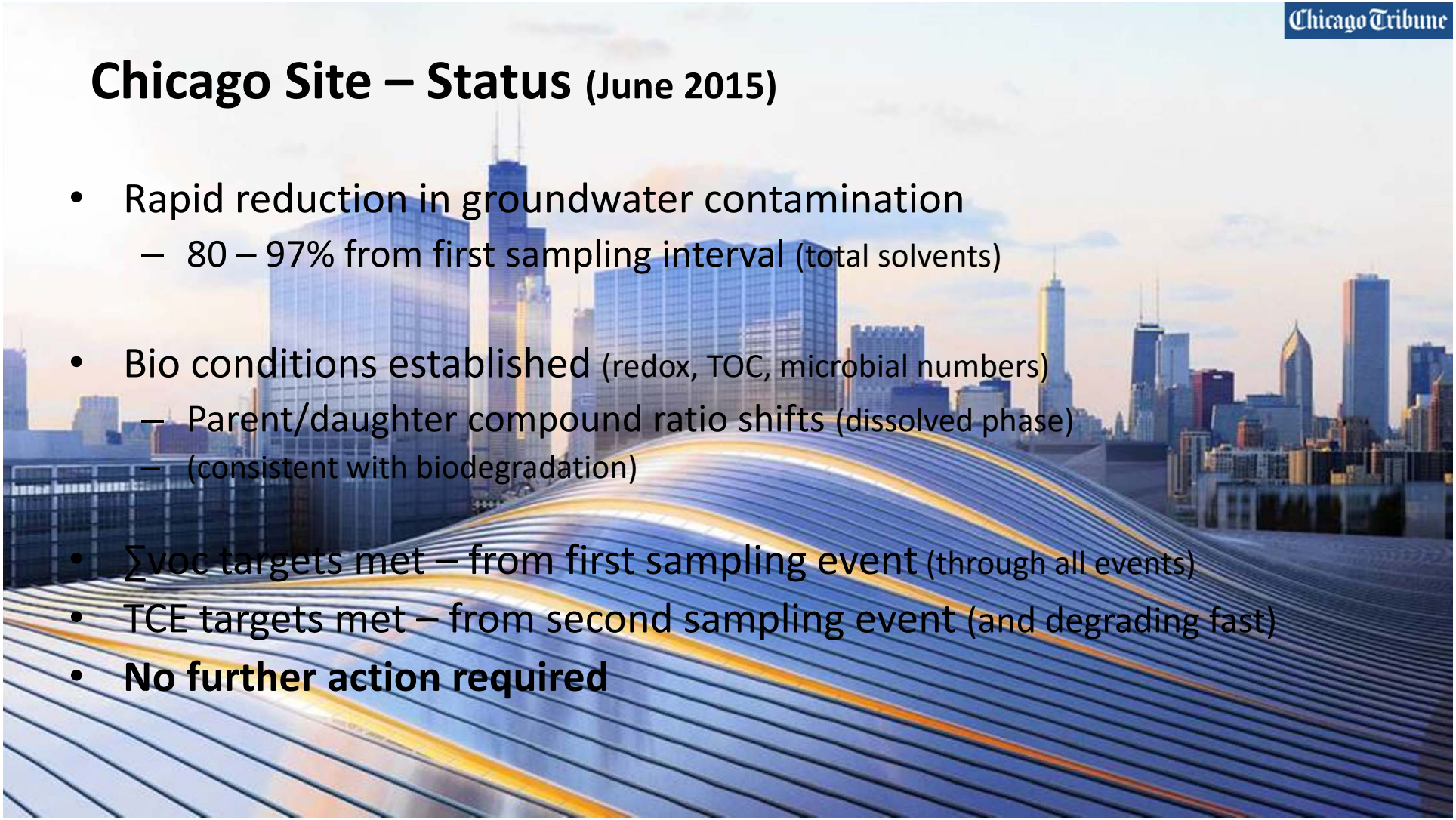

Chicago Site – Status (June 2015)

- Rapid reduction in groundwater contamination
  - 80 – 97% from first sampling interval (total solvents)
- Bio conditions established (redox, TOC, microbial numbers)
  - Parent/daughter compound ratio shifts (dissolved phase)
  - (consistent with biodegradation)
- ∑voc targets met – from first sampling event (through all events)
- TCE targets met – from second sampling event (and degrading fast)
- **No further action required**

When to Use PlumeStop

- Time is critical
- Control of migration of plumes
- Long Term matrix back diffusion
- Secure low clean-up targets (MCLs)
- Risk associated with GW contamination

PLUME STOP
Liquid Activated Carbon

Up-Front Orders of Magnitude Reduction and Accelerated Bio-Destruction Using a Dispersive Injectable Reagent

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