Remediation: When is Clean, Clean Enough?

November 20, 2014

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OUTLINE – 2 NEW ENGLAND SITES

- SITE 1: Large LNAPL “Free Oil” Site – urban area
  - Developed during WWII as a bulk oil terminal
  - 30 acres, deep water frontage, highly developed (and valuable) area –no longer used for oil storage
  - Non-Aqueous Phase Liquid (LNAPL-oil) over 10 acres

- SITE 2: Small Hydrocarbon and Ethylene Glycol GW Impacted Site – rural area

SITE 1 LAYOUT & IMPACTS

SITE 1- LARGE NEW ENGLAND LNAPL SITE – OUR STARTING POINT

Client spent approx. $12 Million/8 years with another consultant prior to our involvement:

- 420 Monitoring Wells
- Multiphase extraction (MPE) system with thermal oxidizer was being used to remove LNAPL and treat groundwater
- Oil skimmers used to recover small amounts of LNAPL
- Remediation standard = less than 0.5 inches of LNAPL measured in MW
- Remedial approach was to remove "all the oil"
- The client was spending approx. $1 million/yr to address impacts mostly by running the MPE system

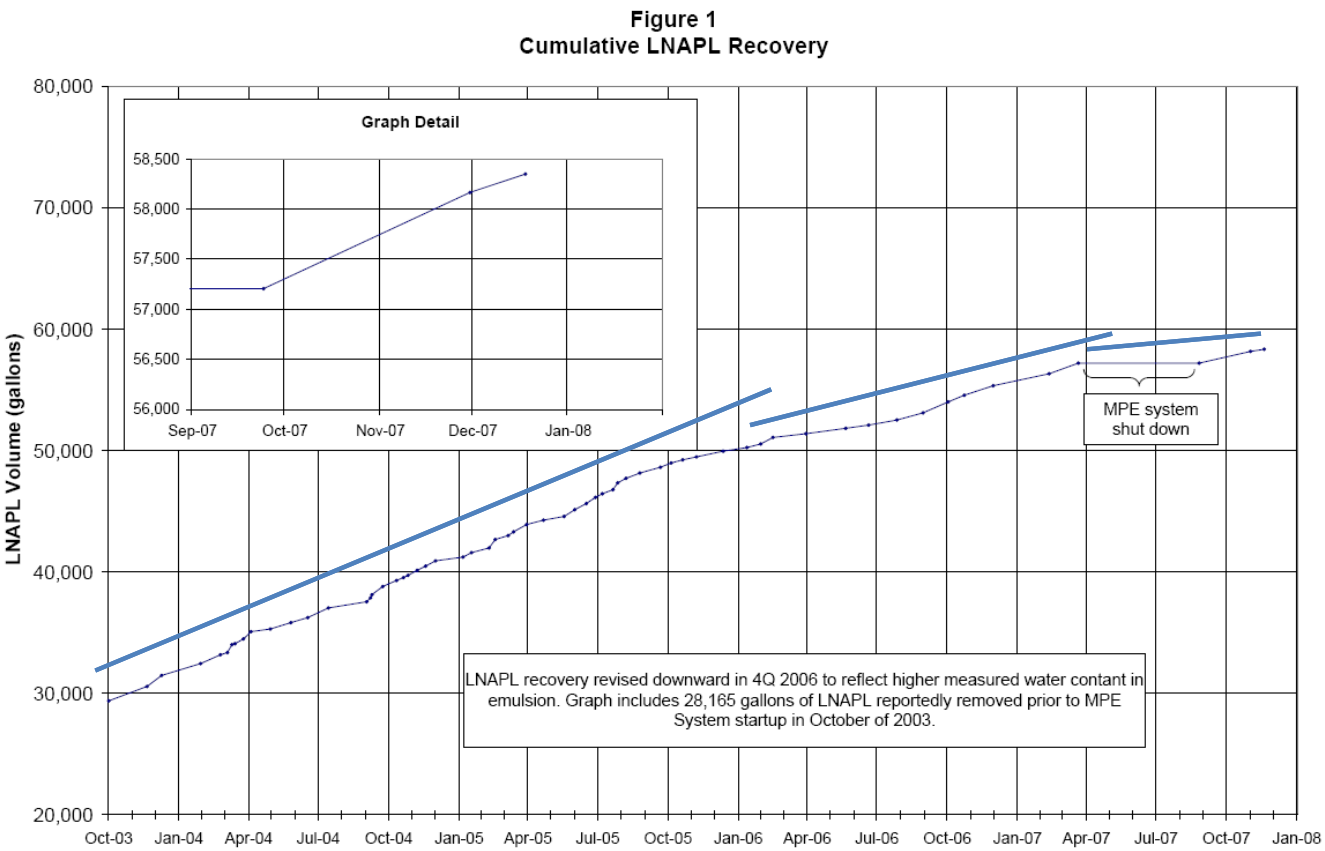
SITE 1- OUR STRATEGY: DEVELOP CONCEPTUAL SITE MODEL

Apply Current LNAPL Science to Evaluate Technical Impracticability of 0.5 inch LNAPL Standard:

- Understand oil types
- Define residual oil saturation C_{sat}/C_{res}
- Characterize GW, Soil Gas impacts
- Consider oil viscosity
- Understand LNAPL mobility
- Evaluate risks to human health and the environment
- Look at trends

- Assess existing remedial approaches

SITE 1: ASSESS MPE SYSTEM RESULTS (5+ years)

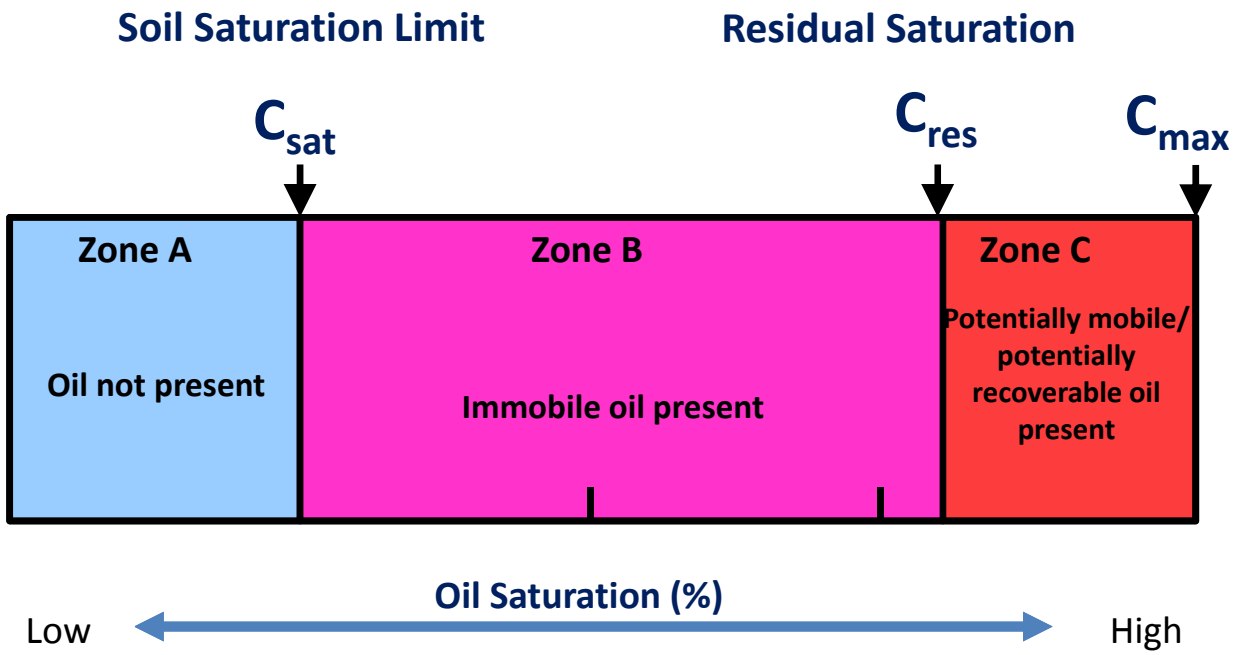


Declining LNAPL recovery

- Pumping more water, less oil
- Increasing energy costs (cracking chemistry, trucking waste streams, etc.)
- Applied Oil Field Recovery Curve Analysis

CONCLUSION: Remedy Not sustainable

Oil Mobility & Recoverability Is Governed By Soil Saturation



SITE 1- CSM FINDINGS

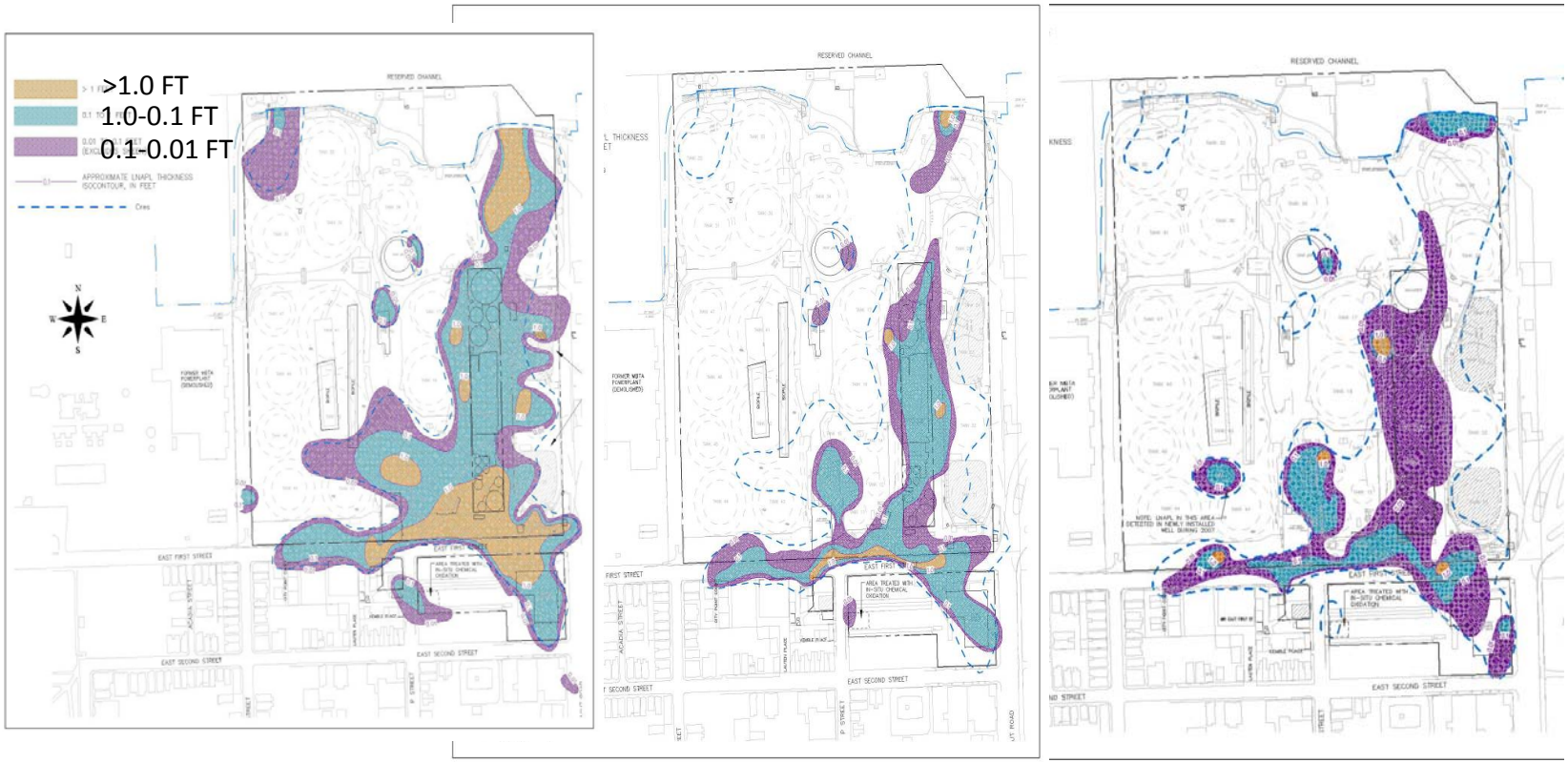
- LNAPL Low mobility
- Total oil recovered is 58,000 gallons
- MPE system removed only 15 gal/day LNAPL
- 200,000 to 300,000 gallons of oil remain in soil at residual saturation (not recoverable)
- Oil not readily soluble - GW standard was met
- Oil was not volatile – soil gas concentrations met standards
- LNAPL at steady state or shrinking

SITE 1- UNSUSTAINABLE REMEDY

- We understood that the remedial approach previously implemented by others was not sustainable:
  - LNAPL skimmers were not effective- removing < 1 gal/mo
  - MPE system used 20,000 gal Propane per month
  - Electricity costs $2,000-$3,000 per month
  - Off-site shipments of MPE waste averaged 4,000 gals/3 days
  - MPE system removed 6.1 million gallons of groundwater
  - Actual LNAPL removed was approximately 58,000 gallons (less than 1% of total fluids removed by MPE) and rate of removal was declining
  - Remedial costs were averaging $1M/yr – no end in sight

For every gallon of diesel fuel removed, the MPE system expended energy equal to approximately 140 gallons of diesel to do it.

SITE 1- DATA SHOW SHRINKING LNAPL – 3 YEARS



SITE 1- NATURAL DECAY DEMONSTRATED

Natural depletion rate (calculated from methane flux) was much greater than the amount of LNAPL recovered by the active systems

(80 gal/day via natural decay vs 15 gal/day via active treatment)

SITE 1 – CONCLUSION

- MPE system ineffective
- LNAPL recovery efforts would not achieve standards
- Widespread LNAPL and residual soil impacts remain
- Human health risks < $1x10^{-5}$ ILCR demonstrated
- Natural attenuation effective

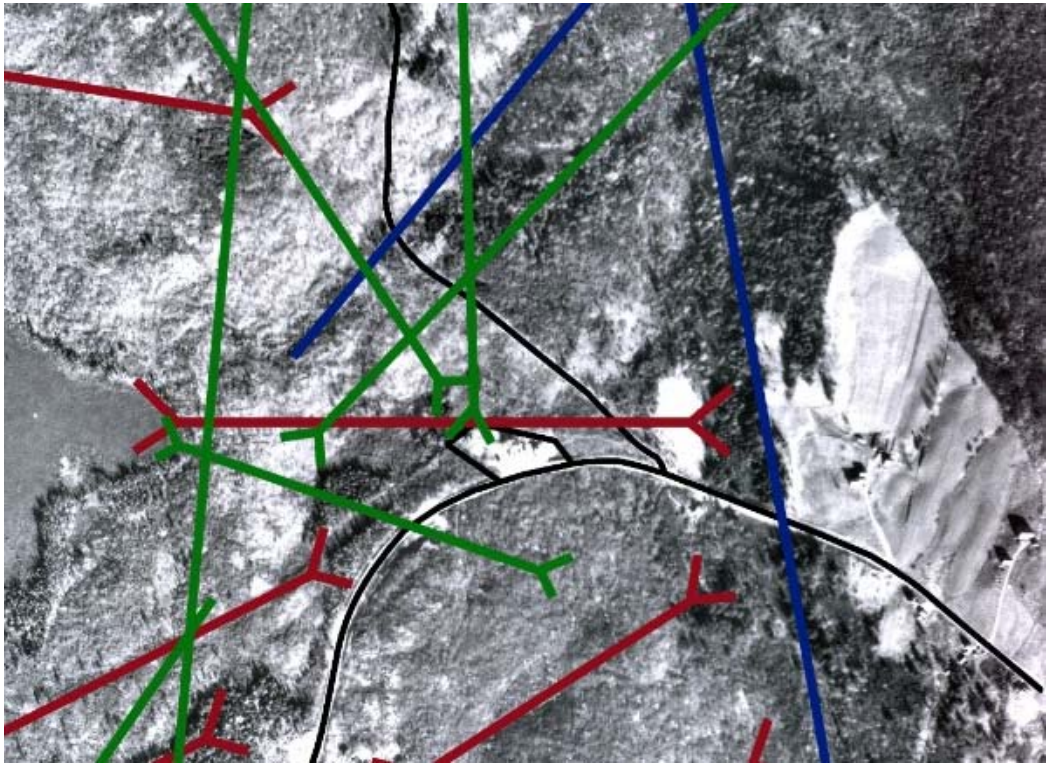
Our data supported a regulatory change to eliminate the 0.5 inch LNAPL standard – new standard based upon risk and recoverability

The site was sold for $29M and is being redeveloped for maritime use.

SITE 2: Industrial Site in Rural Setting

- Industrial Use (Critical Facility) 50+ Years
- Near sensitive receptors:
  - Bedrock Aquifer with water supply wells
  - National Park
  - Wetlands
- Spills
  - Diesel Fuel (500-1,500 gal)
  - Ethylene Glycol (200-300 gal)

SITE 2- Site Geology Controls Risks



- Receptor Survey (Aquifer)
- Fracture Trace Analysis
- Bedrock Cores/Mapping
- Bedrock Monitoring Wells
- Long Term Monitoring
- GW Flow Travel Time (important for EG release)
- Contaminant Fate/Half Life

These analyses confirmed the need for a rapid reduction of source concentration of ethylene glycol

SITE 2- Source Treatment -ChemOx

Hydrogen Peroxide Application

Effervescent Groundwater

ORC Polishing

SITE 2 – Closure

- Source Treatment/Remediation Was Quick (i.e., reactions were over in a few days)
- Long Term Monitoring and Groundwater Analytical Modeling Confirmed Impacts Remained On-Site
- Data Indicated Decay of Source (diesel and EG) By Natural Processes
- No offsite treatment necessary based upon risk analysis

CONCLUSIONS

- Remedies should be selected with the end in mind:
  - Cost Effective Over the Remedy Life Cycle
  - Sustainable (costs, carbon footprint, etc.)
  - Apply Scientific Principles
  - Utilize Natural Processes
  - Consider Future Site Use
  - Manage Exposure Pathways
  - Remedy May Not Need To Remove All Impacts
  - Protection of Human Health and the Environment

Thank you

Questions?

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