SUCCESSIVE USE OF VACUUM-ENHANCED EXTRACTION, IN SITU CHEMICAL OXIDATION, BIOAUGMENTATION AND MATHEMATICAL MODELING FOR THE RESTORATION OF IMPACTED SOIL AND GROUNDWATER

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RemTech 2007

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Content:

- Site Description and Environmental Issues
- Selected Remedial Technologies
- Work Performed
- Results
- Conclusions

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Site Description and Environmental Issues

- Active service-station in Northern Quebec
- Leaking petroleum USTs resulting in 4,000 m^2 LNAPL plume
- Apparent LNAPL thickness up to 4.5 m
- 2m > Water table > 8m
- 8m > LNAPL and contaminated soils > 11m
- Confined/semi confined aquifer
- GW flowing South, towards a lake, 100 m down gradient

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Site Description and Environmental Issues

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Remediation Objectives

- Recover the LNAPL using Vacuum-Enhenced Extraction
- Restore the site to the following targets using Chemical Oxidation and Bioaugmentation:

PARAMETER	SOIL	GROUNDWATER (Warning Threshold)
	mg/kg	µg/L
Total Petroleum Hydrocarbons C_{10}-C_{50}	3,500	1,750
Benzene	5	295
Toluene	30	290
Ethylbenzene	50	210
Xylenes	50	410

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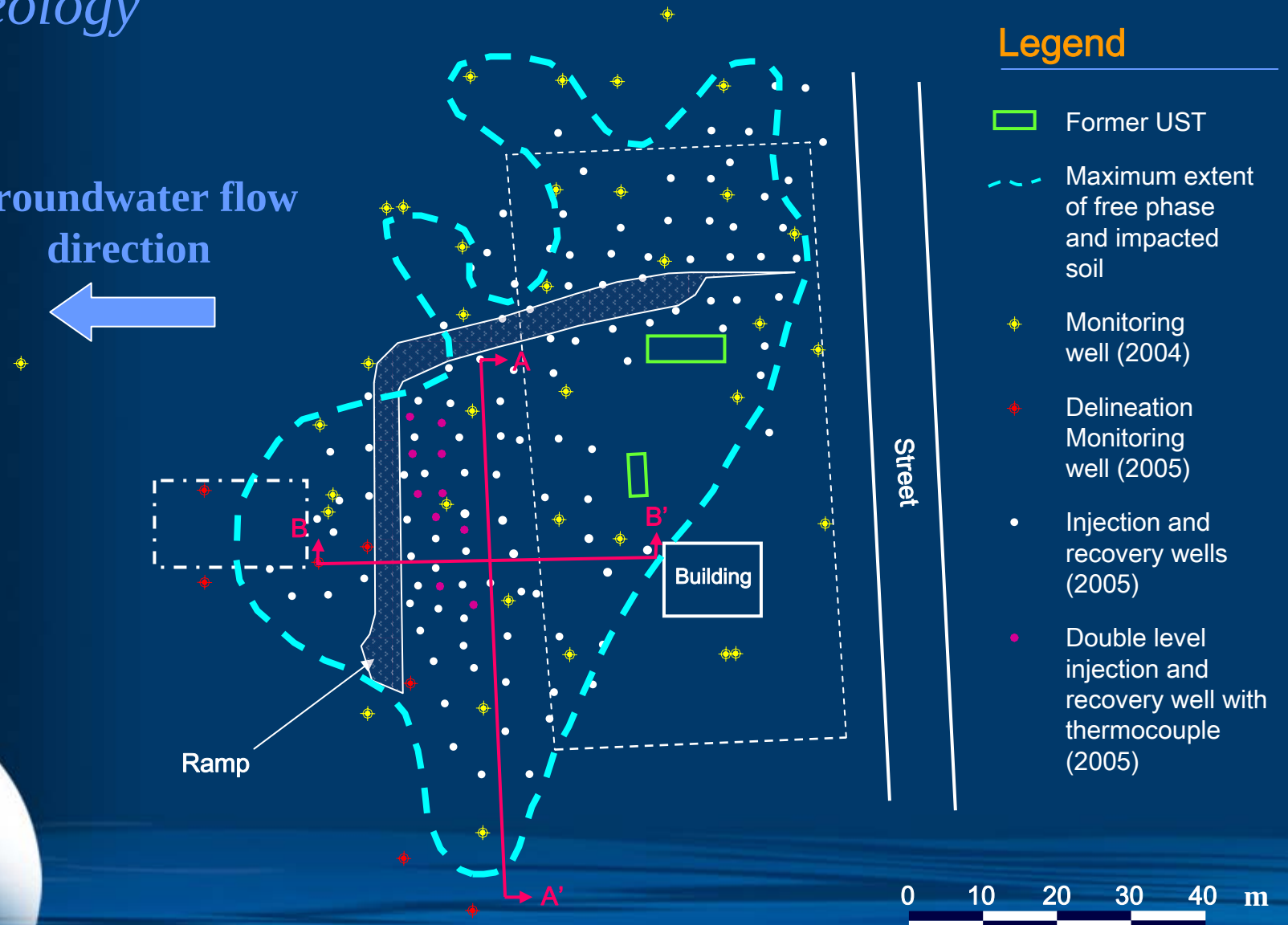
Site Description and Environmental Issues
Geology



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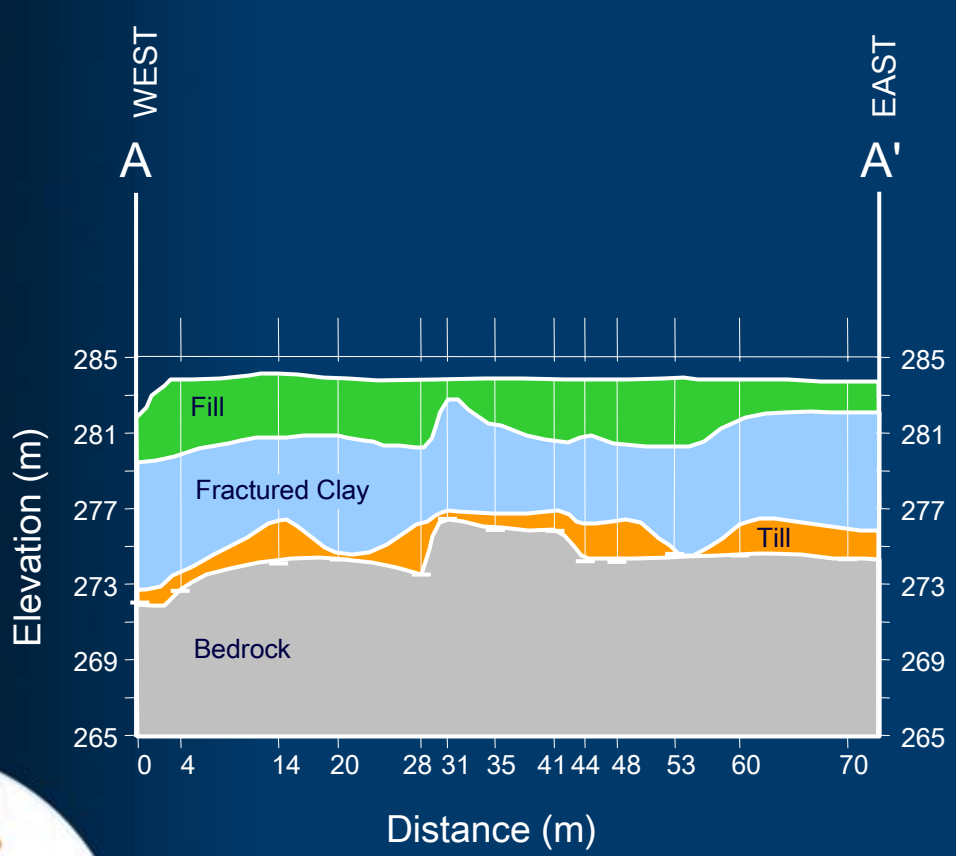
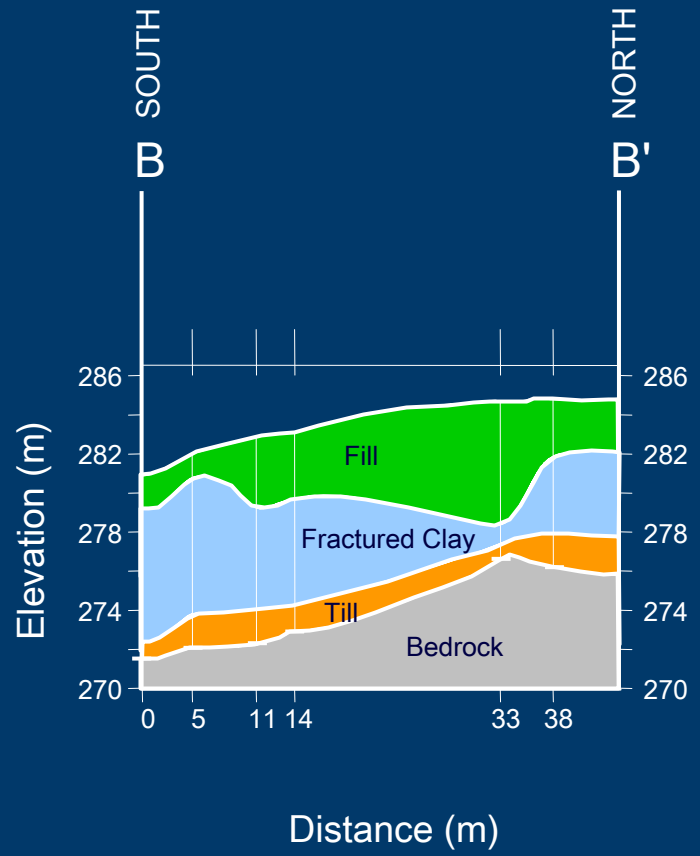
Site Description and Environmental Issues : Geology





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Vertical exaggeration : 2

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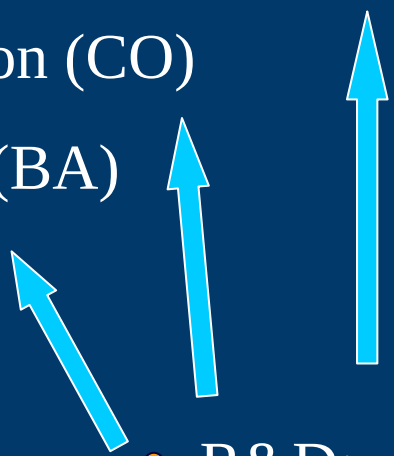
Selected Remedial Technologies

- Vacuum-Enhanced Extraction (VEE)
- Chemical oxidation (CO)
- Bioaugmentation (BA)



- R&D:
  - •Use of CO with VEE
  - •Search for the optimal reagent
  - •Search for Optimal treatment Conditions to Enhance Biodegradation

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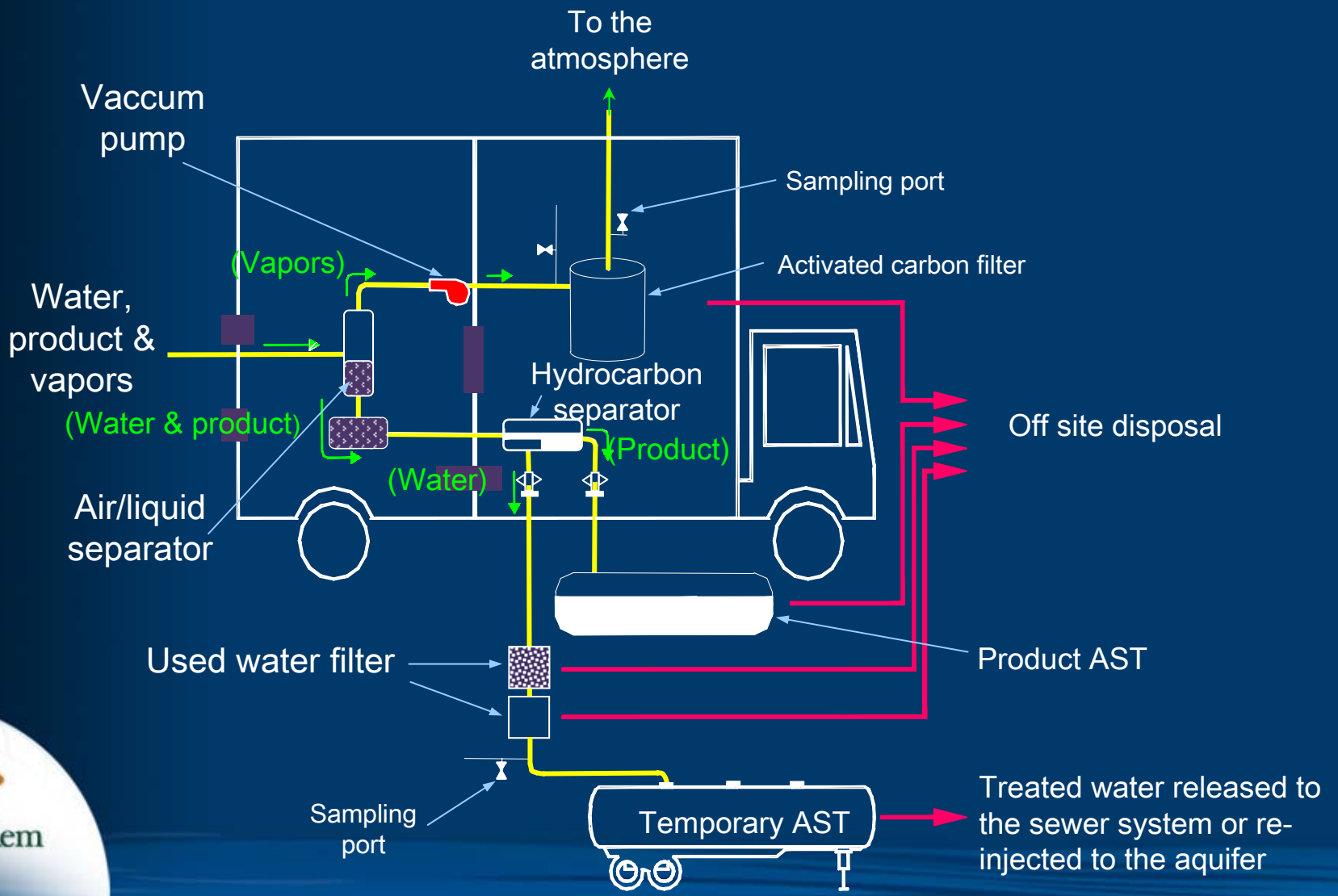
1) Equipment for Vacuum-Enhanced Extraction (VEE)



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1) Vacuum-Enhanced Extraction (VEE)

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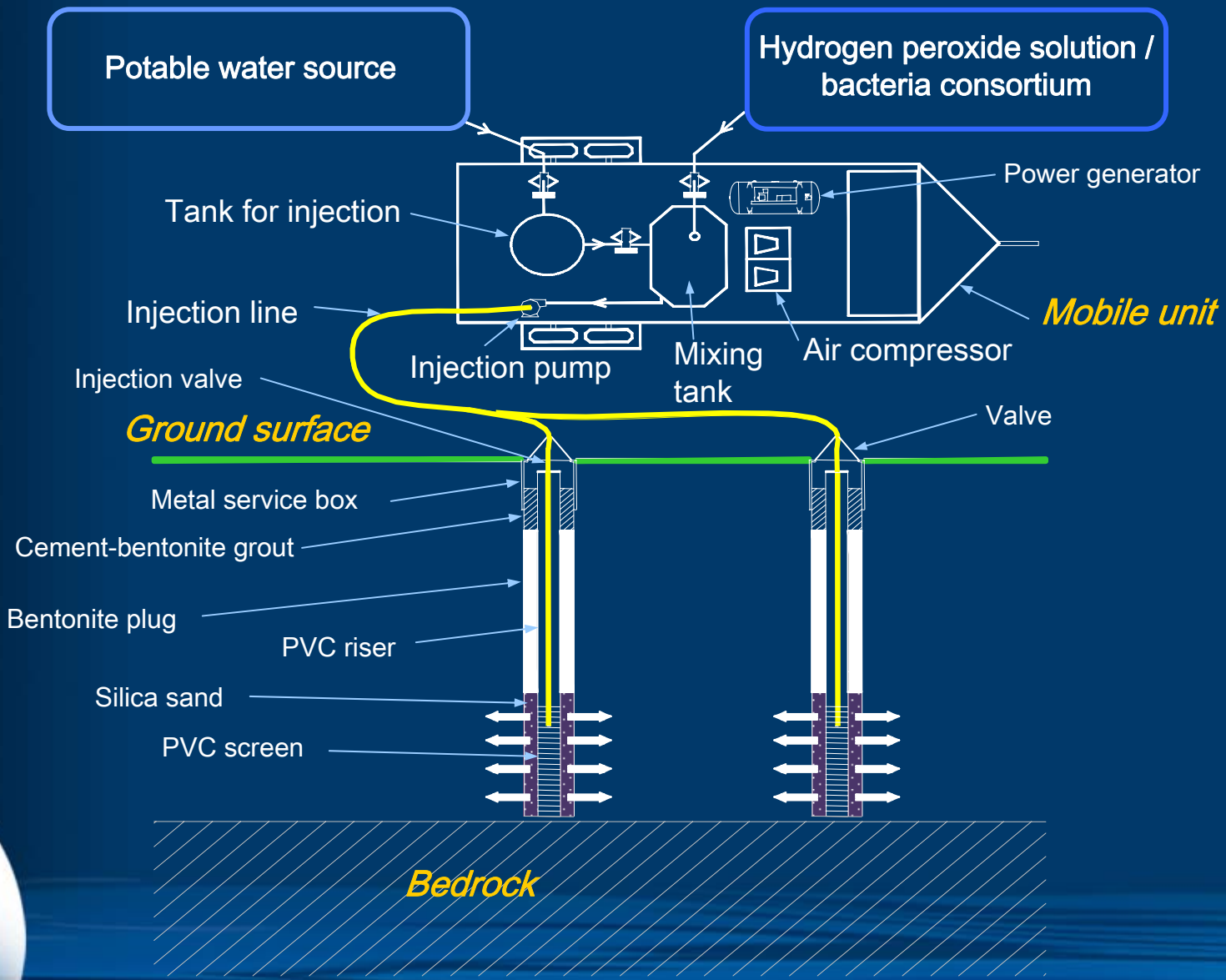
Injection Equipment (CO & BA)



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2) Chemical Oxidation (CO)

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2) Chemical Oxidation (CO)

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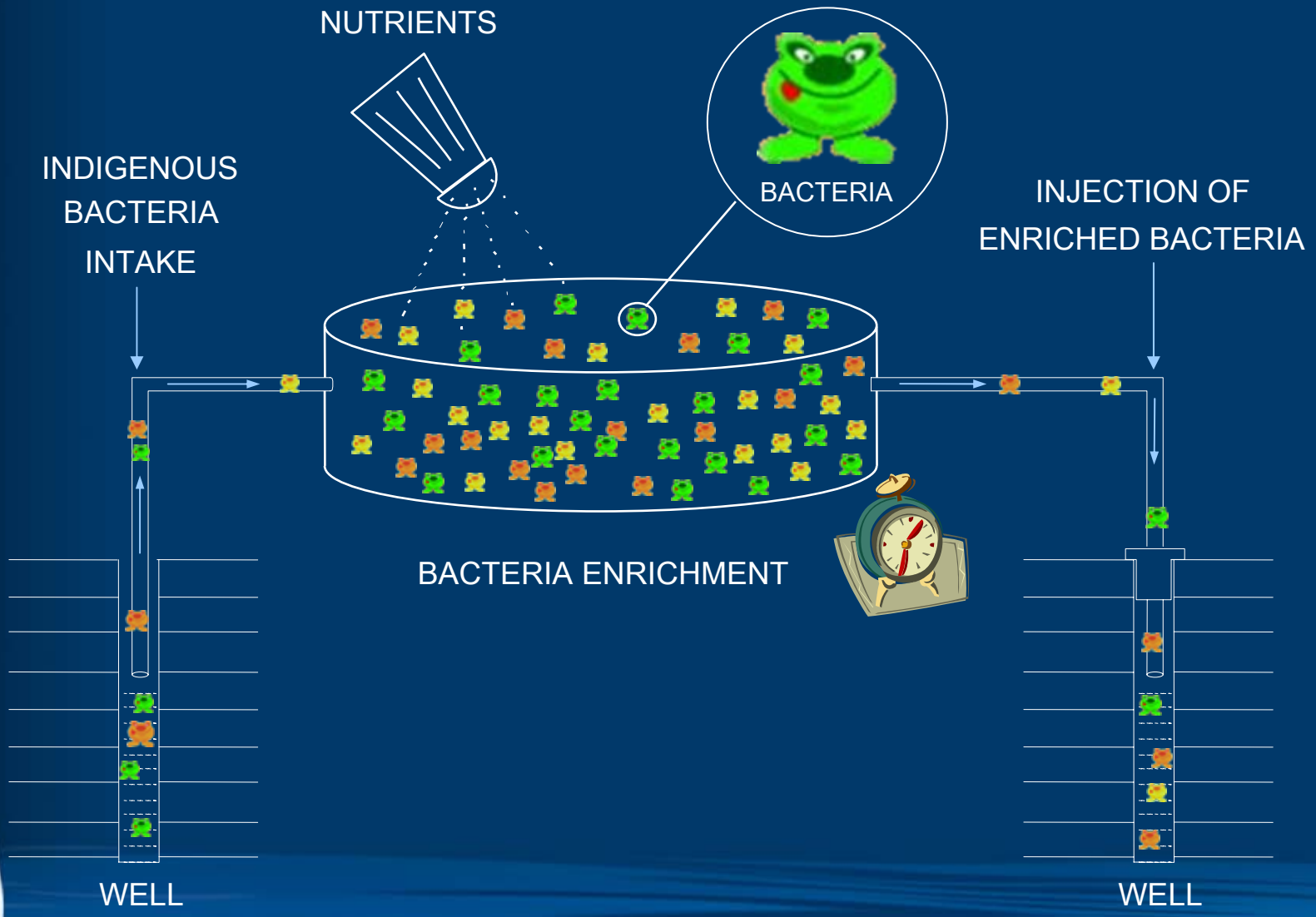
3) Bioaugmentation (BA)



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3) Bioaugmentation (BO)

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Work performed (2005-2006)

- Implementation of 128 pumping/injection wells (totalizing 165 wells), soil sampling, groundwater and LNAPL measurements
- Design, installation, commissioning and operation (4 months) of the VEE system
- Laboratory and bench-scale testing (TechnoRem) to determine the optimal treatment products and conditions for CO
- Laboratory and bench-scale testing (NRC-Biotechnology Research Institute) to determine the optimal treatment conditions for the biodegradation of contaminants

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Work Performed (2006-2007)

- Oxidant solution injection (110,000 L at 50%) for the *in situ* treatment of soil and groundwater and monitoring
- Pumping of groundwater (8,000 L) for the storage and enrichment of indigenous bacteria before re-injection
- Injection of a 8,000 L nutrient- and bacteria-enriched solution throughout the site and addition of slow oxygen release compound to sustain biodegradation of residual hydrocarbons
- Assessment of soil quality after treatment
- Groundwater quality monitoring after treatment
- Mathematical modeling to support the use of enhanced natural attenuation for residual hydrocarbons

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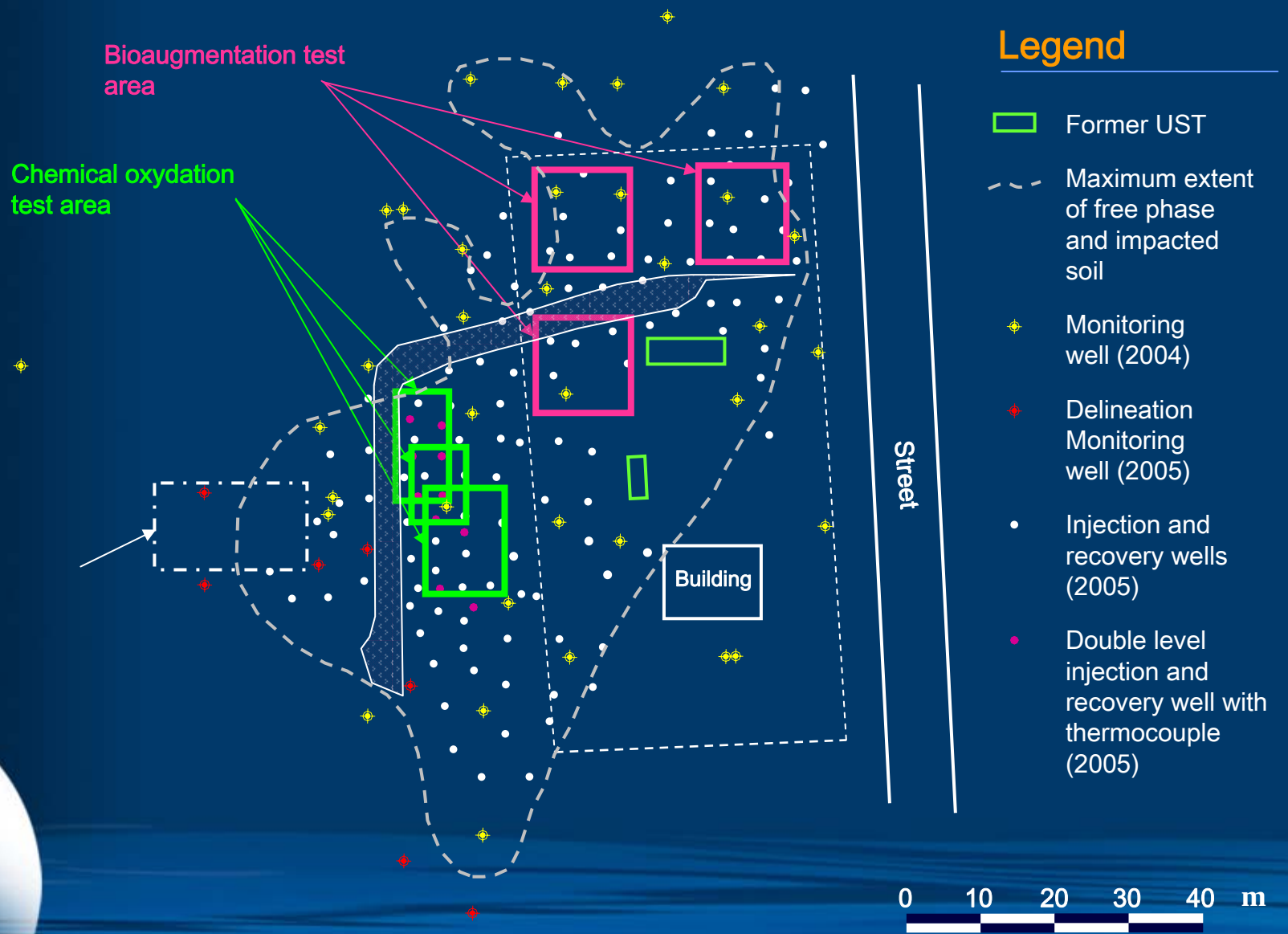
R & D Areas



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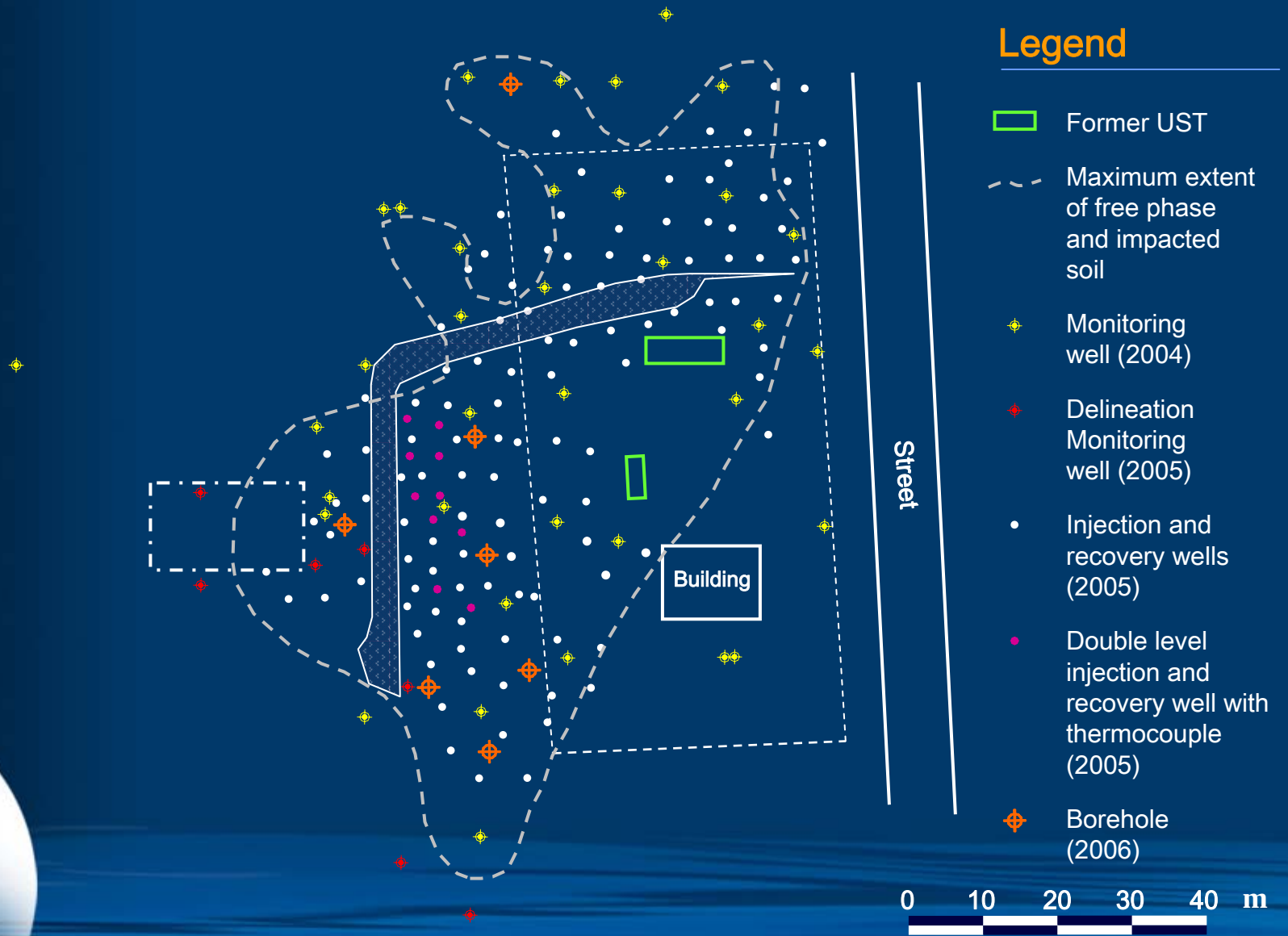
Confirmatory Soil Sampling



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Results

- Recovery of 98,000 L of LNAPL (liquid (65,000 L), dissolved and gas phases (33,000 L)) during the 4 month-operation of the vacuum-enhanced pumping and treatment system

- Pumping of 960,000 L of impacted groundwater and treatment to meet applicable regulation before re-injection into the aquifer

- Laboratory tests on impacted soil from the site allowed determining optimal reagents and chelating agent to be used to oxidize the contaminants

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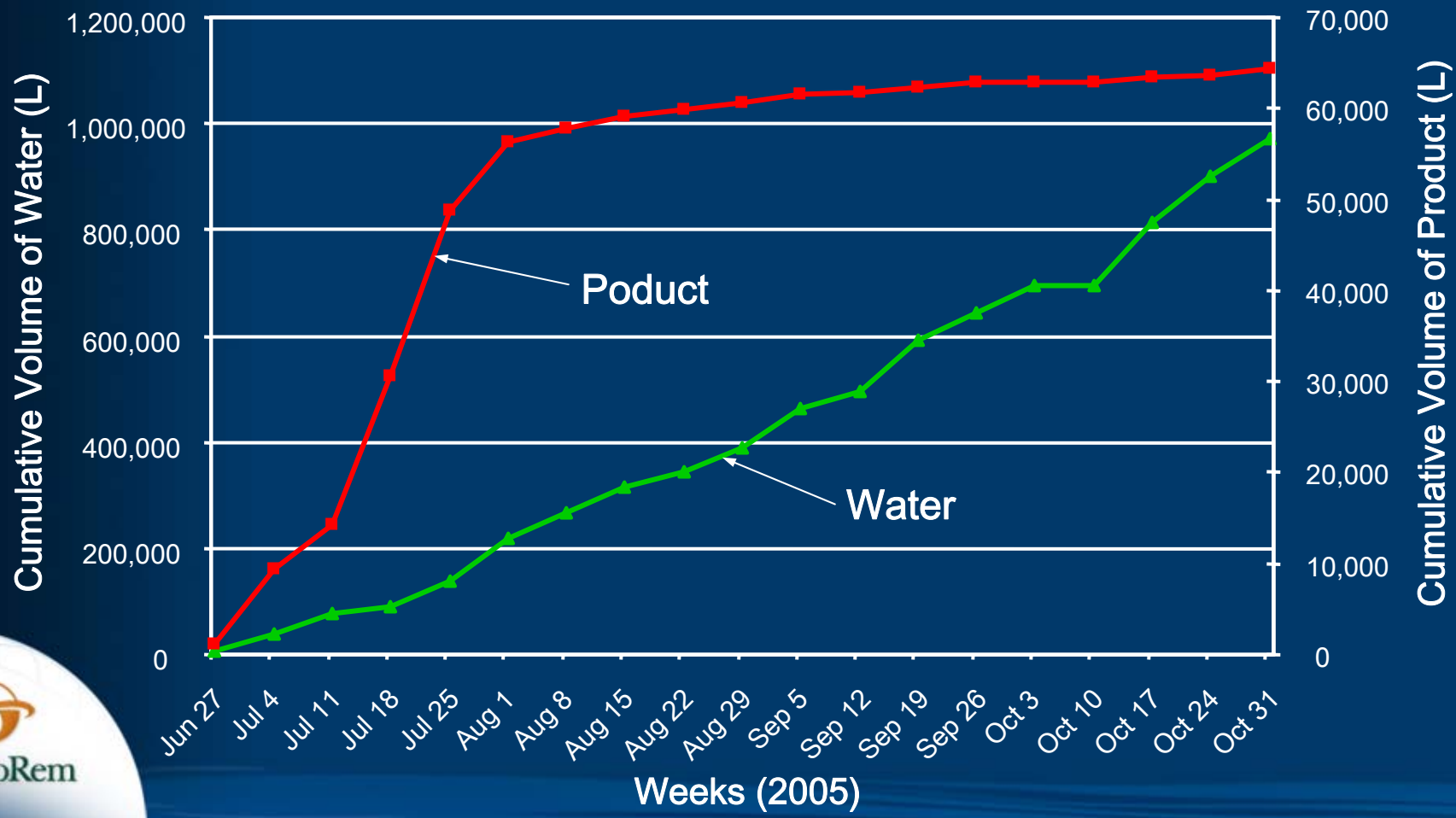
Results

Recovery of Free Phase Hydrocarbons



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Results

- During the first phase of the project (June 2005) LNAPL thicknesses up to 4.5 m were measured in 32 of the 63 available wells
- At the completion of the well implementation and during the first weeks of VEE, (July 2005) LNAPL was measured in 75 of the 165 available wells
- After treatment (Oct. 2006), LNAPL <0.001 to 0.02 m was measured in only 10 wells

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Results

- In Nov 2006, soil analyses indicated concentrations in TPH C_{10}-C_{50} and BTEX meeting the applicable criteria :

PARAMETER	SOIL CRITERIA	SOIL RESULT RANGE (11 SAMPLES)
	mg/kg	mg/kg
Total Petroleum Hydrocarbons C_{10}-C_{50}	3,500	ND - 800
Benzene	5	ND – 0.2
Toluene	30	ND – 0.4
Ethylbenzene	50	ND – 1.1
Xylenes	50	ND – 5.0

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Results

- Laboratory and field tests for bioaugmentation (mineralization in microcosm and enrichment) indicated that the indigenous bacteria could degrade the contaminants if appropriate nutrients were supplied
- Nitrogen is very deficient in groundwater
- The most effective nutrient ratio : 5 C : 10 N : 1 P
- Analytical results on the 8,000 L solution showed a 10 to 100 times increase of ingenuous bacteria counts
- 8 months after injection, bacteria and phosphorus concentrations were still high enough, while additional nitrogen and slow oxygen release compound had to be added to maintain optimal conditions

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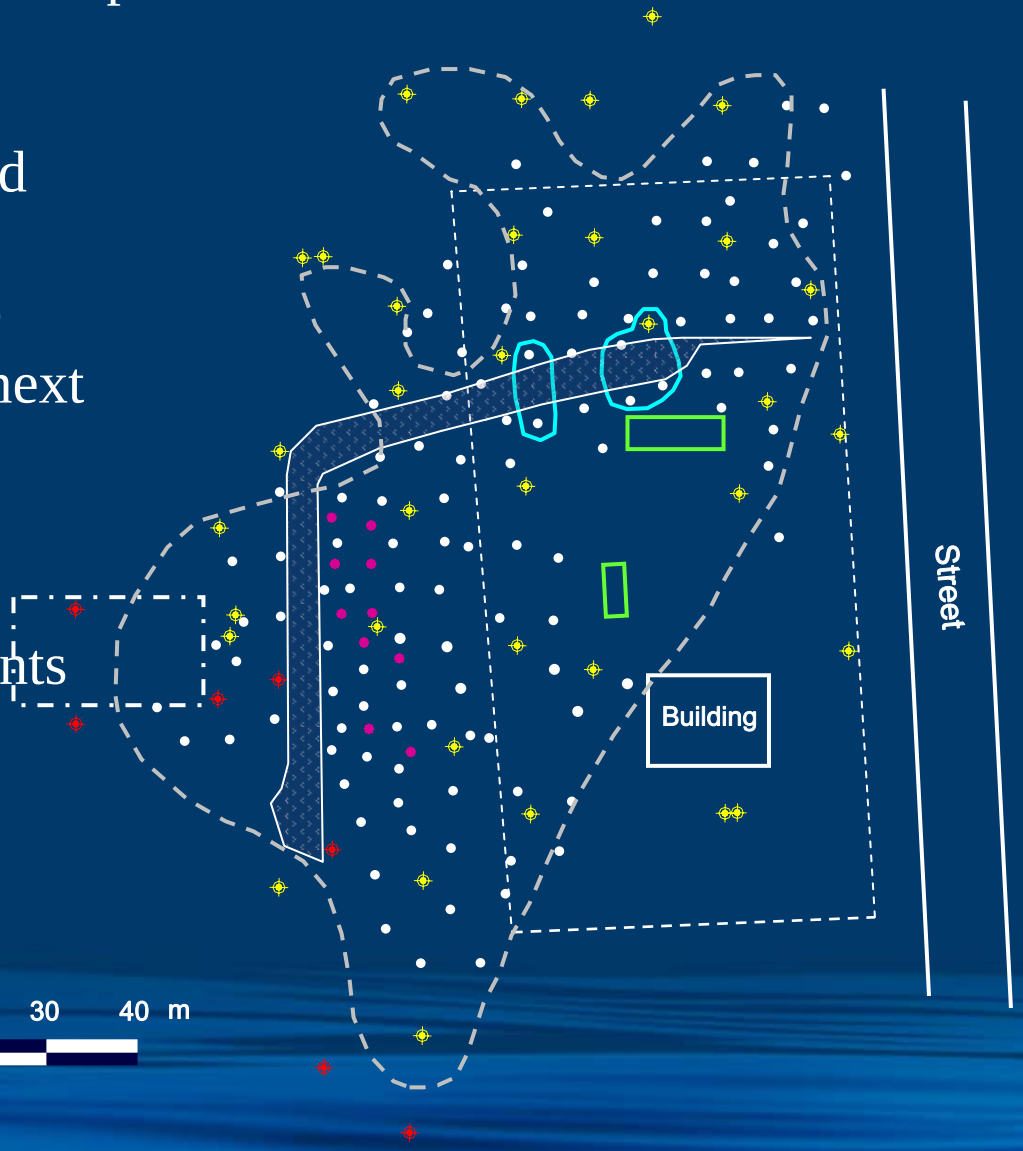
Conclusions

- The contaminated GW plume is now minor and in regression
- GW monitoring and supply of nutrients and oxygen will be performed for the next years, allowing Enhanced Natural Attenuation of the residual contaminants



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Conclusions

- Mathematical modeling was performed to support use of Enhanced Natural Attenuation for residual hydrocarbons as a favored final approach
- Successive use of VEE, CO and BA (NA) was the most cost effective restoration approach for the site
- Knowledge of site specific conditions is key to designing and implementing the most appropriate restoration technology
- “Case by Case” study

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Conclusions

- Thank You!

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