Bioremediation of Petroleum Hydrocarbons and Chlorinated Volatile Organic Compounds with Oxygen and Propane Gas inFusion

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Presentation Overview

- Background on bioremediation methods and technology applied to case study site
- Site conditions and selected remedial actions
- Implementation of remedial actions and outcome

Bioremediation Mechanisms

Chlorinated Aliphatic Hydrocarbons (CAHs)

- Anaerobic reduction
- Aerobic cometabolic oxidation
- Direct biological oxidation (Aerobic Treatment)

Petroleum Hydrocarbons

- Direct biological oxidation (Aerobic Treatment)

Aerobic Treatment of Petroleum Hydrocarbons

- Microorganisms use oxygen as an electron acceptor (~3 lb oxygen per lb HC)
- Hydrocarbons are converted to energy by the transfer of electrons to oxygen
- May require addition of nutrients to maximize biomass growth

Design Considerations

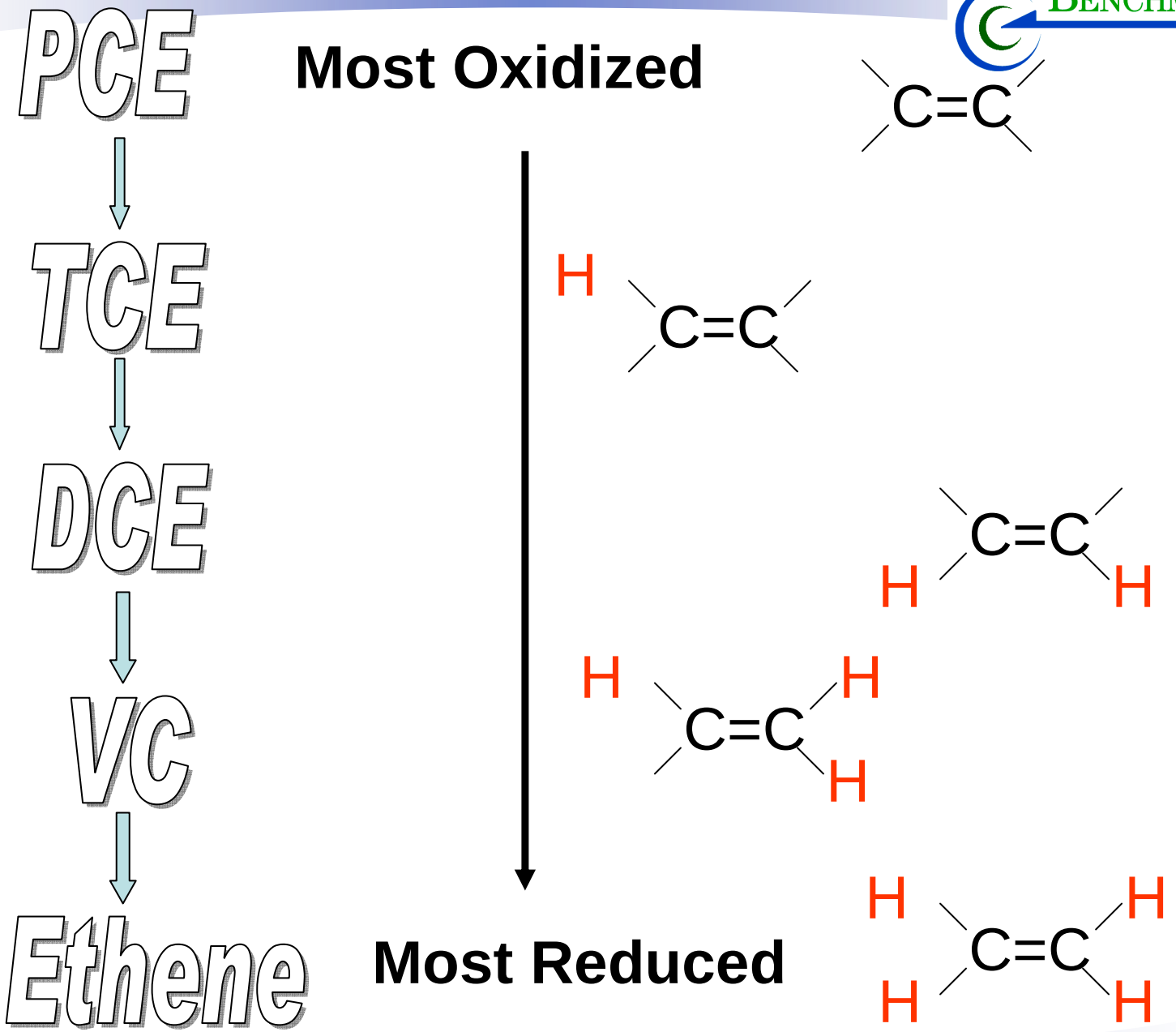
- Mass and distribution of hydrocarbons in the subsurface
- Efficient delivery and distribution of oxygen and nutrients

Aerobic Cometabolic Oxidation

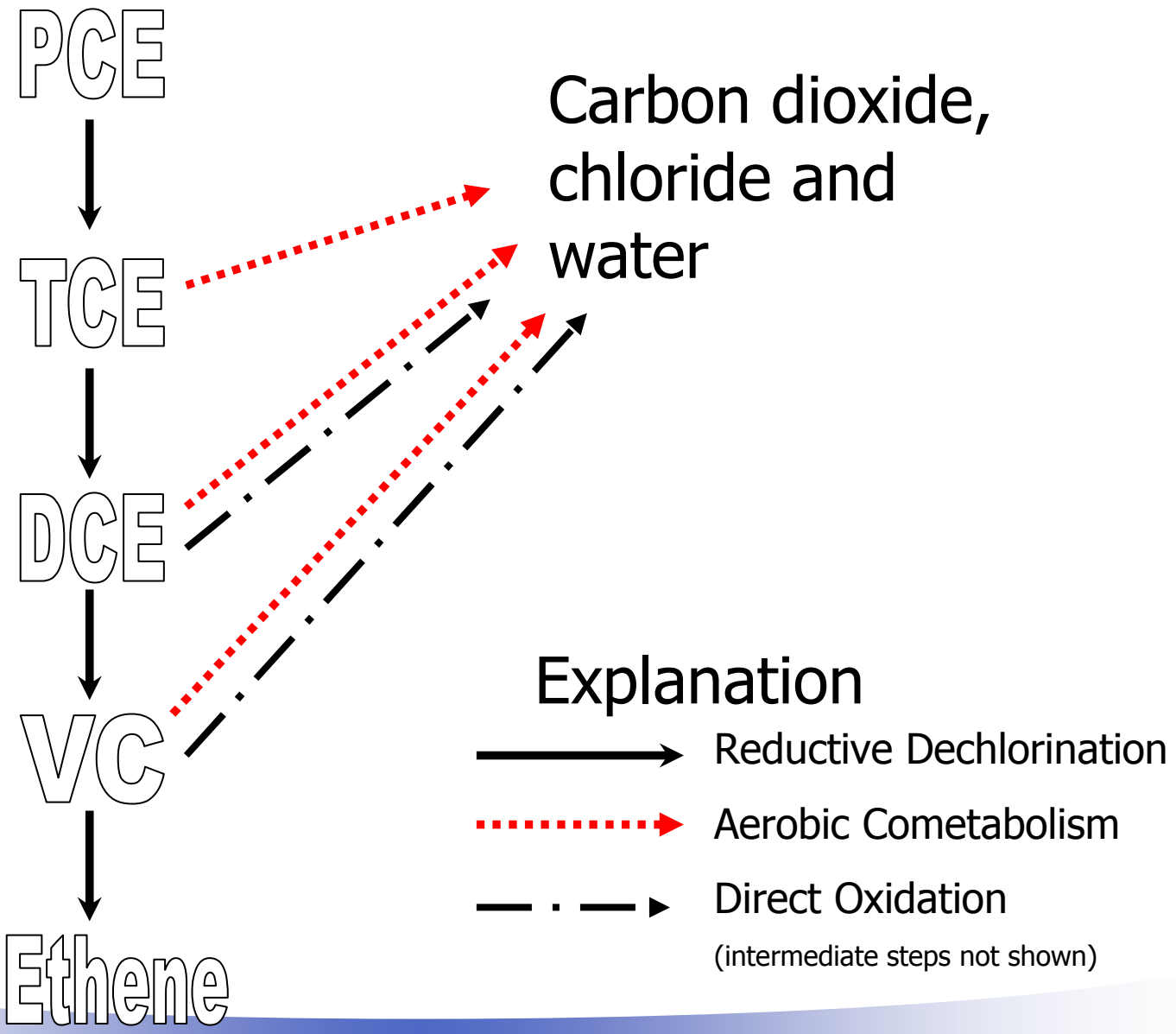
- Microorganisms use oxygen as an electron acceptor
- An added organic substrate (dissolved alkane gas) provides food (energy) to bacteria
- May also require addition of nutrients to maximize biomass growth

Isn't all CAH treatment anaerobic?

Several mechanisms are potentially applicable depending on the compound



Modified from USGS WRI 99-2485



Modified from USGS WRI 99-2485

When to Select Aerobic Cometabolism

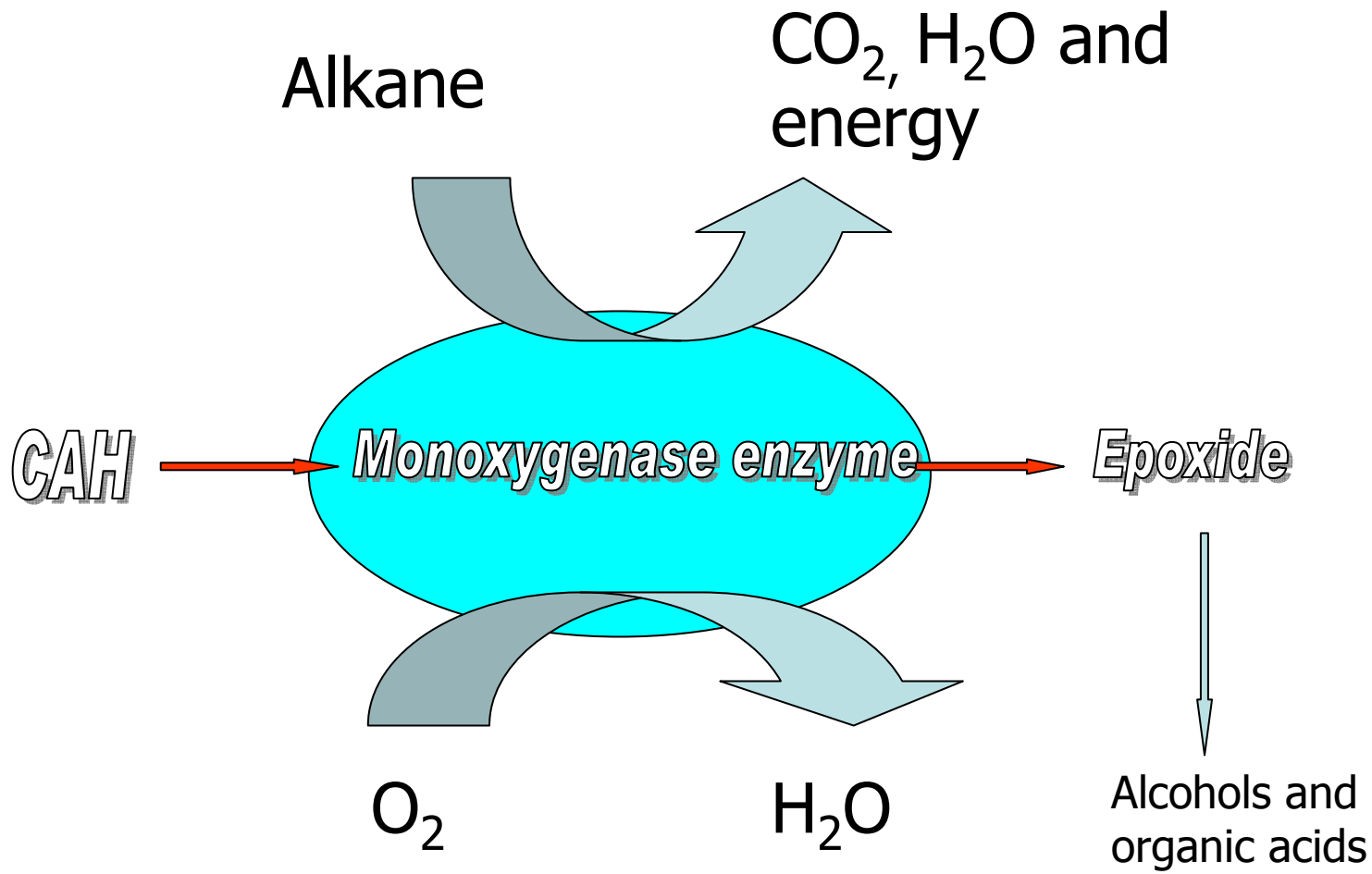
- Targeting lower CAHs (TCE,DCE,VC)
- Redox conditions not highly anaerobic
- CAH Concentrations relatively low (<1,000 ppb ??)

Aerobic Cometabolic Oxidation of Lower CAHs

- Bacteria use a continuous supply of oxygen as the electron acceptor
- A cometabolic substrate (alkane gas) is supplied as a growth substrate (electron donor)

Aerobic Cometabolic Oxidation

- Cometabolic substrate induces the production of monoxygenase enzymes that catalyze the oxidation of CAHs to non-CAH intermediates
- Bacteria gain energy from the cometabolic substrate, not from the CAH



From EPA July 2000

Cometabolic Design

- Maximize delivery and distribution of oxygen to maintain aerobic conditions
- Deliver sufficient alkane gas to stimulate bacterial growth and the production of monoxygenase enzymes

Design Considerations

- Intermittent delivery of alkane gas to limit competitive inhibition (too much alkane slows degradation of CAHs)

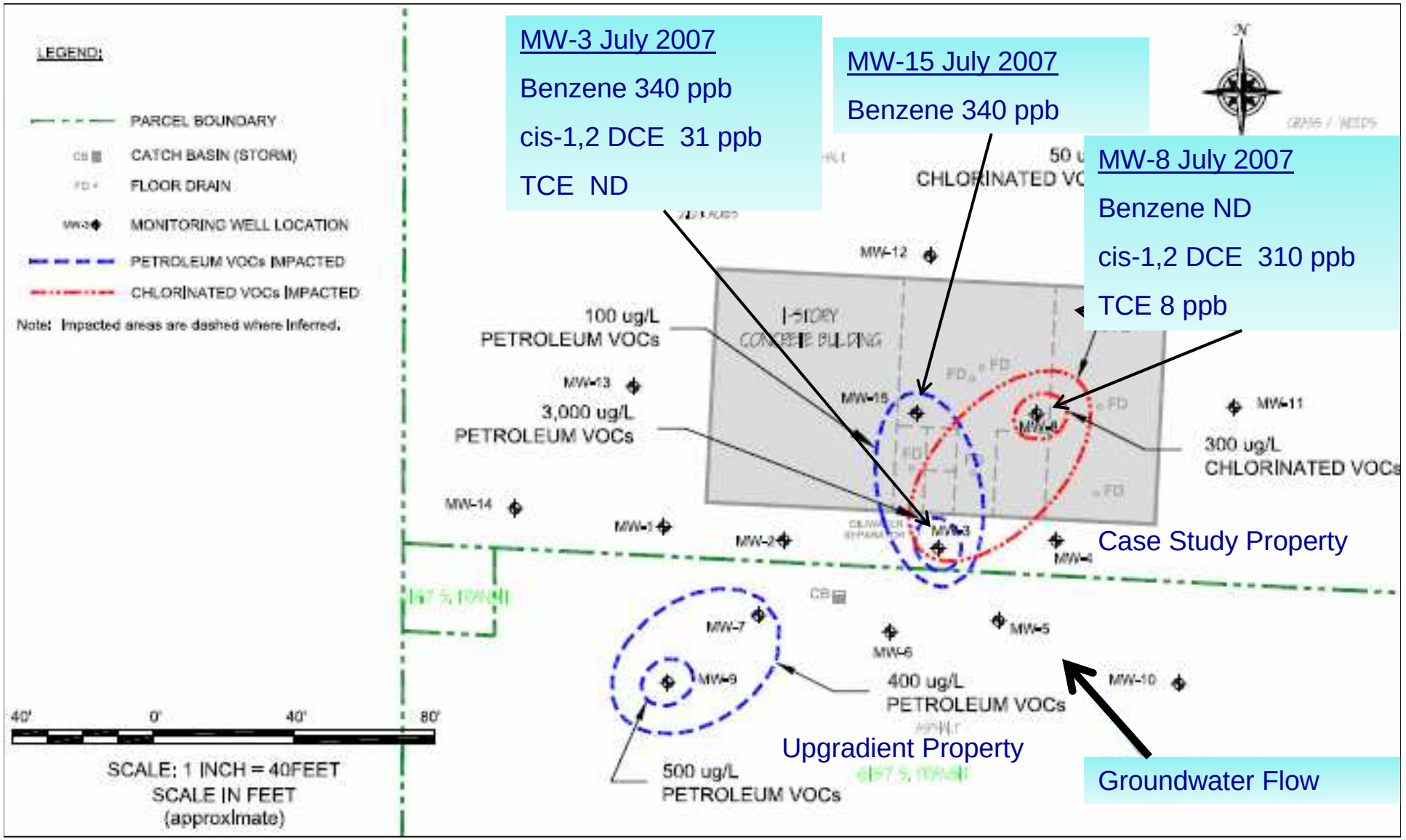
Case Study Site Conditions

- Automotive repair and car dealership in New York
- Historical releases of contaminants from fuel USTs and floor drains
- Soil excavations used to eliminate source areas
- Contaminated groundwater under building with indoor air impacts

Case Study Site Conditions

- Shallow water table
- Predominantly silt with clay and fine sand
- Groundwater flow to the northeast
- Redox potential approximately -100 mV (only moderately anaerobic)

Initial Assessment Concentrations

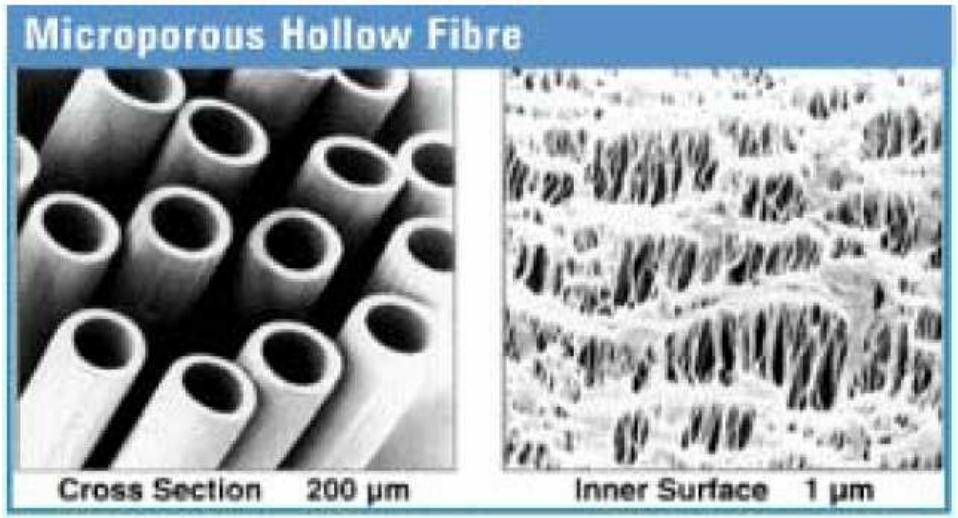


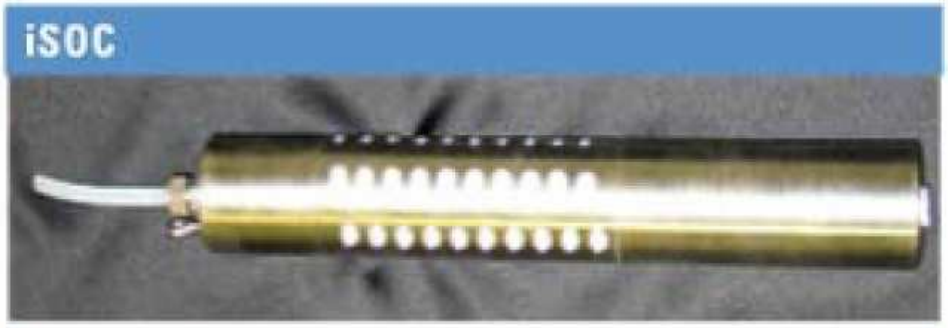
Selected Remedial Action

- in situ bioremediation of groundwater
  - Direct aerobic and cometabolic treatment using the iSOC system to deliver dissolved gasses
- Sub-slab vapor extraction

iTi Gas inFusion™ Technology

Microporous Hollow Fiber

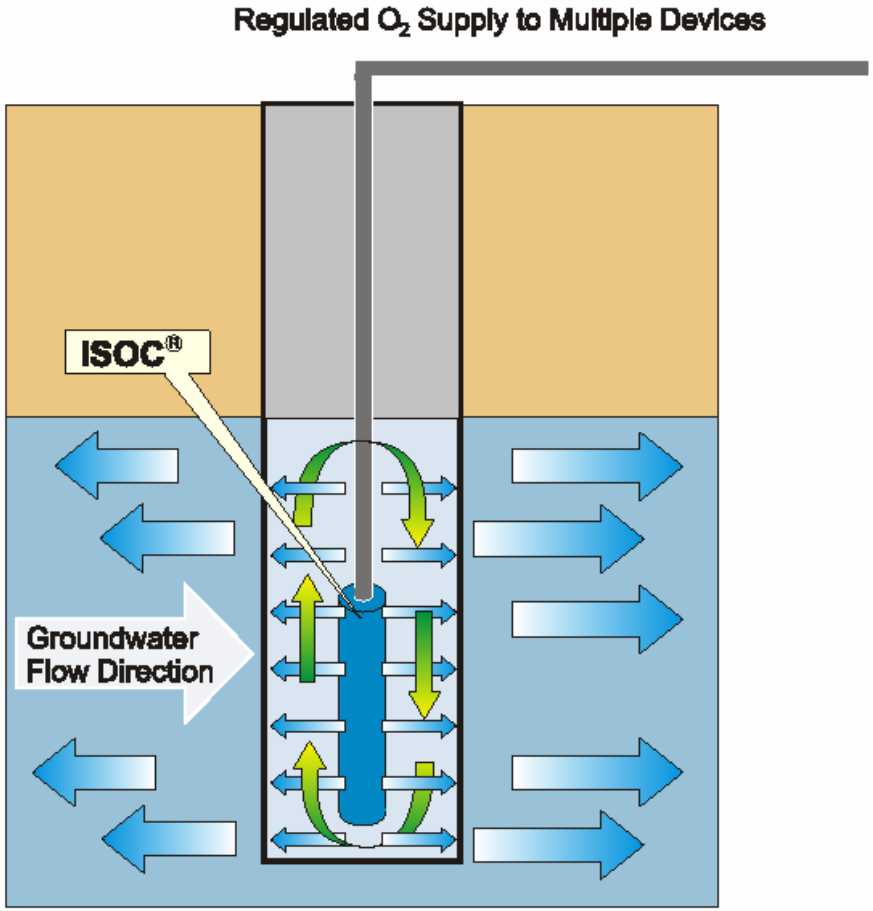




iSOC

Mass-transfer of gasses to groundwater w/out sparging

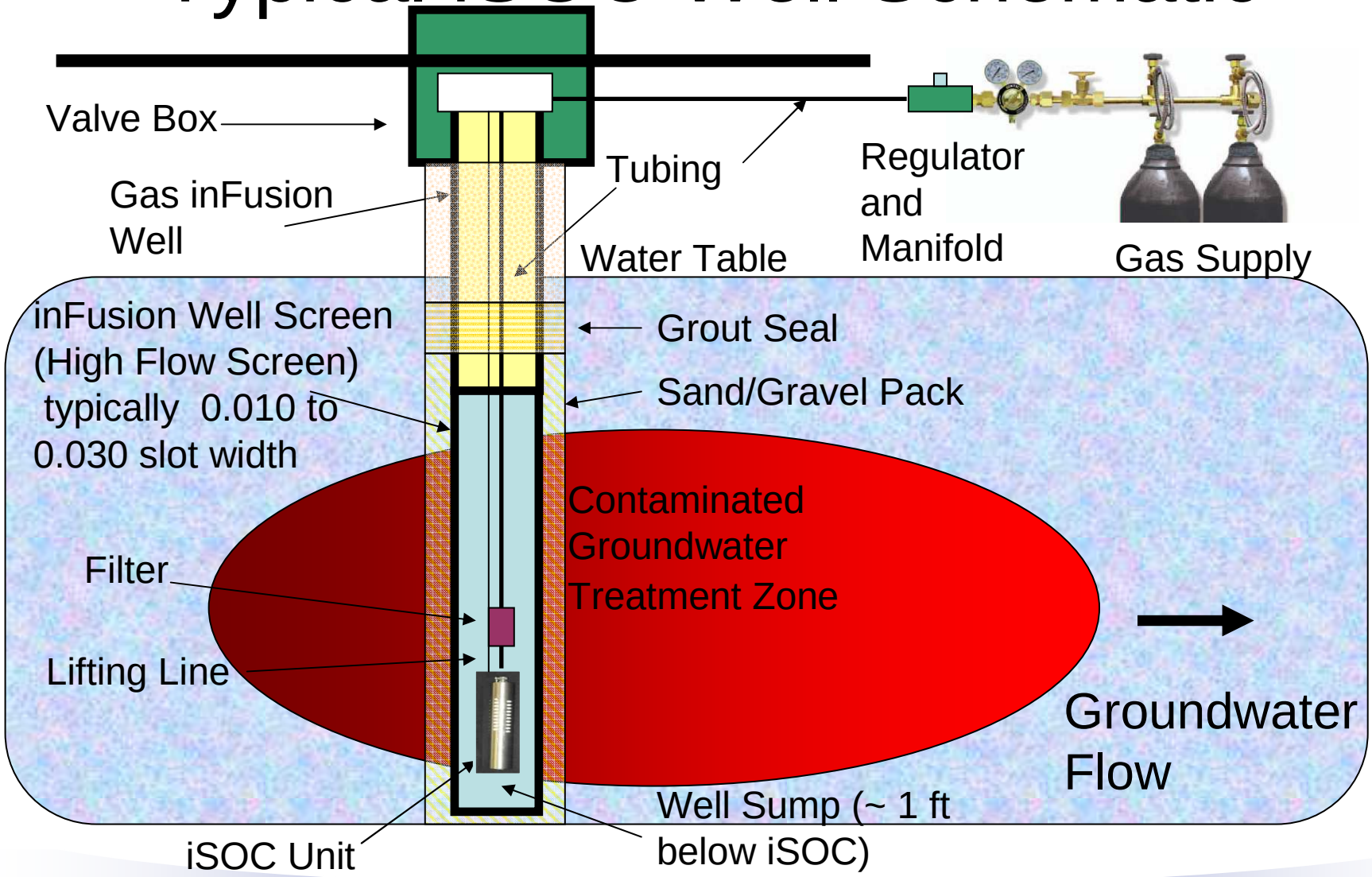
Passive iSOC® Gas inFusion Process



Example direct aerobic treatment:

- iSOC unit supplied with industrial grade oxygen in treatment well
- Saturates well (DO— 40 to 200 PPM
- Natural convection current fills well with uniform DO
- DO disperses into groundwater stimulating bioremediation

Typical iSOC Well Schematic



Oxygen Cylinder Life and Production Rates

*data in cells highlighted in green can be changed

Depth of H2O to Unit (ft)	20	ft
Number of of iSOCs	1	
Oxygen Regulator Setting (psi)	50	psi

Your Water Pressure (psig)	9	
Total Pressure (atm)	1.6	
System Oxygen Flow	19.7	standard cc/min

Oxygen Cylinder Volume (ft^3)	Oxygen (pounds)	Actual Cylinder Life for Y iSOCs
250	21	230
200	17	184
80	7	80

Max Dissolved Oxygen @ Y depth (ppm)	65

Oxygen Production Rate (Grams / Day)	34.2
(mg / Day)	34.2 $x10^3$
(ug / Day)	34.2 $x10^6$

*caution: pressure guages are often inaccurate after a period of use, particularly at low pressures
*temperature variations can effect the pressure reading by as much as 15%

iSOC (APPROXIMATE) 5 % Propane Cylinder Life (Propane Flow at 15 CC/MIN)
Propane Production Rate (Grams/day)
(Cylinder Pressure 1909 psi at 70F)

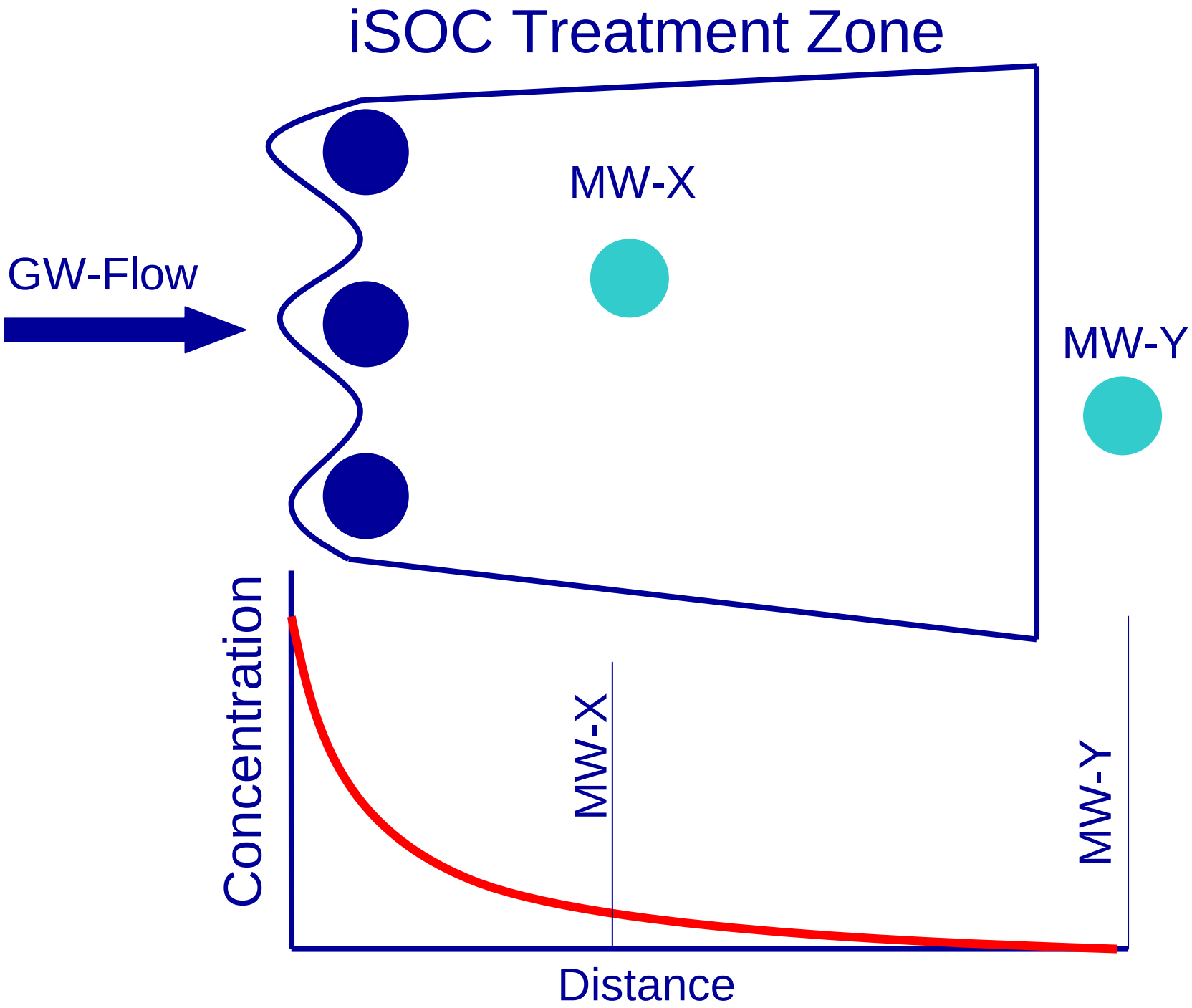
	X= Depth H_2O to Unit (ft)	Y= No iSOC Units
Input your data here:	20	1

Your Water Pressure (psig)	9
Total Pressure (atm)	1.6

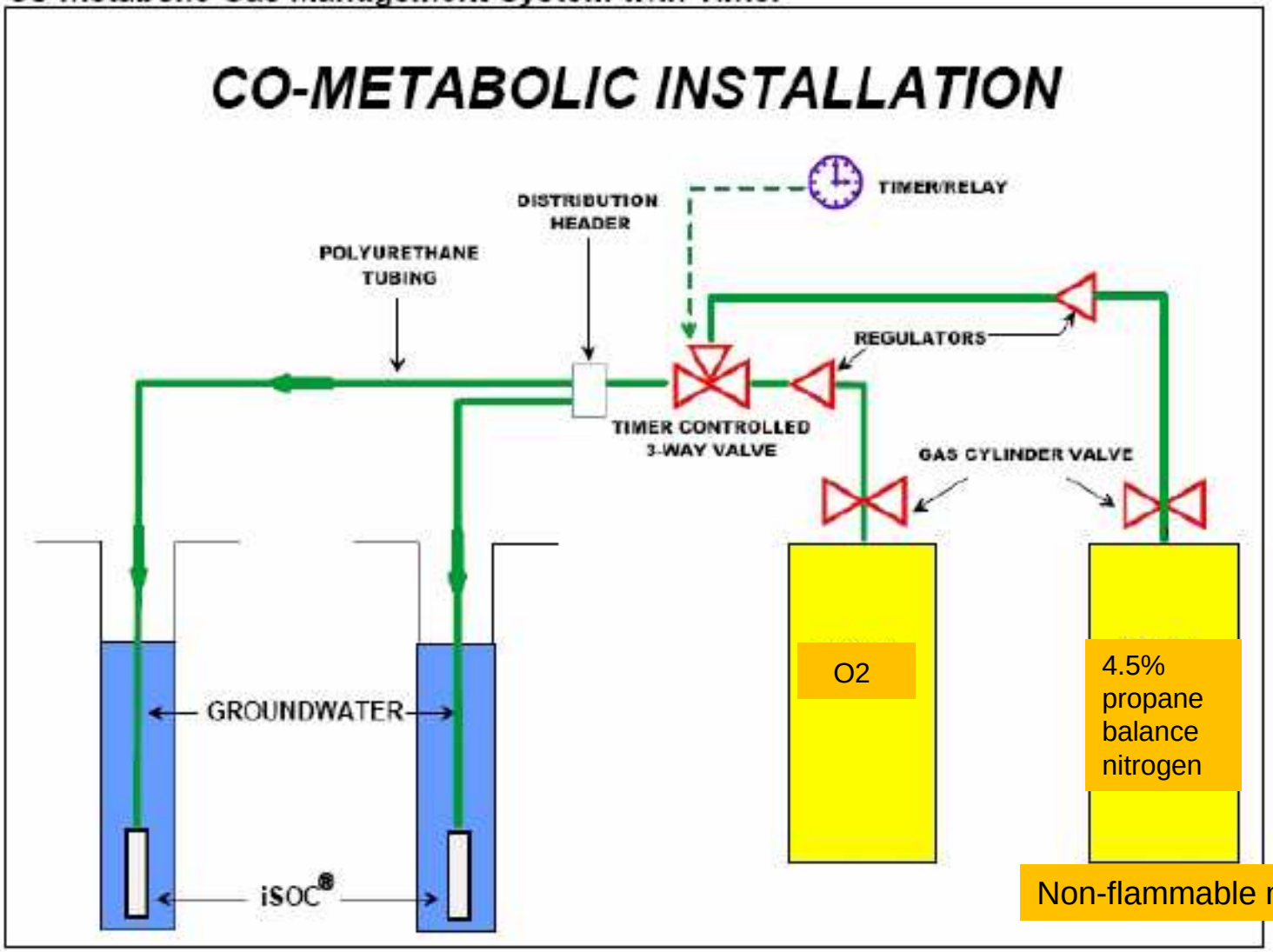
Propane (pounds)	4.5 % Propane gas balance nitrogen Cylinder Volume (ft3)	Cylinder Life for 1 iSOC (Days)	Actual Cylinder Life for Y iSOCs (Days)
1.21	237	237	**237**

Dissolved Propane (ppm)	4.2
Pounds of Propane delivered/year	1.9
Pounds propane per Day	0.005
Propane Production Rate (Grams / Day)	2

Note: Solubility of 4.5% propane mg/l at 25C is 2.655 mg/L


iSOC Treatment Zone
GW-Flow
MW-X
MW-Y
Concentration
MW-X
MW-Y
Distance

Co-metabolic Gas Management System with Timer



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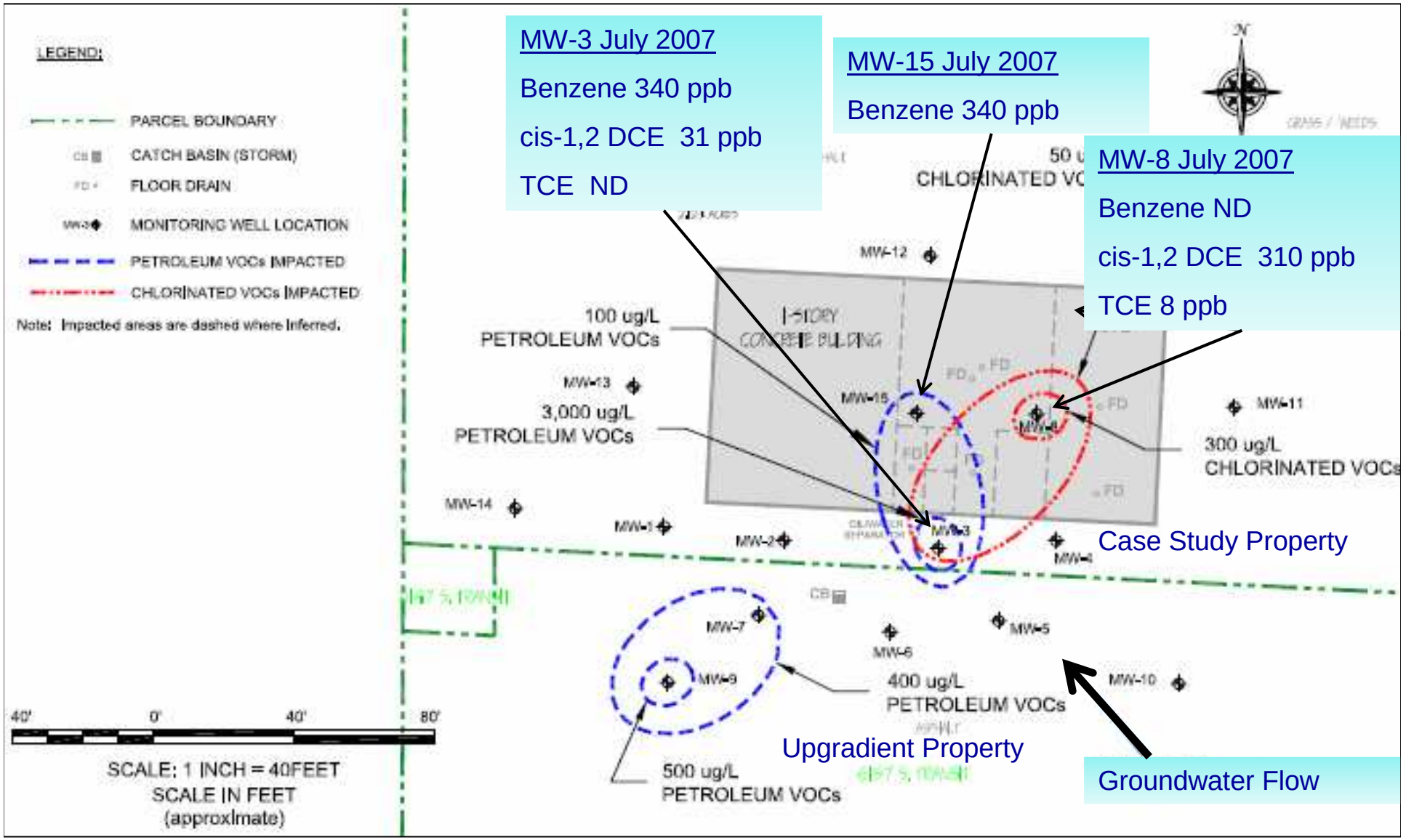
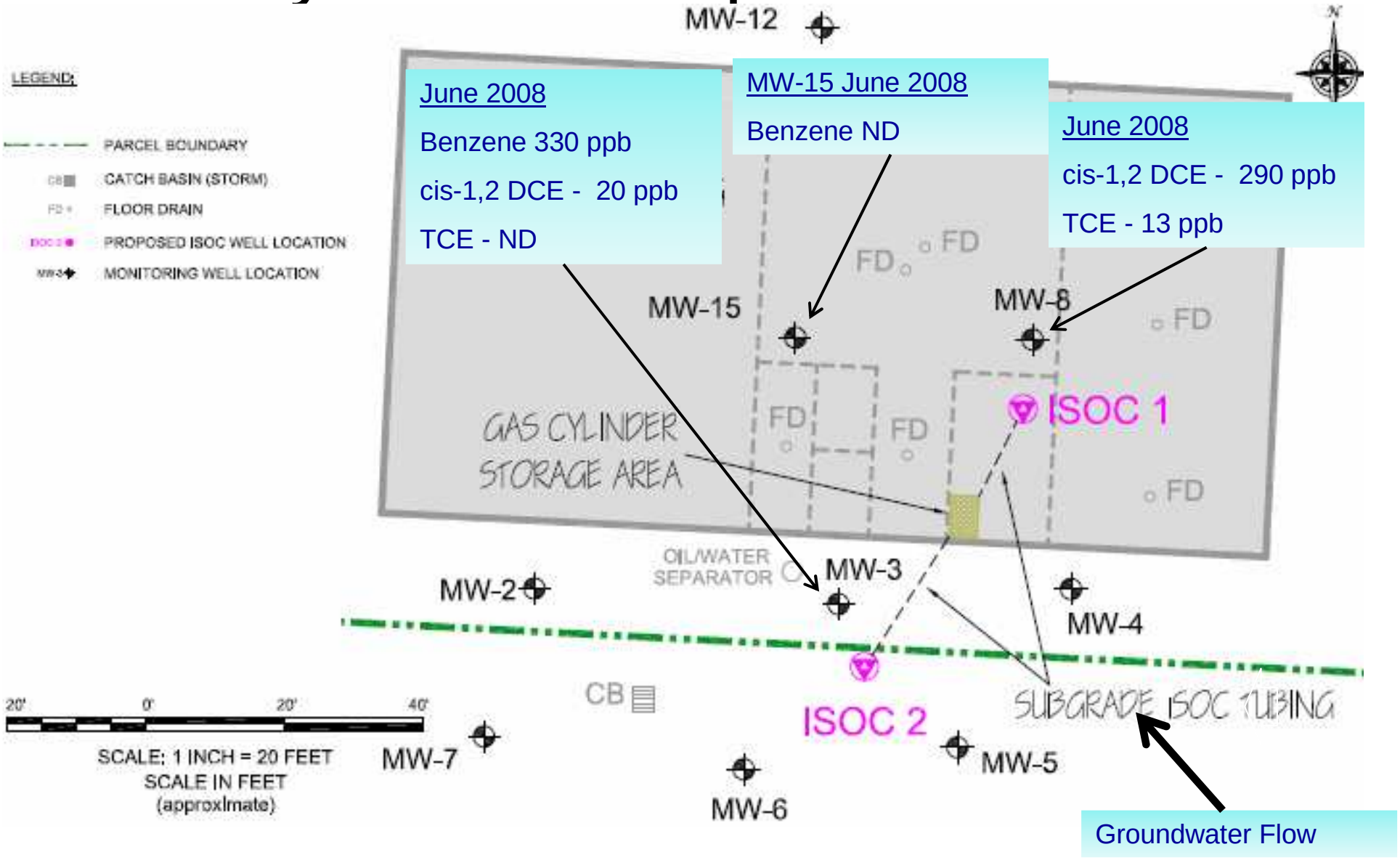
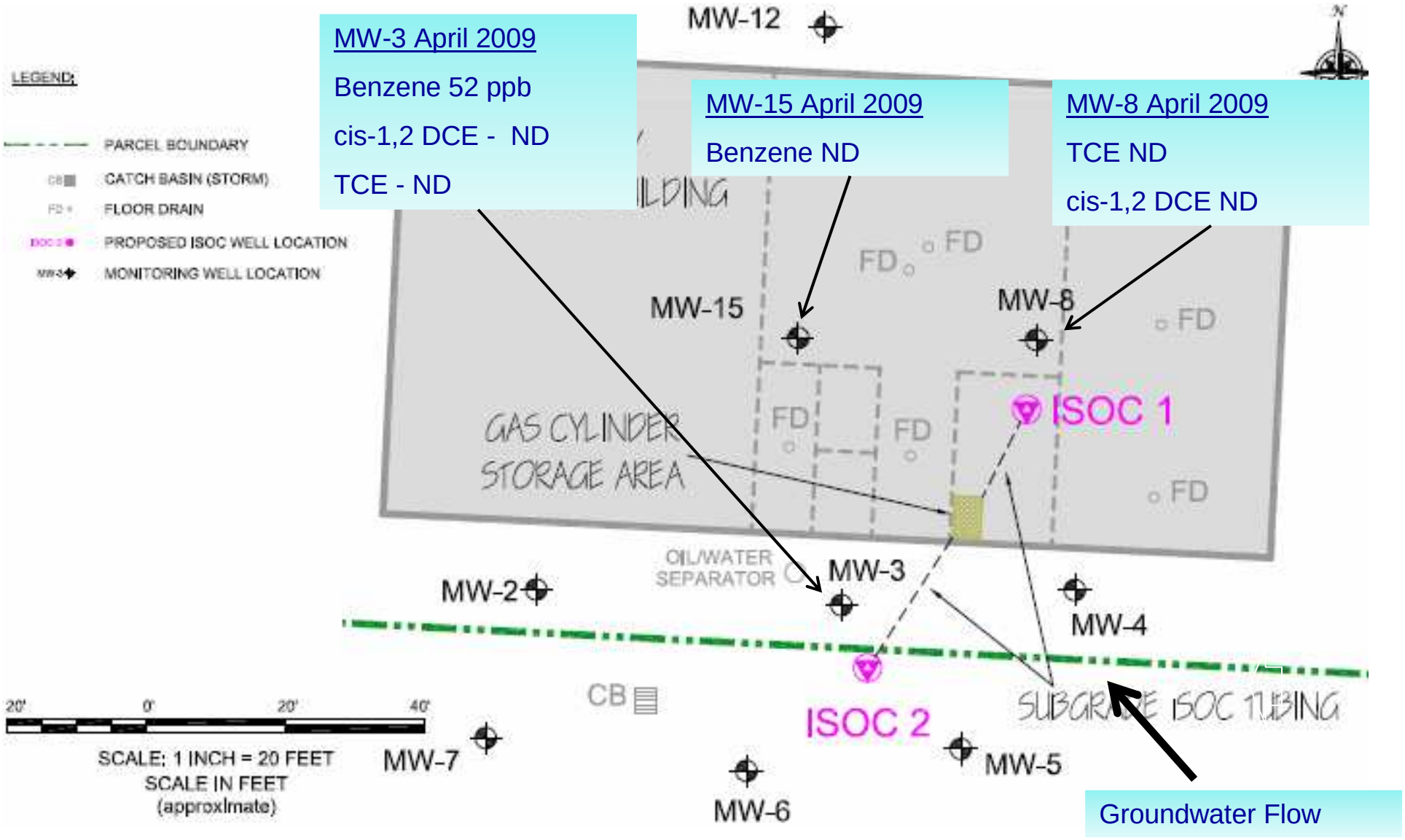


iSOC Layout
System Startup June 2008



Completion of Active Remedial Actions April 2009



Site Status

- Limited bacteriological monitoring indicated significant increase in bacteria levels during treatment
- in situ bioremediation/enhanced attenuation of petroleum hydrocarbons and CAHs achieved remediation goals in groundwater
- Currently in post remedial monitoring

Questions?