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# Combining ISCO and ISB Under a Performance-Based Project Delivery

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## Alameda Point Project Attributes

### Performance-based Fixed Fee Contracting and Project Delivery

- 10% Retention of Construction Costs until Commercial Remedial Goals
- Turnkey Eight Project Documents (RD, RAWP, SAP, LUC-RD, WMP, etc.)

### Combination of Remedial Technologies

- Navy Specified In-situ Bioremediation (ISB)
- TRW made ISB-only not viable
- Geosyntec Offered In-situ Chemical Oxidation Enhanced ISB

### Combination of Delivery Methods

- Passive (Direct Emplacement) and Active Delivery (DPT)
- Auger Borings
- Biovent Wells
- Three Phases Direct Push Injections



# Performance-based Project Delivery

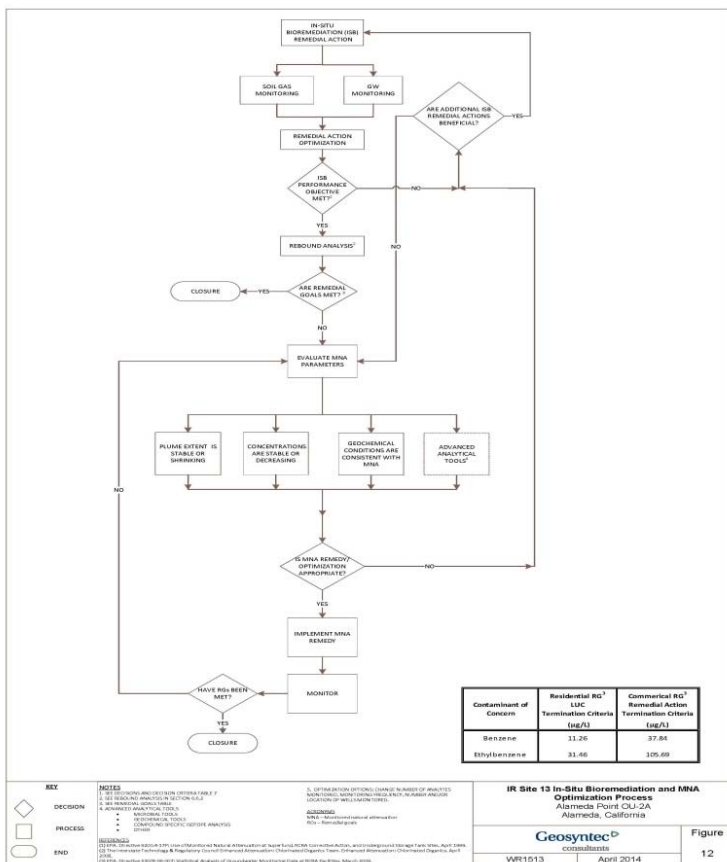
## Performance Objectives

- Reduce Concentration 90%
- Dissolved Oxygen Greater than 4 mg/L

## Decisions and Decision Criteria

- Biovent Operational Mode
- Continued ISB Evaluation Criteria
- MNA Transition
- Remedy Optimization Criteria

## Land Use Controls - Remedial Design





<b>Contaminant of Concern</b>	<b>Residential RG LUC Termination Criteria (<math>\mu\text{g/L}</math>)</b>	<b>Commercial RG Remedial Action Termination Criteria (<math>\mu\text{g/L}</math>)</b>
Benzene	11.26	37.84
Ethyl benzene	31.46	105.69

- The remedial goals (RGs) are the basis for measuring the success of remedial activities.
- Commercial vapor intrusion criteria are remedial action RGs
- Residential vapor intrusion criteria is the institutional controls termination criteria for residential reuse restrictions



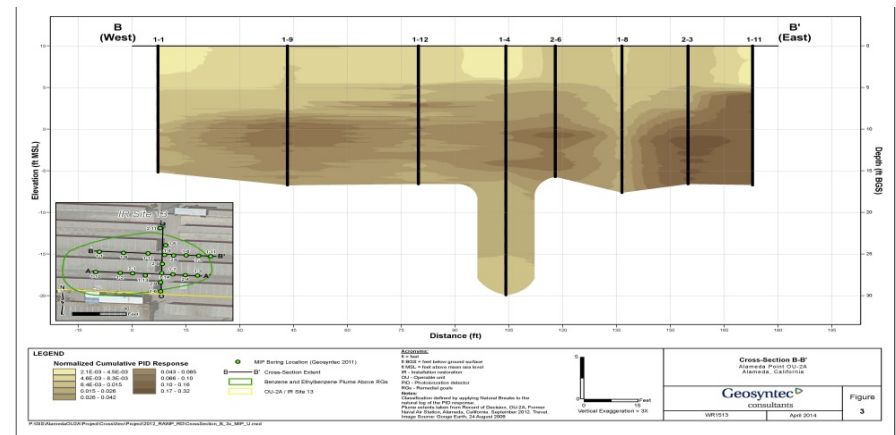
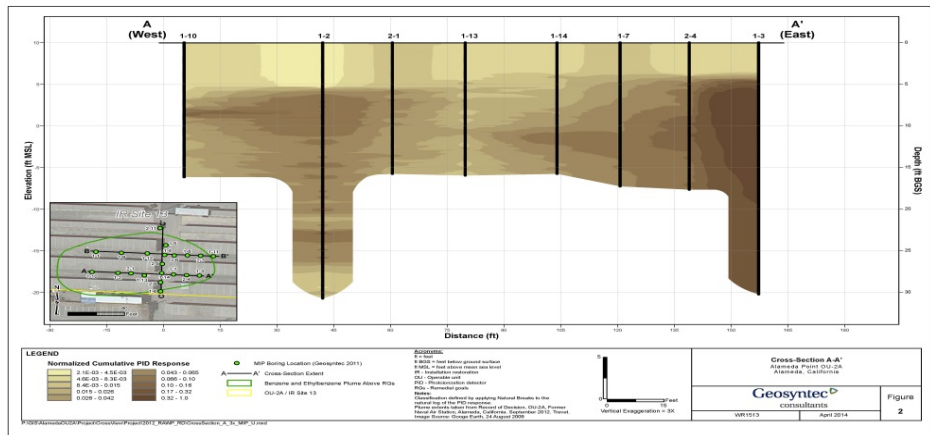
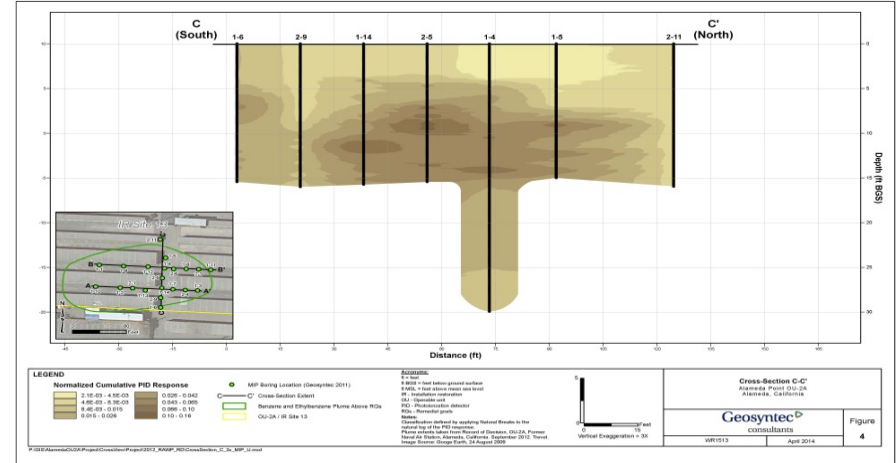
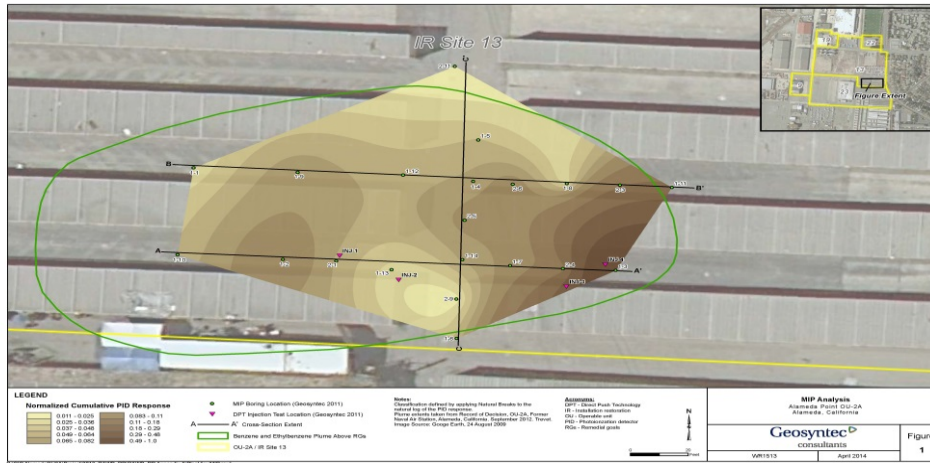
# Pre-Remediation Activities

Map the geology and extent of benzene within the target remediation zone.

Activities included:

- **Membrane Interface Probe (MIP) Investigation**
  - Ratio of Photo-ionizing Detector to Flame-ionizing Detector response
- **Injection Testing**
  - Establish pressures and flow-rates for DPT Injections
- **Biodegradation study**
  - Evaluate limitations on aerobic biological degradation of benzene and ethylbenzene
  - Results indicated that  $O_2$  is the rate limiting factor

Remedial design focused on increasing and maintaining oxygen concentrations using multiple delivery methodologies





# Combining ISB and ISCO

Partial oxidation of complex wastes improves bioavailability

Challenges include:

- Selecting the dosage of chemical and biological amendments
- Determining the temporal separation of amendments
- Determining performance monitoring metrics to guide effective technical decision making

When properly implemented, can effectively minimize the overall remediation program costs and time







## ISCO DOES NOT STERILIZE SOIL

Journal of Ozone Science and Engineering (1965 forward)

Marvin et al (1998)

- Continuous ozone – decreased population density and stressed community

Klens et al (2001)

- Populations decreased, released DOC stimulated aerobic activity

Droste et al (2003)

- Persulfate/permanganate stimulated reductive dechlorination

Fernandez et al (2004)

- $\text{NaMnO}_4$  IRM stimulated reductive biological activity
- Case Example #2

Azadpour-Keeley et al (2004)

- No change in community structure - stimulated activity briefly

Sahl and Munakata-Marr (2006)

- The Effects of In Situ Chemical Oxidation on Microbiological Processes: A Review



# Amendment Selection

Klozur® CR – 50:50 of sodium persulfate and calcium peroxide

- Provides short-term ISCO to partially oxidize non-target long-chain hydrocarbons
- Provides long-term source of oxygen and base to maintain neutral pH

PermeOx® Plus - calcium peroxide

- Hydrolysis of calcium peroxide induces the alkaline activation method
- Increase calcium hydroxide concentrations to propagate radical oxidative reactions

Limestone gravel

- Buffer pH to offset acidity from oxidation of hydrocarbon and iron

Atmospheric Oxygen

- Bioventing blowers injected over 100 liters/minute per well
- Passive turbines produced



## Delivery Methods

### Passive

- 69 12” auger borings to 15 ft bgs
  - Klozur® CR in backfill
  - Limestone gravel (buffer pH)
  - Surface seal
- Provide primary porosity to enhance delivery and distribution

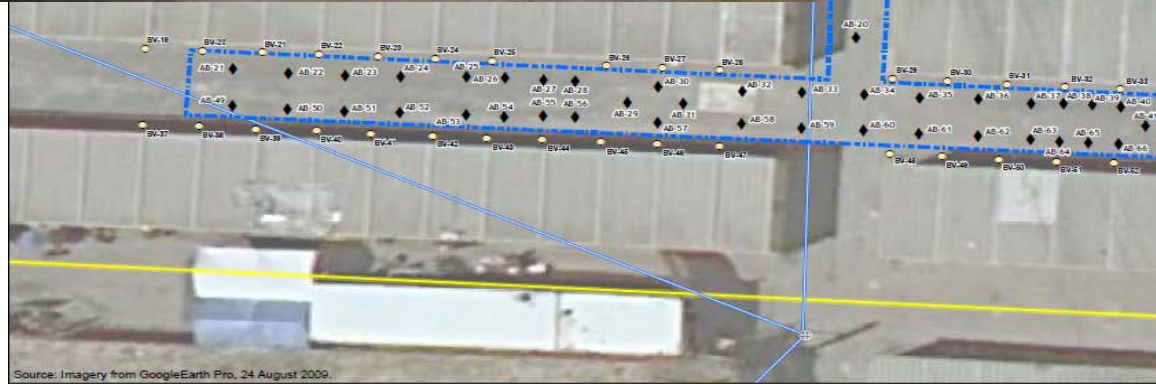
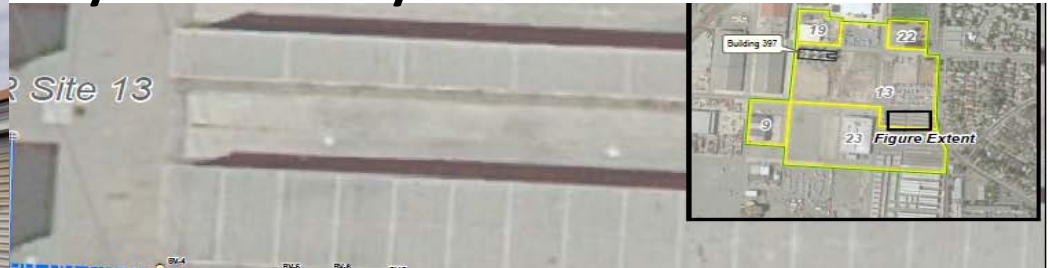
### Active

- Replenish oxidant and oxygen
- Biovent wells in blowing (fan) and suction (wind-driven)
- DPT Locations adjusted to O&M data





# Biovent Treatment System Layout





# Direct Push Injection Approach





## Direct Push Injections

- Three phases of DPT Injections
  - First (August 2014) – Klozur® CR
  - Second (December 2014) – Calcium Peroxide
  - Third (March 2015) – Klozur® CR
- First phase uniform distribution throughout the remedial area
- Second and third events
  - 15 Locations based on benzene, ethylbenzene in groundwater
  - 10 Locations selected based on DO values





## Bioventing System

Oxygen delivery to vadose zone, capillary fringe and groundwater

54 46-cm auger borings to 3-m depth

- Klozur® CR in backfill
- Limestone gravel (buffer pH)

Low Pressure Blowers

- Introduce air to stimulate microbial activity

Wind-turbines in suction mode

- Induce pressure gradients to enhance air distribution

Screens set from 1.5 to 6 ft bgs

- Tidal influence limited air injection in winter





## Results

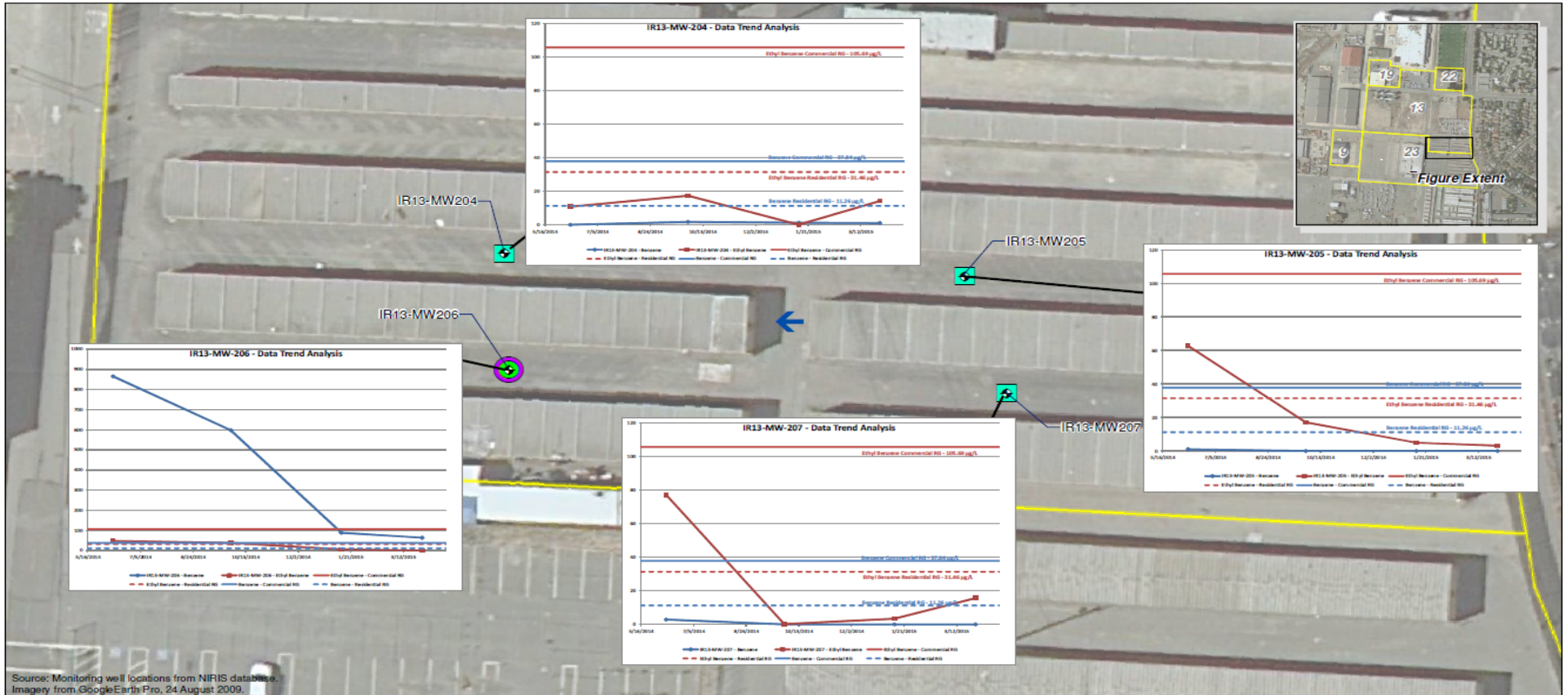
Within 9 months benzene and ethyl benzene concentrations in groundwater reduced to below residential RGs or 90% from baseline

- All monitoring wells below residential RGs for ethyl benzene
- 3 of 4 monitoring wells below residential RGs for benzene
- MW-206 reduced from 865 ug/L to 62 ug/L for benzene – still exceeds commercial level RGs

PID reading decreased 90% from baseline

Soil vapor oxygen greater than 20%







## Lessons Learned

- Navy was less agile than expected – delays are the norm
  - One Year O&M option to be exercised by 30 Sept
- Tidal influence limited winter bioventing operations
  - Biovent fans overheated and required replacement
- Persulfate-based ISCO can be coupled to Aerobic ISB
  - ISCO does not sterilize soil
- Shortened remedial timeframe and lower project costs