

GROUNDWATER & ENVIRONMENT NEWSLETTER

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MODELLING LNAPL RECOVERY

What is LNAPL?

Hydrocarbon spillages or leaks into aquifers pose a significant environmental threat. When present in soil or groundwater it can form a continuous source of contamination until recovered. Light Nonaqueous Phase Liquids (LNAPL) floating on the water table as Phase Separated Hydrocarbons (PSH) can also form a continuous source of dissolved phase contamination to groundwater flow. The recovery of hydrocarbons from aquifers can be complicated as LNAPL may be trapped in the soil and water pore spaces.

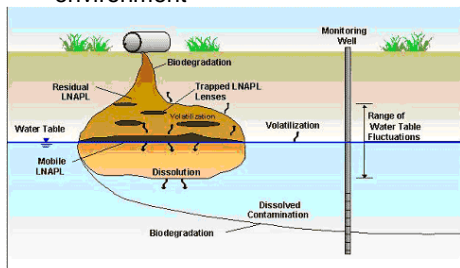


<http://www.epa.gov/oilspill/photo.htm>

Characterisation of LNAPLs in Groundwater

LNAPLs are complex multi-component organic mixtures with varying properties, such as solubility. The complexity in characterisation needed prior to remedial work is reflected in:

- Partitioning (separation) between LNAPL, water, air and soil
- Fluctuations in the water table
- Slow rates of LNAPL dissolution
- Viscosity variations
- Complex subsurface geologic environment



Flow within fractured rock is even more complex due to the properties of the fluid, the geometry of the fracture network, and

physical/ chemical reactions between the rock matrix and the solute/ groundwater regime.

Numerical solutions to characterise LNAPL releases to a natural system are therefore complex and often multiple stage solutions are needed.

LNAPL Recovery Models

Selected models for hydrocarbon recovery include:

- **API LNAPL Distribution and Recovery Model (LDRM)** simulates different hydraulic technologies to recover PSH.
- **Petral Eclipse**
- **MARS2D/3D** (finite-difference model for groundwater & LNAPL migration with **Biof&t**: transient multi-solute L/DNAPL flow
- **MOVER**, an areal three-phase (water, oil and gas) finite-element model, simulate the flow of water, oil and gas, & optimize the recovery of LNAPL and water by minimizing NAPL entrapment in the saturated/unsaturated zones.
- **NAPL Simulator** estimates the contamination of soils and aquifers from the release of organic liquids
- **BIOPLUME** - 3D Transport of dissolved hydrocarbons undergoing oxygen-limited biodegradation.

The NAPL transport models are often coupled with two-dimensional contaminant transport models to predict contamination of soil gas and groundwater resulting from a LNAPL migrating on the water table.

MARS2D/3D

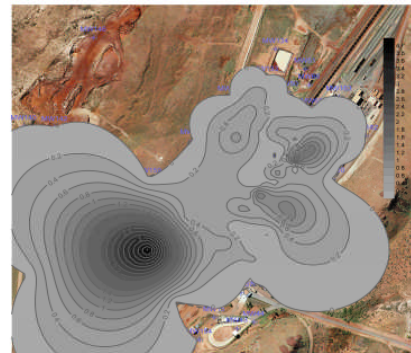
The Multiphase Areal Remediation Simulator (MARS2D) was recently used by Hydrosolutions to characterise LNAPL occurrence & optimise recovery at a 7ha diesel spillage site. It models the coupled areal flow of water and LNAPL, and can be used with other software such as BIOF&T (2D or 3D) to represent dissolved phase transport of up to five species in groundwater. Input parameters may include:

- Soil characteristics (i.e. porosity, van Genuchten parameters alpha and n, irreducible water saturation, residual LNAPL saturations in the vadose and saturated zones).

- Fluid properties (i.e. density, viscosity, and interfacial tensions).
- Groundwater elevations.
- LNAPL thickness in the monitoring well.

Case Study

Hydrosolutions constructed a numerical model to assess remedial options at a hydrocarbon spill site in WA. MARS 2D incorporated field derived groundwater elevations, apparent PSH thickness & hydraulic conductivity parameters. Model calibration was achieved by varying the hydraulic conductivity, corresponding soil parameters and recharge values. The model simulated a combination of Total Fluid Recovery bores and skimmer bores in the downgradient direction that will control further downgradient migration of PSH.



Under a range of scenarios, the model successfully simulated the number of recovery bores, pumping volumes, and reinjection rates required to dispose of water from dual-phase recovery without significantly raising the heads in groundwater. A recovery and dewatering scheme is currently being designed.

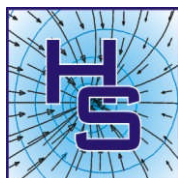
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Next issue - Remedial Options for Hydrocarbon Contaminated Aquifers



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