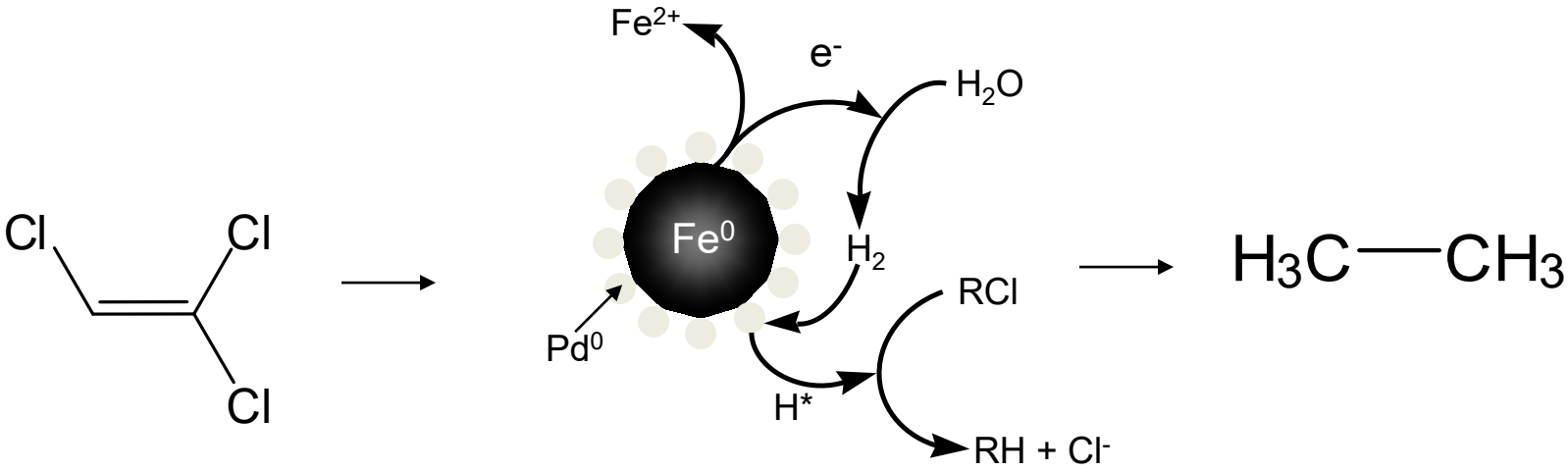
Nano-Particle Project



UK

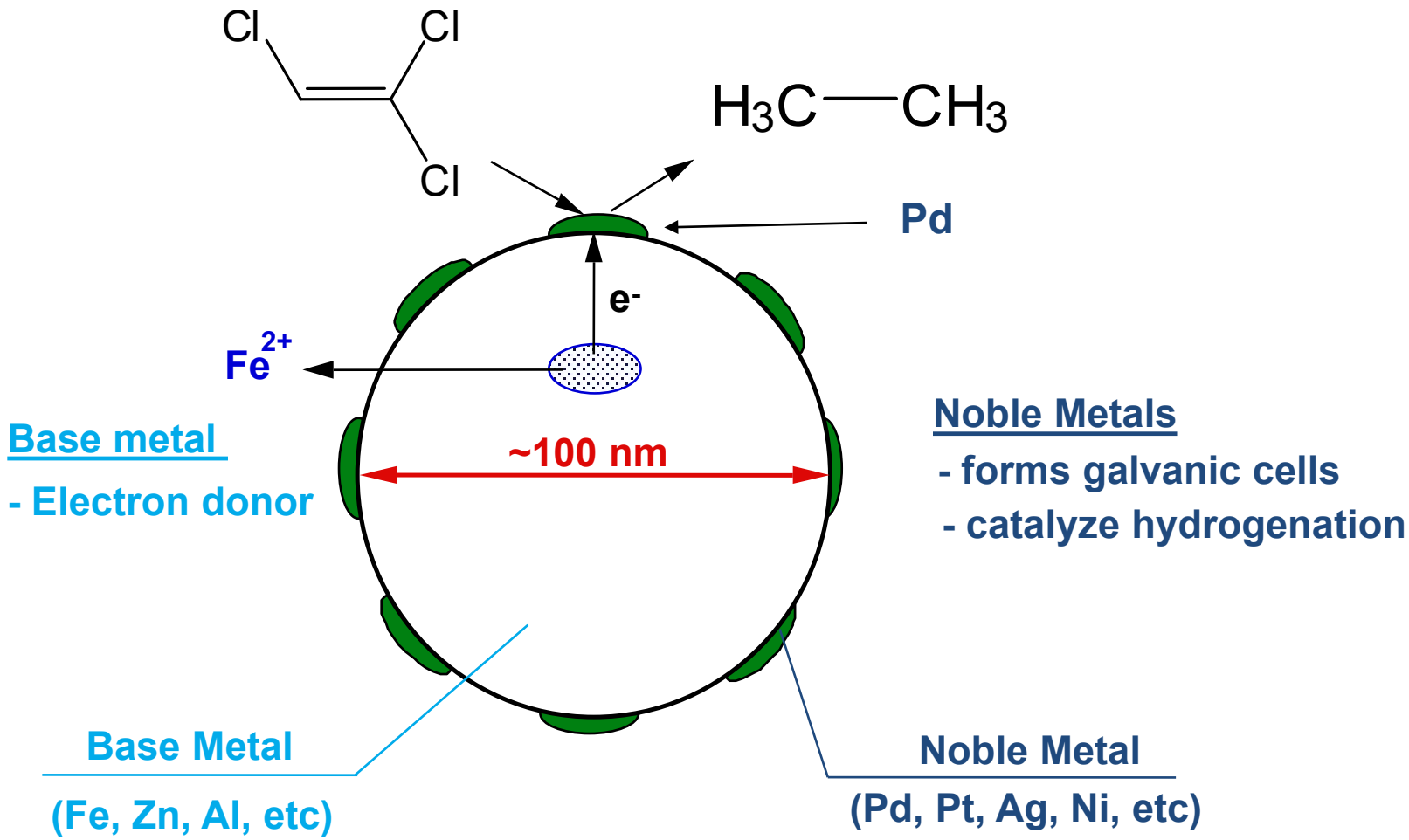
KRCEE

Kentucky Water Research Institute

History

- Project is a follow up to previous research projects:
  - **Project 13: Bench Scale Demonstration of Nano-Structured Bi-metallic systems**
    - **Dr. D.B. Bhattacharyya, UK Engineering**
  - Project 3: Groundwater Modeling
    - Dr. Sirinivasa Lingireddy, Dr. Chandramouli Viswanathan; UK Engineering
  - Project 16: Field Seismic and Groundwater Investigation to Identify Structural Features Relating to the Discharge of contaminated Groundwater to Little Bayou Creek through Seeps
    - Dr. Alan Fryar, UK Geology; Dr. Stephen Greb

Nano-Particle Remediation



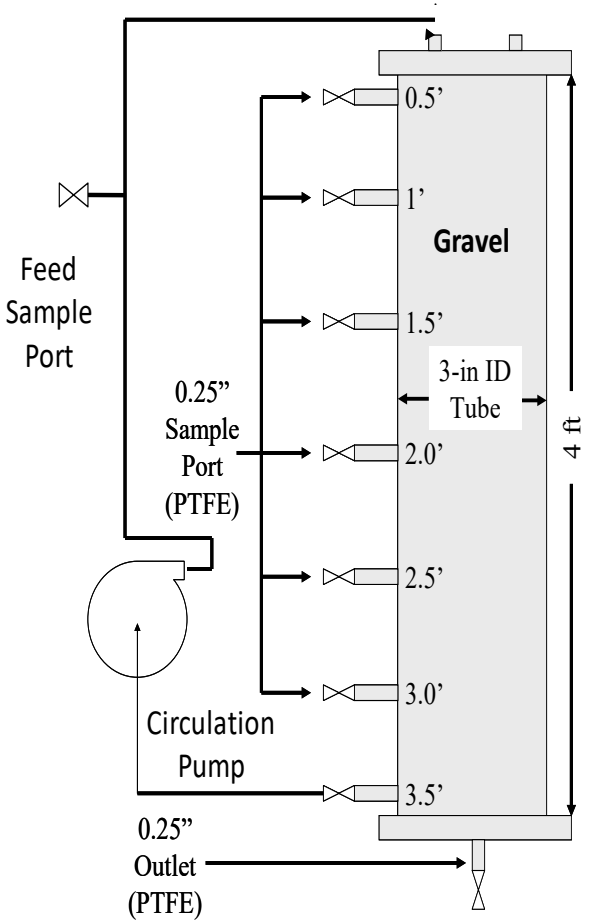
Environmental Contaminants

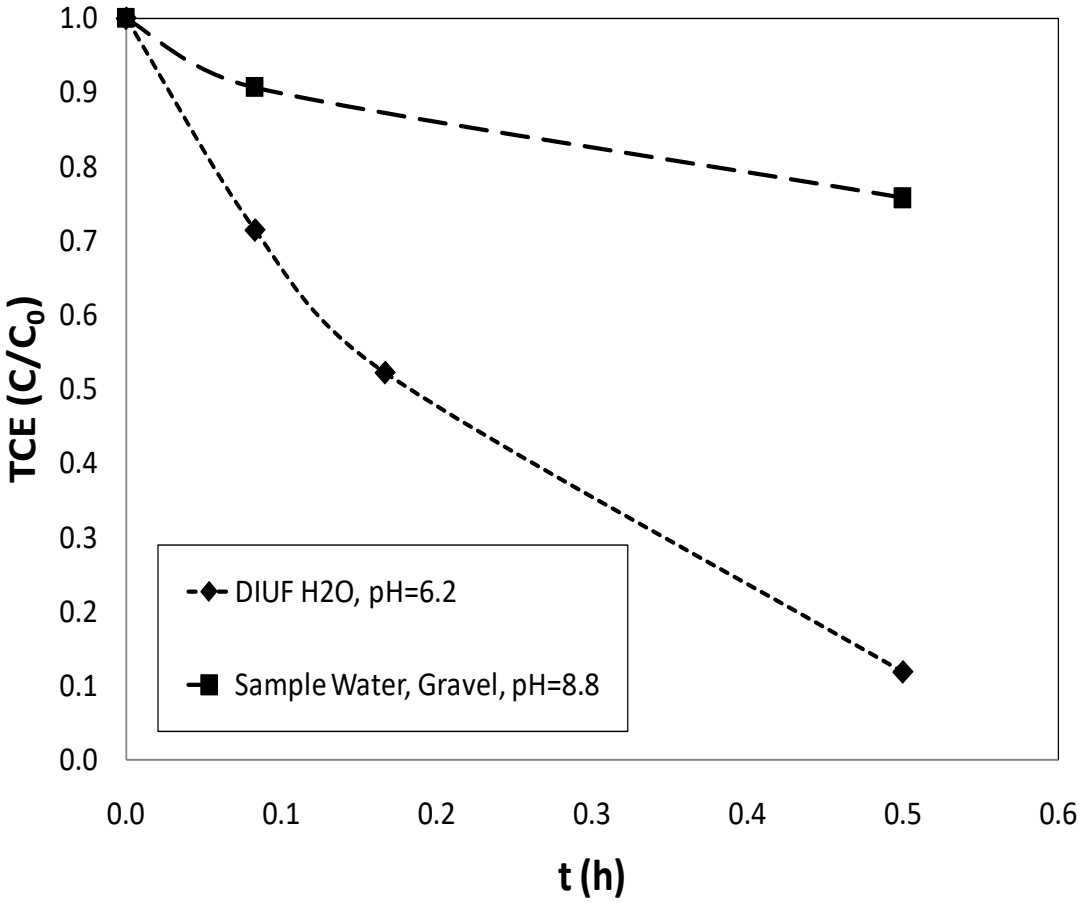
Table 1. Common environmental contaminants that can be transformed by nanoscale iron particles

- Chlorinated methanes
  - Carbon tetrachloride (CCl_4)
  - Chloroform ($CHCl_3$)
  - Dichloromethane (CH_2Cl_2)
  - Chloromethane (CH_3Cl)
- Chlorinated benzenes
  - Hexachlorobenzene (C_6Cl_6)
  - Pentachlorobenzene (C_6HCl_5)
  - Tetrachlorobenzenes ($C_6H_2Cl_4$)
  - Trichlorobenzenes ($C_6H_3Cl_3$)
  - Dichlorobenzenes ($C_6H_4Cl_2$)
  - Chlorobenzene (C_6H_5Cl)
- Pesticides
  - DDT ($C_{14}H_9Cl_5$)
  - Lindane ($C_6H_6Cl_6$)
- Organic dyes
  - Orange II ($C_{16}H_{11}N_2NaO_4S$)
  - Chrysoidine ($C_{12}H_{13}ClN_4$)
  - Tropaeolin O ($C_{12}H_9N_2NaO_5S$)
  - Acid Orange
  - Acid Red
- Heavy metal ions
  - Mercury (Hg^{2+})
  - Nickel (Ni^{2+})
  - Silver (Ag^{+})
  - Cadmium (Cd^{2+})
- Trihalomethanes
  - Bromoform ($CHBr_3$)
  - Dibromochloromethane ($CHBr_2Cl$)
  - Dichlorobromomethane ($CHBrCl_2$)
- Chlorinated ethenes
  - Tetrachloroethene (C_2Cl_4)
  - Trichloroethene (C_2HCl_3)
  - *cis*-Dichloroethene ($C_2H_2Cl_2$)
  - *trans*-Dichloroethene ($C_2H_2Cl_2$)
  - 1,1-Dichloroethene ($C_2H_2Cl_2$)
  - Vinyl chloride (C_2H_3Cl)
- Other polychlorinated hydrocarbons
  - PCBs
  - Dioxins
  - Pentachlorophenol (C_6HCl_5O)
- Other organic contaminants
  - N-nitrosodimethylamine (NDMA) ($C_4H_{10}N_2O$)
  - TNT ($C_7H_5N_3O_6$)
- Inorganic anions
  - Dichromate ($Cr_2O_7^{2-}$)
  - Arsenic (AsO_4^{3-})
  - Perchlorate (ClO_4^{-})
  - Nitrate (NO_3^{-})

Nanoscale Iron Particles for Environmental Remediation: An Overview
Wei-xian Zhang, Journal of Nanoparticle Research 2003

Bench Studies






See Figure 1.c
Column Study
Sample Collection
Location

Journal Publications

- Lewis, Lynch, Bachas, Hampson, Ormsbee, Bhattacharyya, Chelate-Modified Fenton Reaction for the Degradation of Trichloroethylene in Aqueous and Two-Phase Systems, Environmental Engineering Science, 2009
- Meyer, Hampson, Ormsbee, Bhattacharyya, A study of Groundwater Matrix Effects for the Destruction of TCE using Fe/Pd Nanoaggregates, Environmental Progress, American Institute of Chemical Engineers Journal of Environmental Progress, 2008
- Xu and Bhattacharyya, Modeling of Fe/Pd Nanoparticle-Based Functionalized Membrane Reactor for PCB Dechloritnaion at Room Temperature, Journal of Physical Chemistry, 2008
- LaSage, Sexton, Mukherjee,Fryar,Grebe Groundwater discharge along a channelized Coastal Plain stream, Journal of Hydrology, 2008

Presentations

- Bhattacharyya
  - Membrane Immobilized Nanostructured Metals for Detoxification of TCE and PCBs, NIEHS-SRP Annual Conference, 2008
  - Nanotechnology-Based Membrane Systems for Detoxification for Chlorinated Organics from Water, EPA International Environmental Nanotechnology Conference, 2008
  - Chloro-organic degradation from water by naonsized metallic systems by hydroxyl radical reaction, Engineering Conferences International, Tomar, Portugal, 2007
- Ormsbee
  - University of Kentucky Superfund Basic Research Program Research Translations Activities at the Paducah Gaseous Diffusion Plant, NIEHS-SBRP Annual Conference, 2008
- Ormsbee and Bonczek
  - Partnering with Universities In Support of Superfund Cleanup, NARPM, 2009,

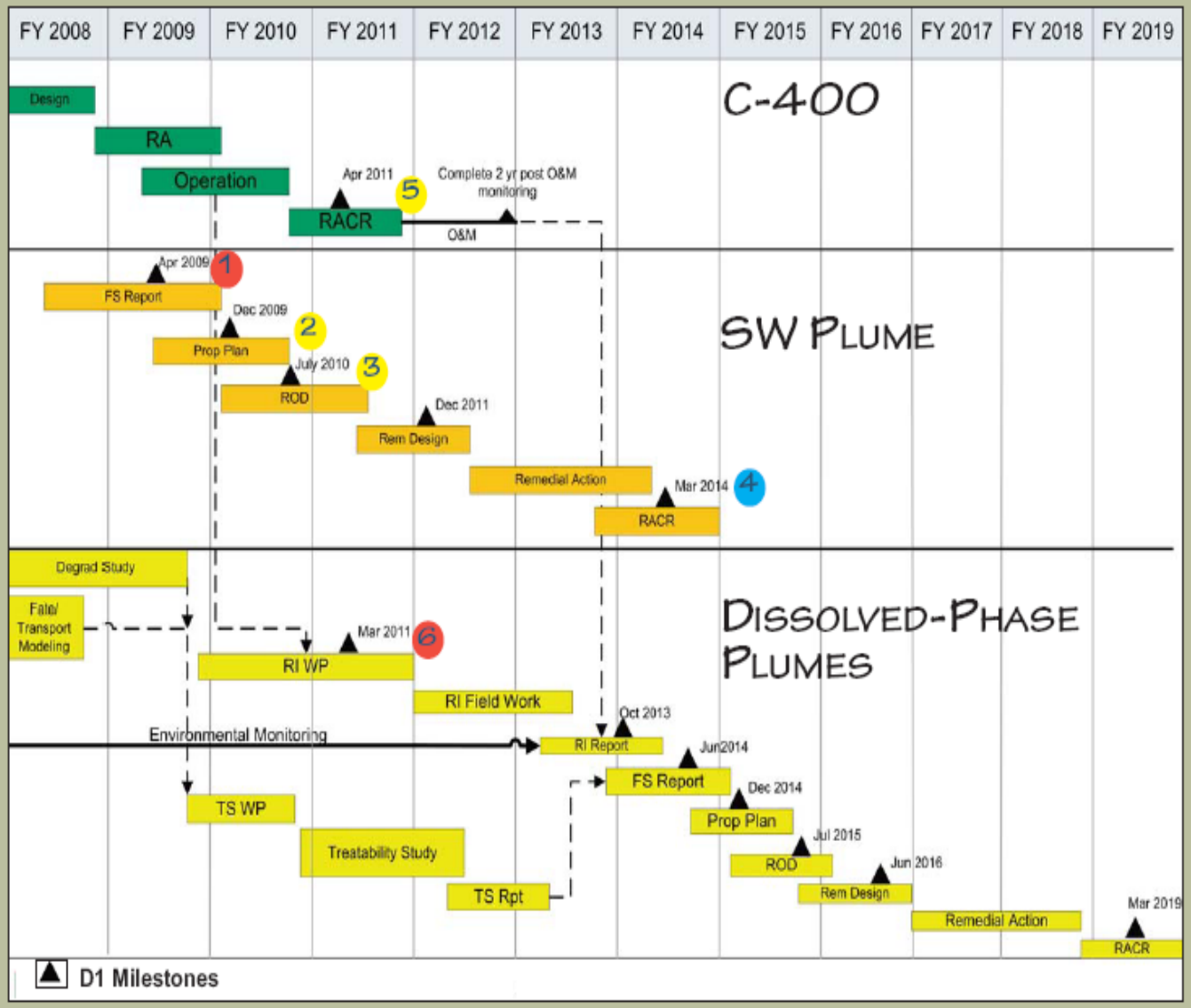
Project Goal

- To develop a Treatability Study Workplan for a Nano Particle Treatability Study at the PGDP.
  - Treatability Study (TS) Goal: “Demonstrate the feasibility and effectiveness of nanoparticles to remediate dissolved phase TCE in PGDP groundwater.”

Project Guidance

- Guidance for Conducting Treatability Studies Under CERCLA, EPA/540/R-92/071a, October 1992
  - Iron Filings Treatability Study Work Plan for the Northwest Plume Interim Remedial Action, DOE/OR/07-1271&D2 1995
  - Treatability Study Work Plan for the Permeable Treatment Zone, DOE/OR/07-1861&D1, 2000
  - Treatability Study Work Plan for C-Sparge, Groundwater Operable Unit, DOE/OR/07-2018&D1 2002

Groundwater Operable Unit Schedule

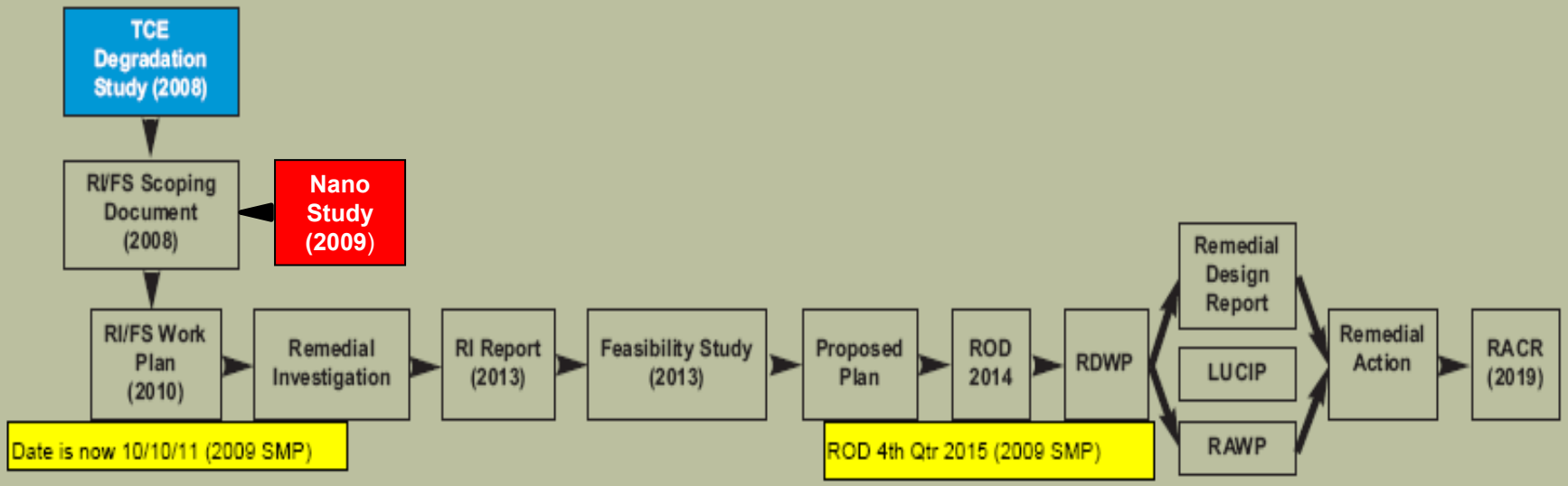


SMP Milestones

1. SW Plume FFS - 7/28/09
2. SW Plume Proposed Plan — 3/25/10
3. SW Plume ROD — 9/17/10
4. SW Plume Remedial Action Completion Report — 6/28/15
5. C-400 Remedial Action Completion Report — 4/26/2011
6. Dissolved-Phase Plume RI/FS Work Plan — 3/10/11 (planning date)

- FY-07 SMP Approved Enforceable Milestone included in FY-08 SMP
- FY-08 SMP Proposed New Milestone
- Out-year milestone proposed for evaluation/modification in FY09 SMP

Dissolved Phase Plume Schedule Overview and Status



Near-Term 2006 - 2009

- Support TCE Fate & Transport analysis by performing necessary fieldwork and analysis as identified by Fate & Transport Working Group
- Update groundwater model
- Develop and submit to regulators RI/FS Scoping Document

Out-Year 2010-2019

- Development and regulatory approval of RI/FS Work Plan
- Implement RI fieldwork
- Development and regulatory approval of RI Report
- FS development and regulatory approval
- Development and regulatory approval of Proposed Plan
- Development and regulatory approval of ROD and LUCIP
- Development and regulatory approval of Remedial Design Work Plan
- Development and regulatory approval of Remedial Design Report and Remedial Action Work Plan
- Implement remedial action
- Development and regulatory approval of Remedial Action Completion Report

Tentative Project Team

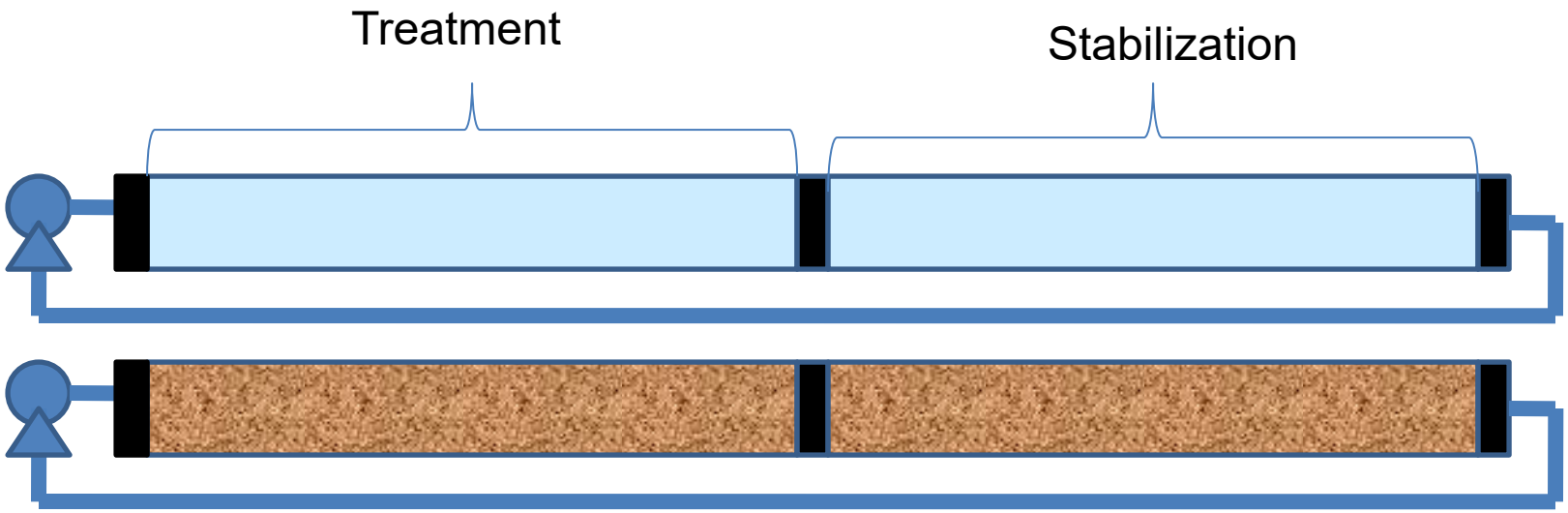
- Dr. Lindell Ormsbee (UK)
- Dr. D. Bhattacharyya (UK)
- Dr. Vasile Smuleac (UK)
- Scott Lewis (UK)
- Noah Meeks (UK)
- Steve Hampson (UK)
- Dr. David Sedlak (UC – Berkley)
- Dr. Subhas Sikdar (EPA – Cinn)
- Dr. Greg Lowry (Carnegie Mellon)
- Dr. Rich Bonczek (DOE)
- Dave Dollins (DOE)
- Jeff Carman (PRS)
- Brian Clayton (PRS)
- Ed Winner (EEC)
- Todd Mullins (EEC)
- Brian Begley (EEC)
- John Farrell (PRC)
- Walt Richards (PRC)
- Turpin Ballard (R4-EPA)
- Ben Bentkowski (R4-EPA)
- Elliot Jones (R4-EPA)

Project Draft Workplan

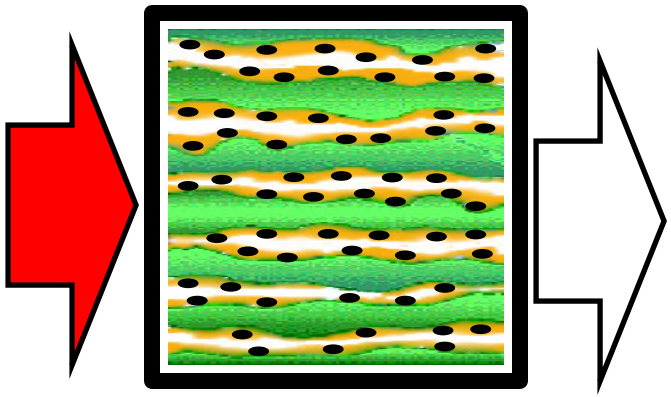
- Perform baseline experiments
- Perform ex-situ experiments at P&T site
- Characterize health and safety of proposed nano-particles
- Characterize aquifer geology, chemistry and flow path
- Perform tracer study to confirm flow path
- Perform in-situ experiments

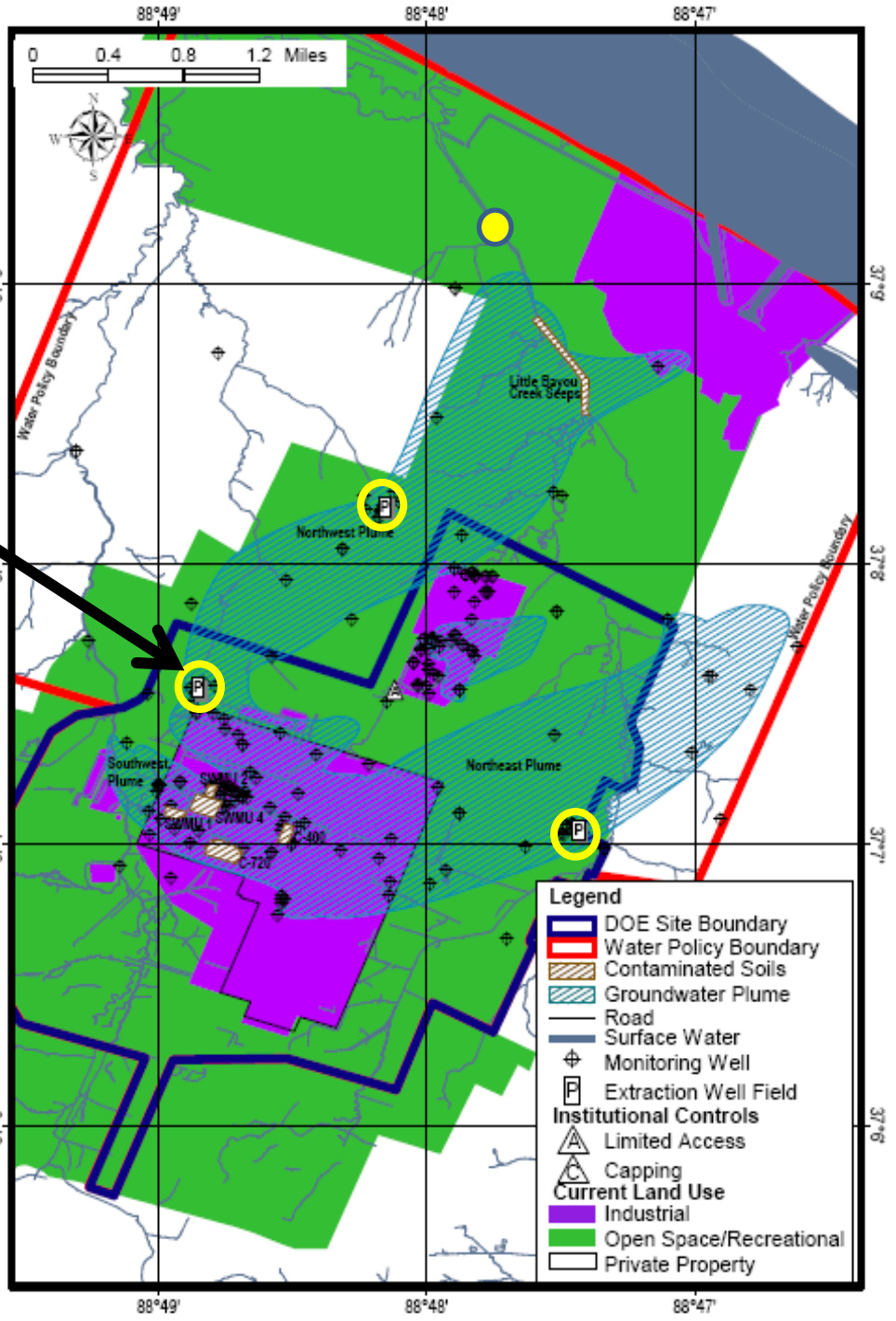
Perform Baseline Experiments

- Static (Batch) Experiments
  - Temperature
  - Oxygen
- Dynamic (Reactor) Experiments
  - Nano Particles (Fe/Pd)
  - Water/Media
  - Static (membrane)/Dynamic (particles)

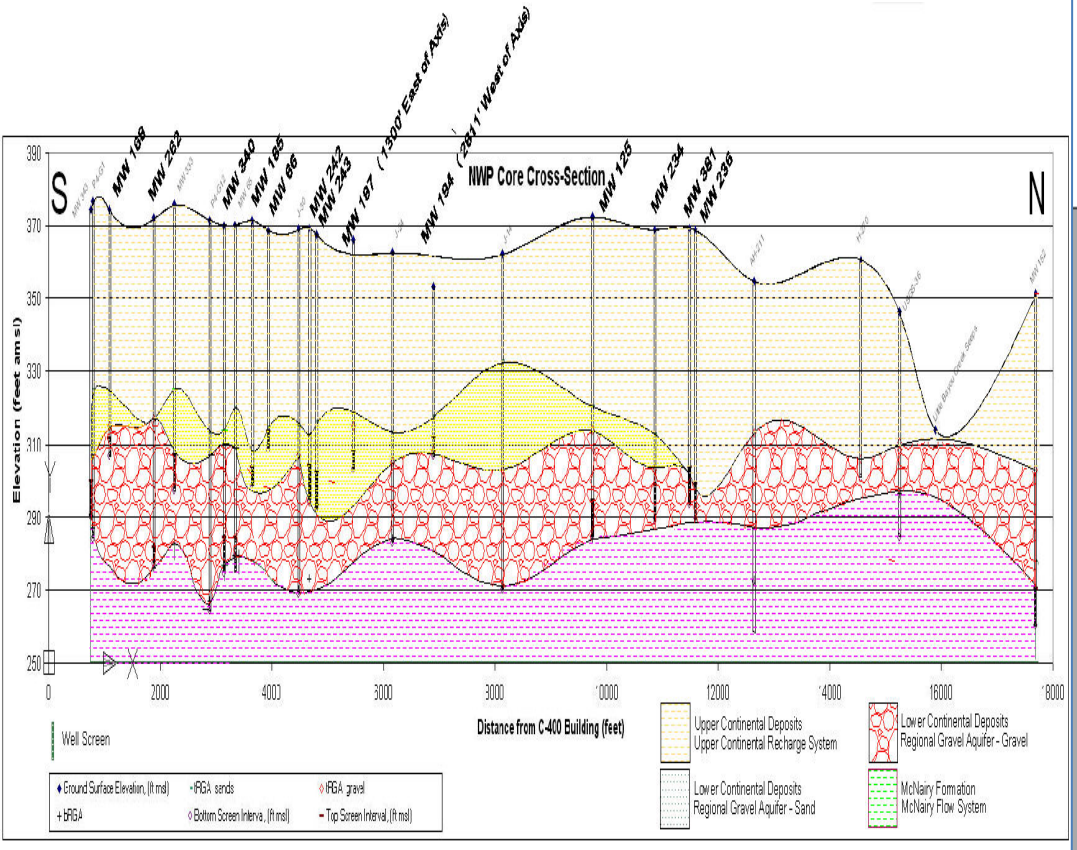


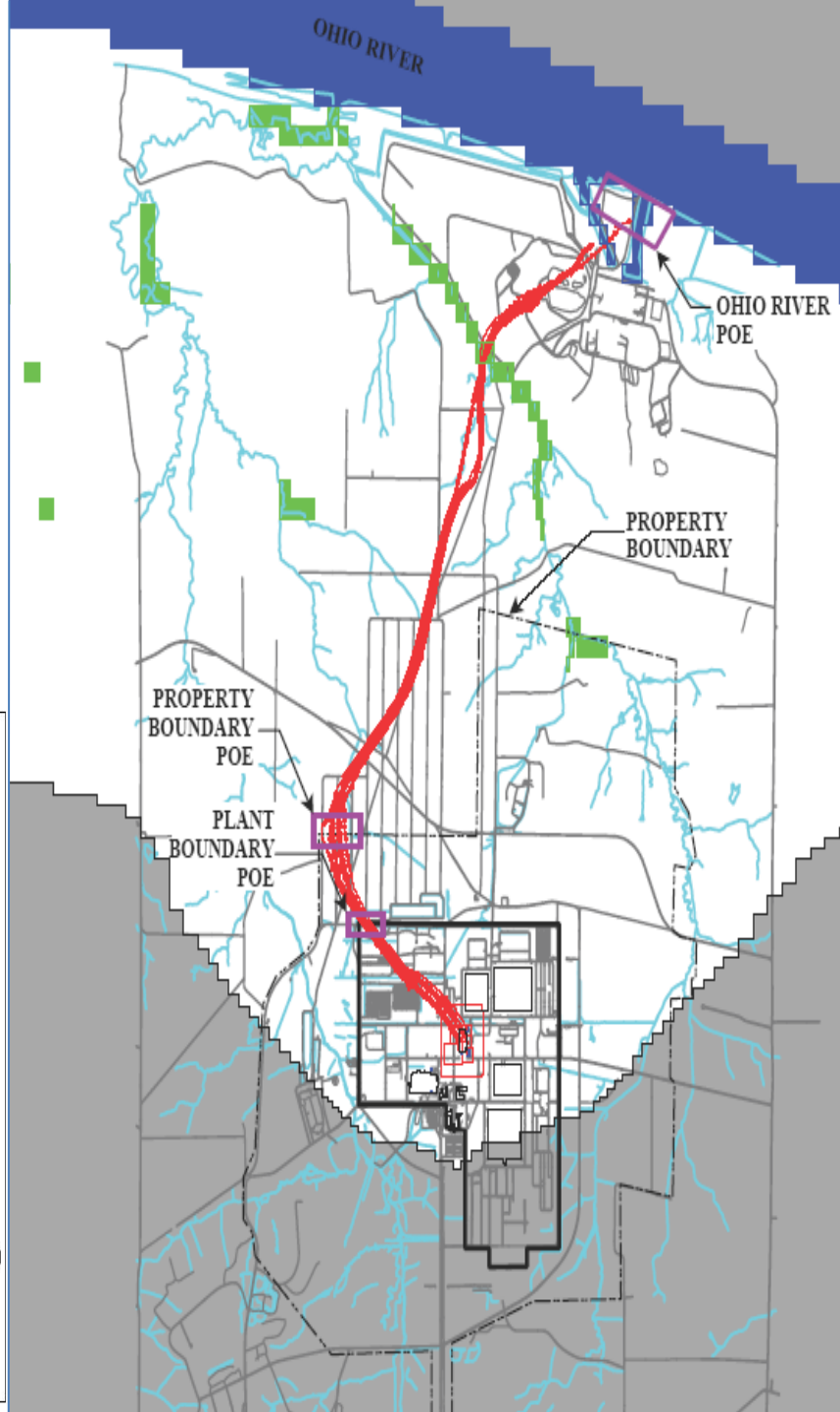
Perform Ex-situ Experiments at P&T site





Characterize Aquifer Geology and Flow Path





Ohio River

ash pond

94

95

96

97

98

99

100

LB1

LBC-1

LBC-2

LBC-3

LBC-4

LB6

LBC-7

MW137

PU

LBC-8

EB1

EB2

EB3

EB4

MS1

MS2

WB1

WB1.5

RR

LBC-6

WB2/2A/3

LBC-5

PGDP

Bayou Creek

Little Bayou Creek

N

(a)

IL

MO

KY

study area

TN

stream gauging site

spring

monitoring well

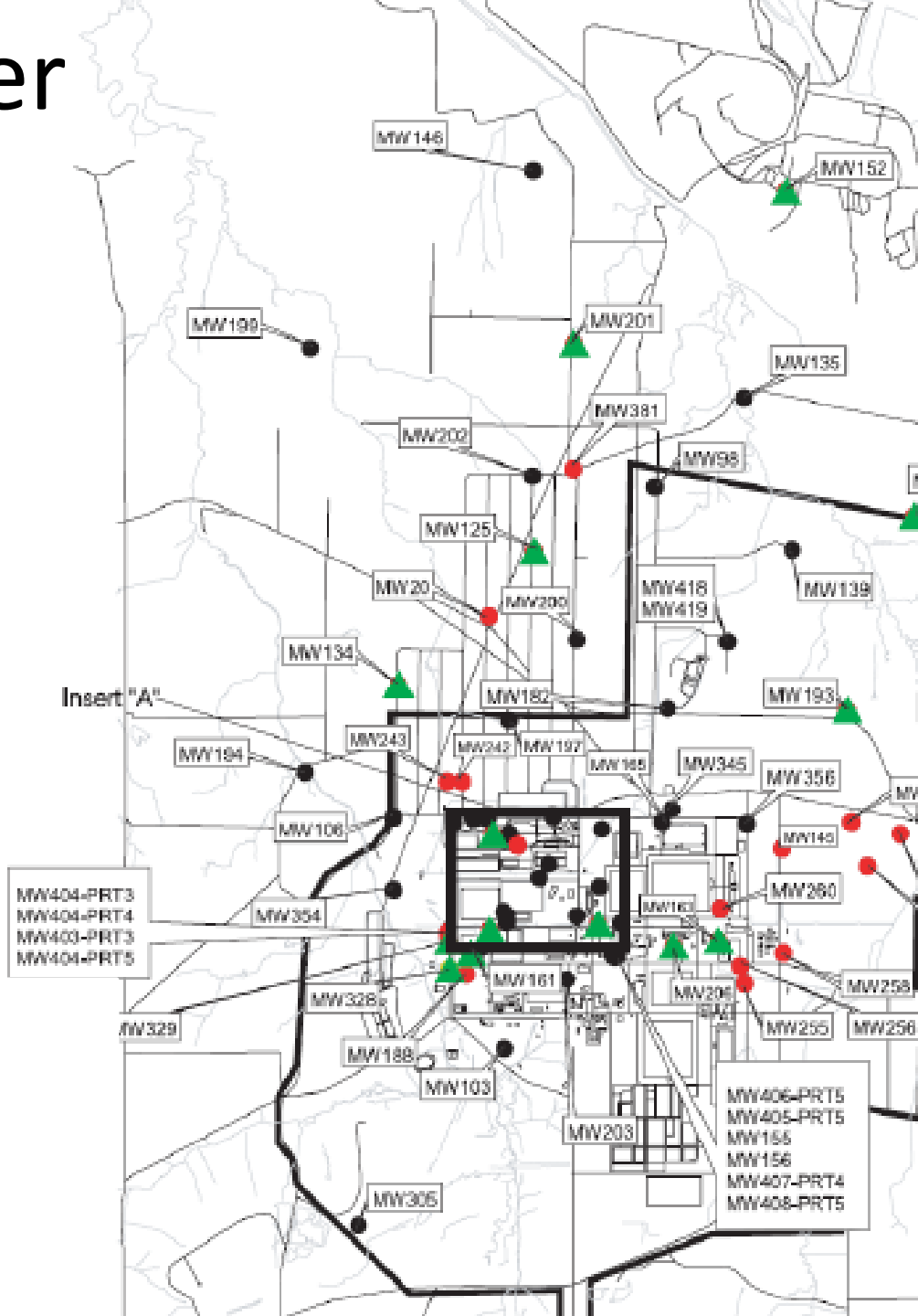
0 500 1000 m

Characterize Aquifer Chemistry

Table C.18. Surveillance Geochemical Wells (35)
MW20
MW99
MW100
MW125
MW134
MW145
MW152
MW161
MW163
MW188
MW193
MW206
MW201
MW242
MW243
MW255
MW256
MW257
MW258
MW260
MW261
MW288
MW291
MW292
MW328
MW329
MW339
MW343
MW381
MW403 Port 3
MW404 Port 3
MW404 Port 4
MW404 Port 5
MW409
MW414

Table C.19. Surveillance Geochemical Annual Analytical Parameters

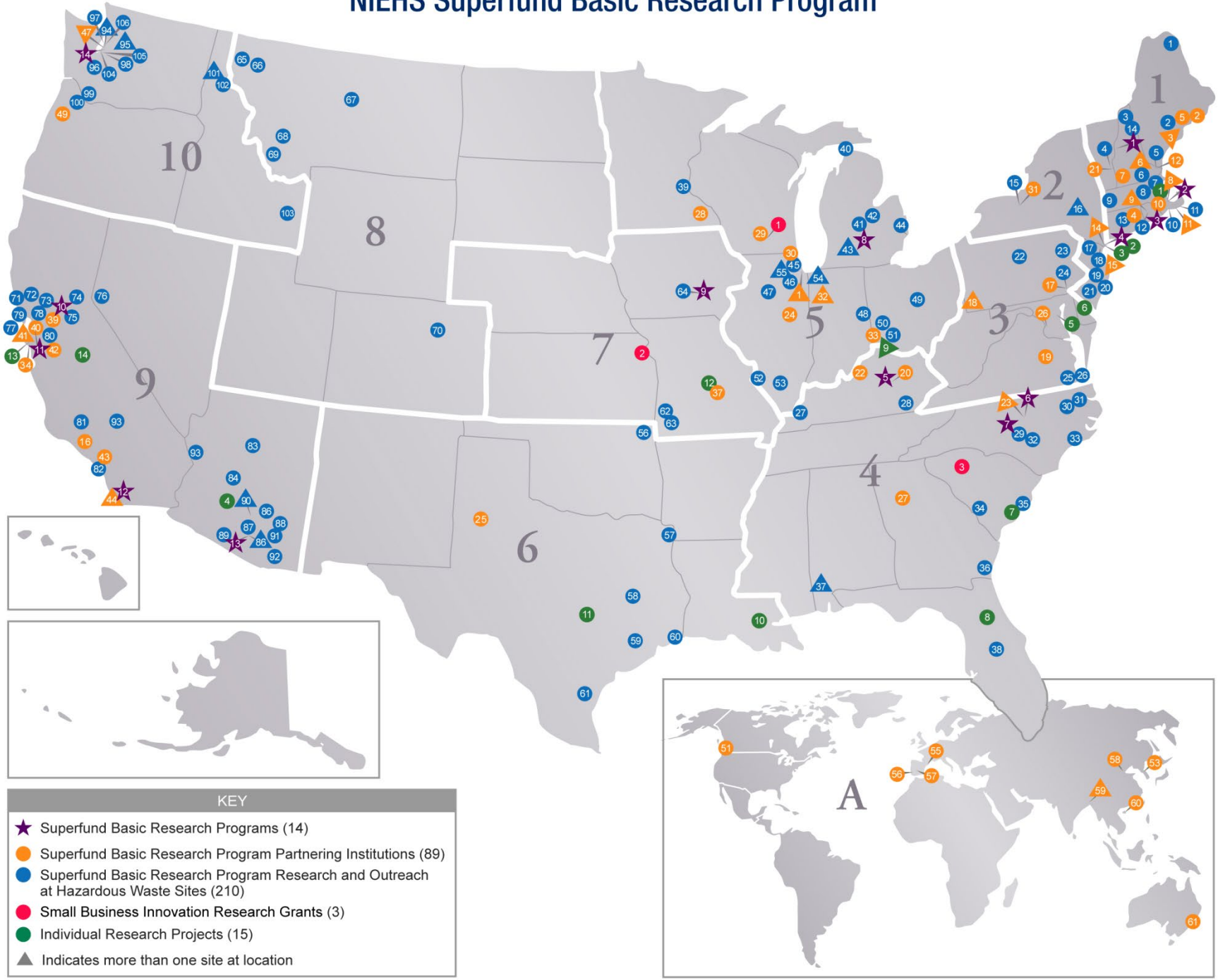
Other	Metals (total and dissolved)*
Sulfate	Aluminum
Nitrate	Antimony
Total Organic Carbon	Barium
Chloride	Beryllium
Total Dissolved Solids	Cadmium
Silica	Calcium
Fluoride	Chromium
Phosphate	Cobalt
	Copper
Field Parameters	Iron
Barometric Pressure	Lead
Specific Conductance	Magnesium
Depth to water	Manganese
Dissolved Oxygen	Molybdenum
Eh	Nickel
pH	Potassium
Temperature	Silver
Turbidity	Sodium
Alkalinity	Zinc
Ferrous Iron	Arsenic
	Mercury
Volatiles	Selenium
Ethene	Uranium
Ethane	
Methane	**PCBs**
	PCB, Total
	PCB-1016
	PCB-1221
	PCB-1232
	PCB-1242
	PCB-1248
	PCB-1254
	PCB-1260
	PCB-1268



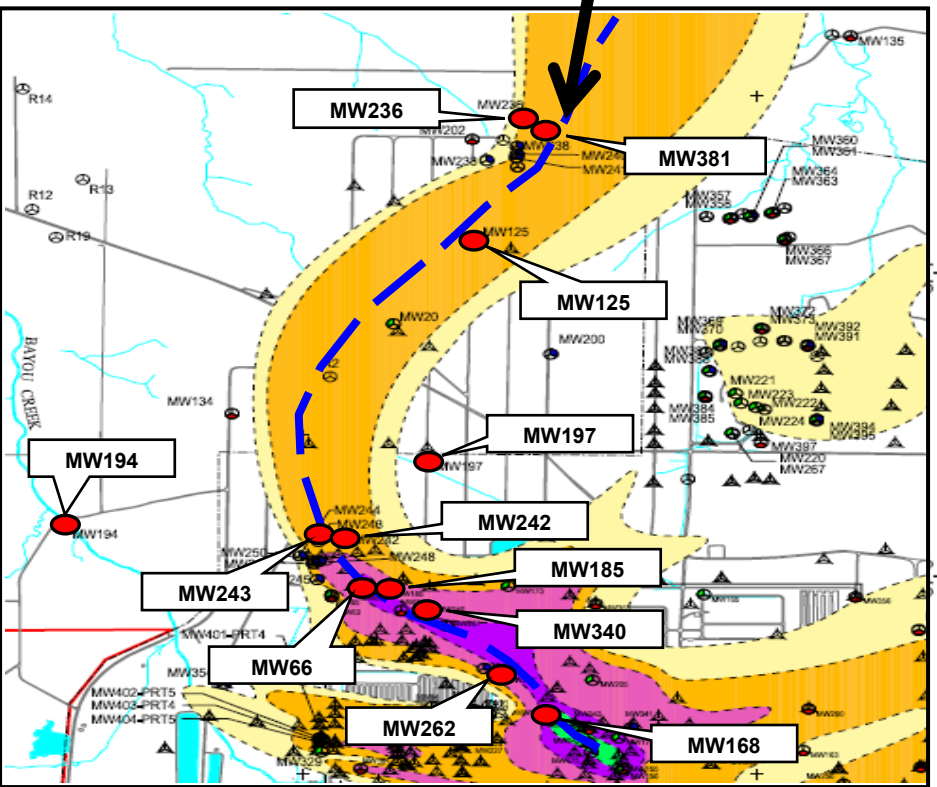
Characterize health and safety of proposed nano-particles

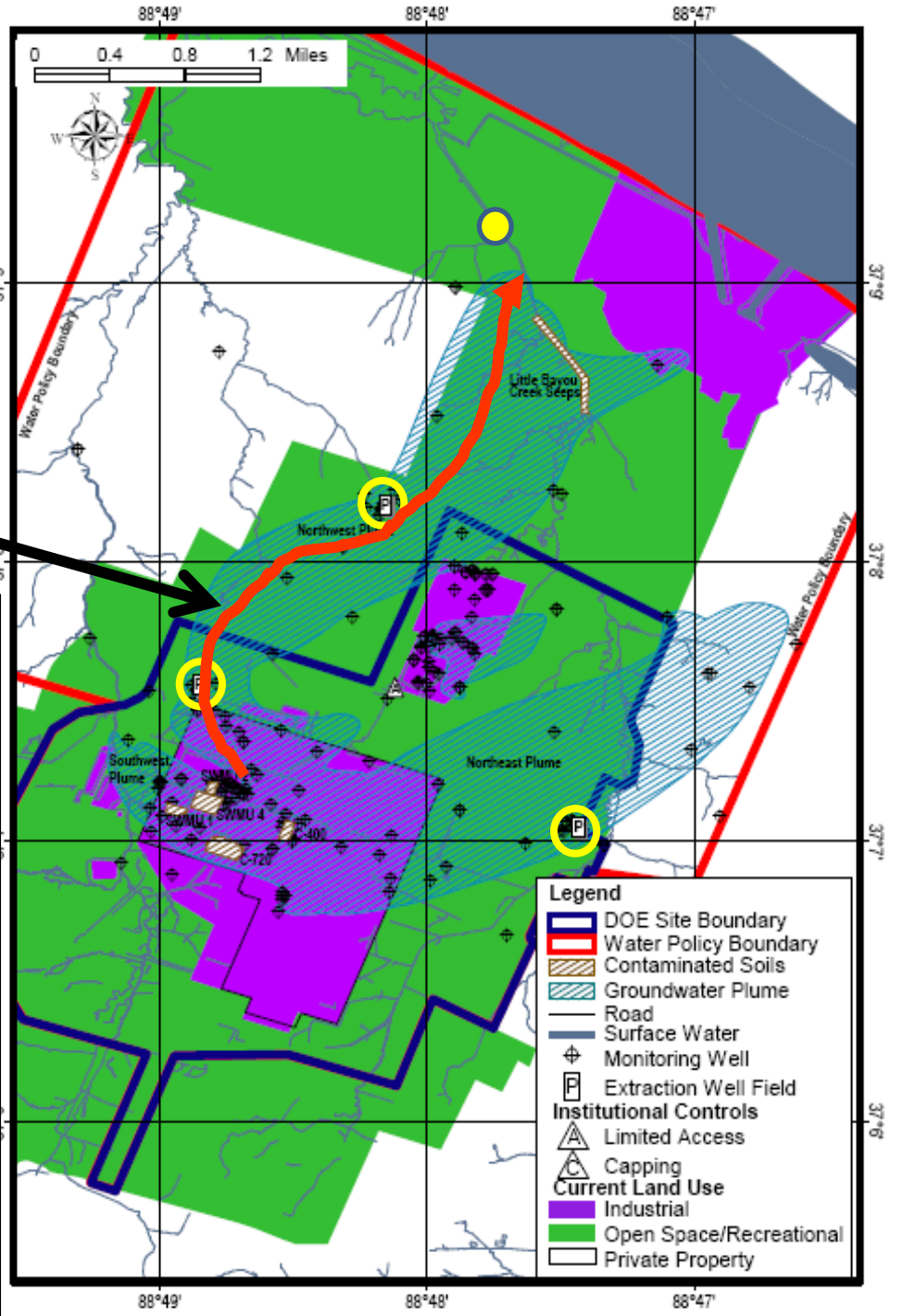
- EPA National Risk Management Research Laboratory
  - Dr. Subhas Sikdar, Asssociate Director for Science
- NIEHS-SRP
  - Bill Suk, Director
- NIEHS-SRP
  - 14 programs

NIEHS Superfund Basic Research Program

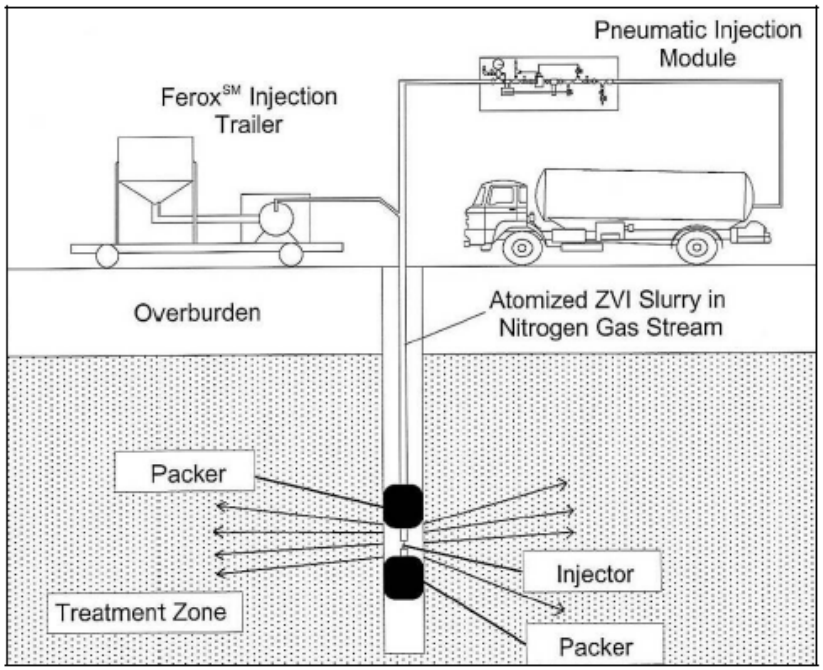


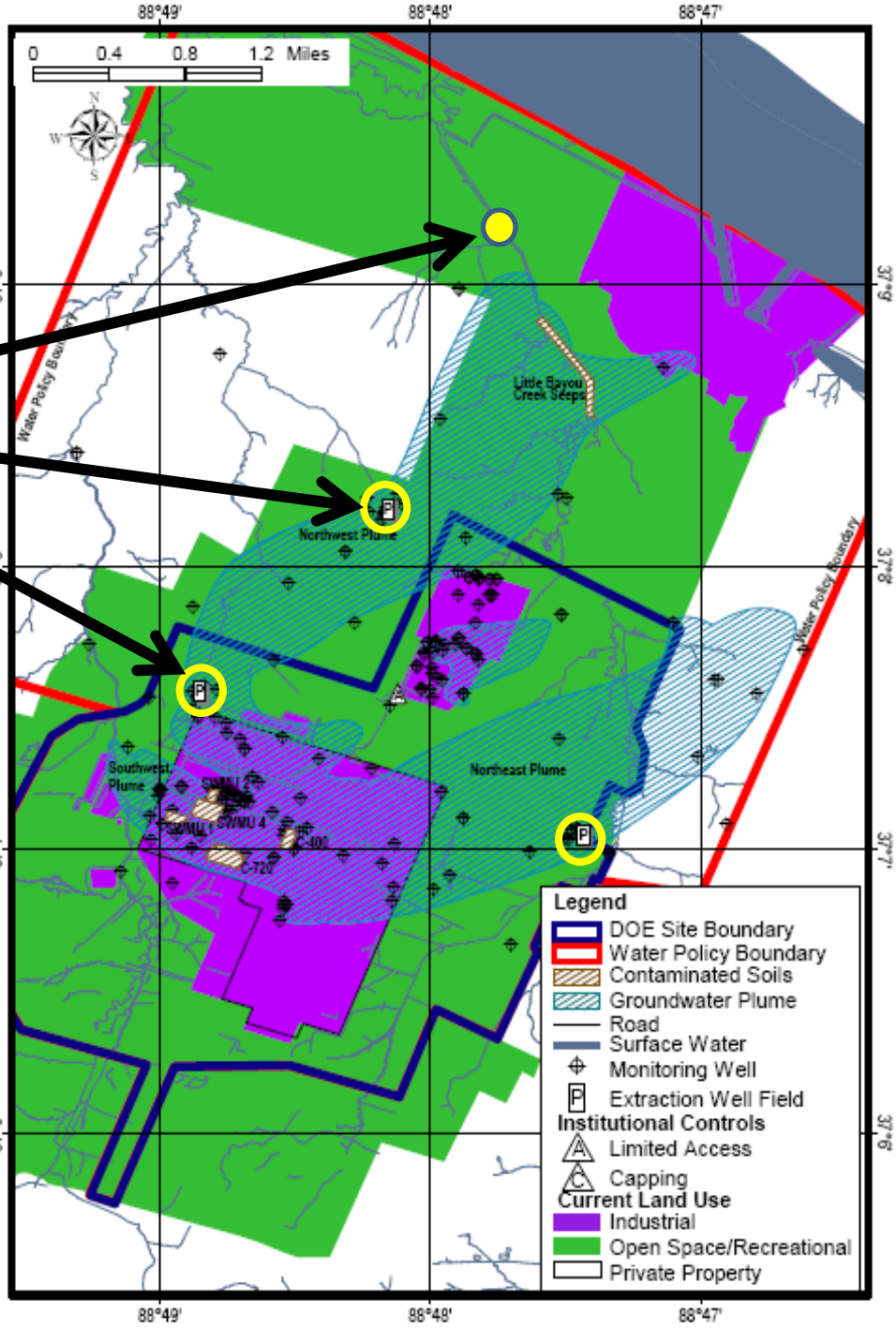
Perform Tracer Study to Confirm Flow Path





Perform In-Situ Experiments





Tentative Project Schedule

- Internal Project Kickoff Meeting (July 29th)
- Internal Project Team Meeting (August 17th)
- *Project Team Kickoff Meeting (Sept 2nd)*
- *Scoping Document Final (Nov 20th)*
- *Treatability Study Final (March 19th)*

Additional Research

- EPA International Environmental Nanotechnology Conference: Applications and Implications, October 2008
  - Remediation
  - Fate and transport
  - Water Pollution Control
  - Toxicity
- Bhattacharyya, Sedlak, and Ormsbee, NIEHS-SRP Supplemental Award, $300,000, October 2009-September 2011
  - Reductive pathways
  - Oxidative pathways

Additional Studies

- Cost and Performance Report Nanoscale Zero-Valent Iron Technologies for Source Remediation, Naval Facilities Engineering Command, 2005

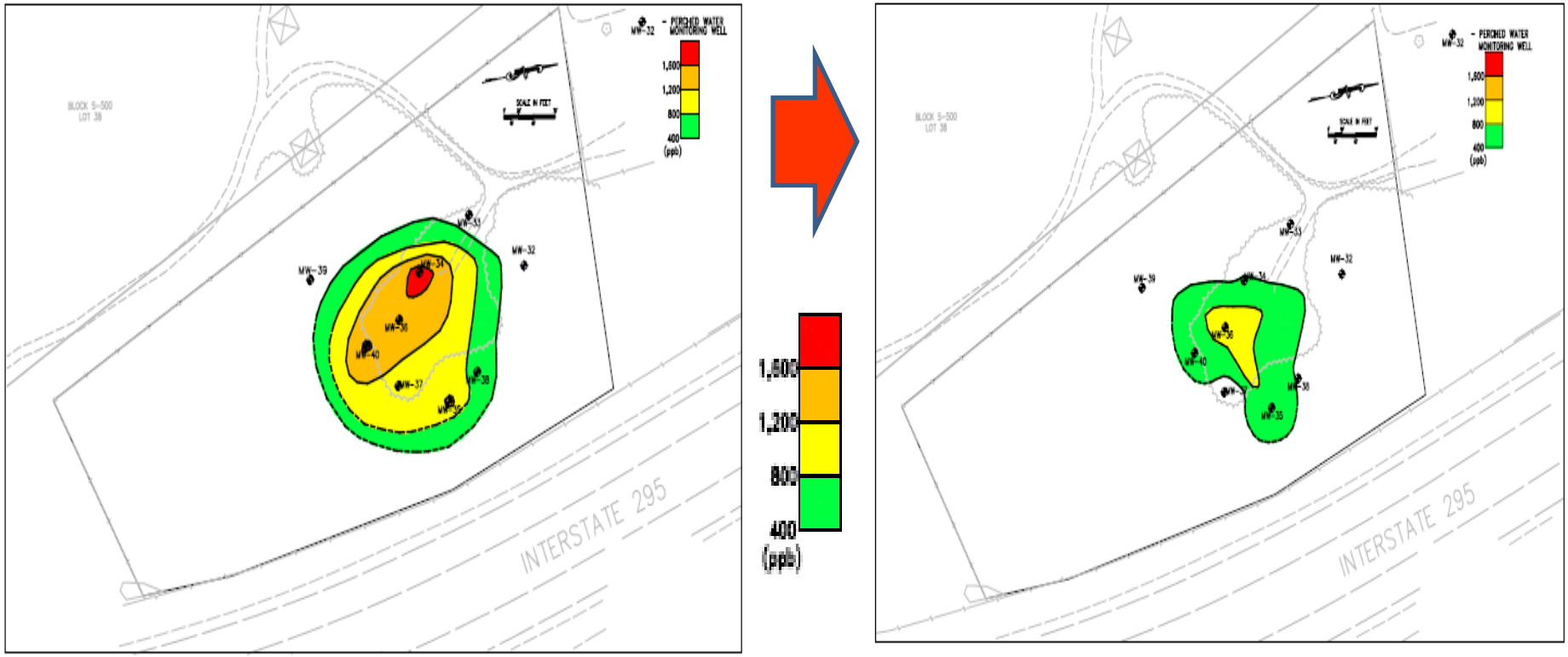
Table 3-2. Cost Breakdown for the Hunters Point, NAS Jacksonville, and NAES Lakehurst Sites

	Hunters Point Study #1	Hunters Point Study #2	NAS Jacksonville	NAES Lakehurst
	$31,000 - Mobilization		$28,000 - Mobilization	
	$62,000 - Labor/Drilling for injection		$52,000 - Monitoring Well Installation	$24,400 - Monitoring Well Installation
	$100,000 ($32,500 of which are for ZVI) - Equipment/Supplies for injection:	$770,000 – Treatability study field effort	$67,000 ($37,000 of which are for NZVI) - Injection/Circulation Events	$154,600 - NZVI Treatment
	$96,000 – Monitoring, IDW disposal, and miscellaneous costs	$452,000 – Monitoring, sampling, and analysis	$112,000 – Monitoring and investigation-derived waste (IDW) disposal, miscellaneous costs	$58,400 – Sampling and Analysis
		$168,000 – Project manage-ment, data management, and reporting	$153,000 - Project Management, Work Plan, Bench-Scale Study	$18,100 - Reporting
Demonstration Total:	**$289,000**	**$1,390,000**	**$412,000**	**$255,500**
Treatment Volume (yd^3):	**1,683**	**27,778**	**967**	**9,500**
Cost per yd^3 of Soil Treated:	**$172**	**$50**	**$426**	**$27**

Additional Studies

Full-Scale Nanoiron Injection for Treatment of Groundwater Contaminated with Chlorinated Hydrocarbons, Varadhi, et al., PSE&G Trenton Switchyard, New Jersey

Groundwater contaminants targeted for reduction consisted of 1,1-dichloroethane (1,1-DCA), 1,1-dichlorethene (1,1-DCE), 1,1,1-trichloroethane (1,1,1-TCA), 1,2-dichloroethane (1,2-DCA), and trichloroethene (TCE).



PARS International