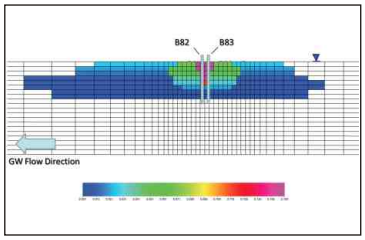
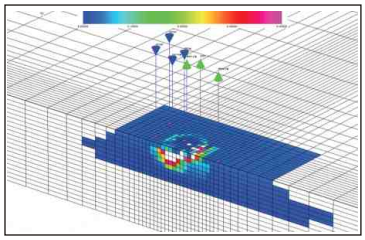
SETUP AND CALIBRATION OF A THREE-DIMENSIONAL NUMERICAL MULTIPHASE MODEL FOR DESIGN OF IN-SITU REMEDIATION OF JET FUEL WITH SURFACTANT

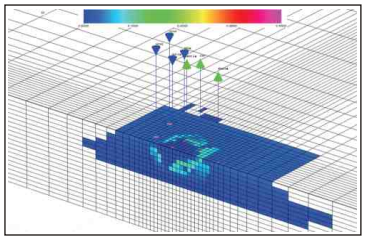
BACKGROUND

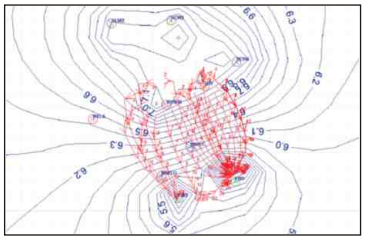
Storage and pumping of jet-fuel have caused a severe contamination of soil and groundwater at a military facility in Denmark. The contamination was detected in 2001. The Danish Defence has conducted a series of investigations and set up a skimmer system, that has recovered approximately 25 m^3 of jet-fuel. In 2005, the recovery stopped, and the remaining jet-fuel is trapped as a residual light non-aqueous phase liquid (LNAPL) comprising approximately 45 m^3 jet-fuel in a 1000 m^2 source area. In the ground water downstream of the source area, there is an extensive diving plume of contaminants.

In part of the source area, the Danish Defence and NIRAS have launched a pilot Scale Surfactant Enhanced Aquifer Remediation (SEAR) in order to demonstrate mobilization of LNAPL from the sediment. The pilot remediation was carried out using non-ionic surfactants (Ivey-sol®) from Ivey International Inc. for injection in a line of injections wells. The mobilized oil and injected surfactants were recovered from a downstream line of extraction wells. The recovered oil/ground water was treated on site, and the treated water was re-injected up-gradient in a line of hydraulic control wells. The effect of the pilot SEAR was monitored by sampling and analyzing the ground water from the extraction wells and by estimation of trapped jet-fuel in an oil-water separator as part of the on-site treatment, supplemented by post soil sampling/analyses from boreholes. The 3 different methods gave different results for the mass balance, and the estimated effect of the pilot remediation ranged from 25 kg to 150 kg of hydrocarbons.









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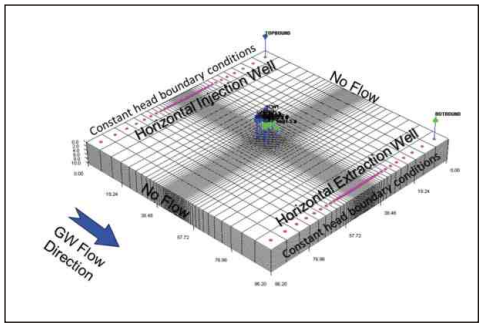
WATER BALANCE

- Extraction – 12 m^3/day (0.5 m^3/h)
- Reinfiltration – 8 m^3/day (0.33 m^3/h)
- Injection 0.15 – 1 m^3/day
- Discharge – 4 m^3/day (0.17 m^3/h)
- Hydraulic control – 2 weeks
- 7 injections of Ivey-sol® (0.15 – 1.0 m^3 – 1.3 – 3.0 % surfactants)
- Hydraulic control for 7 weeks post injection

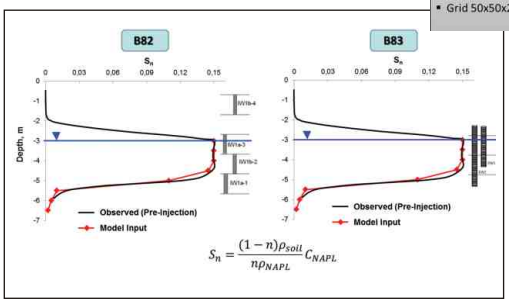
To validate the effect of the Pilot Remediation, GSI Environmental Inc. has set up a three-dimensional numerical multiphase model by using the University of Texas' Chemical Compositional Simulator UTCHEM.



SETUP UTCHEM

- Input – vertical oil saturation based on soil samples

- *dx = dy* = variable
  - Min = 0,5 m (center)
  - Max = 7,7 m (boundaries)
- *dz* = 0,5 m
- 100 m x 100 m x 10 m
- Grid 50x50x200



SIMULATIONS UTCHEM

- 70 days – Injections of Ivey-sol® surfactants from day 20 to day 27
- 7 injections of surfactants – 1.3 – 3.0% Ivey-sol®
- Oil saturation as function of time
- Accumulated oil from extraction wells
- Capture of surfactants in extraction wells
- Comparison of simulations with no injection of surfactant

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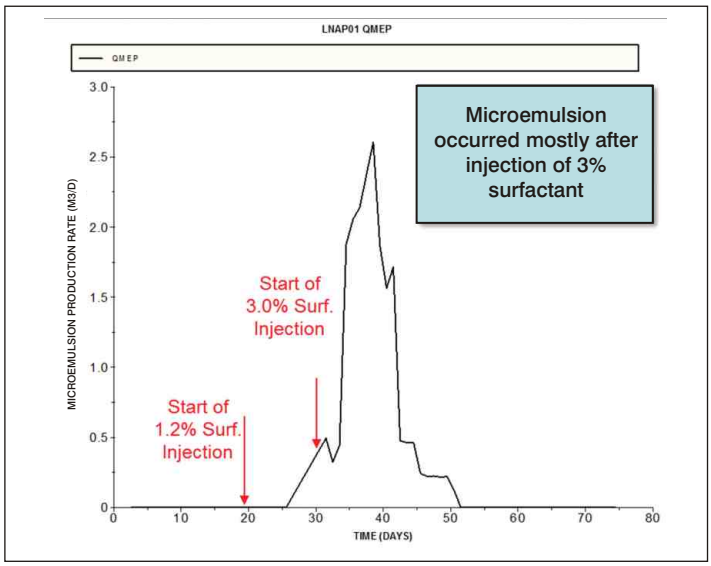
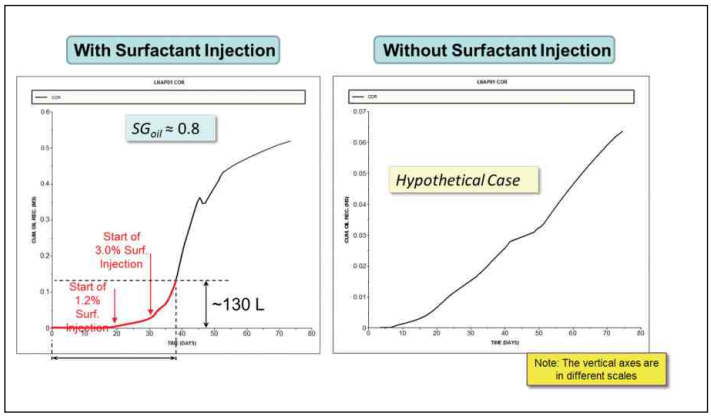
RESULTS

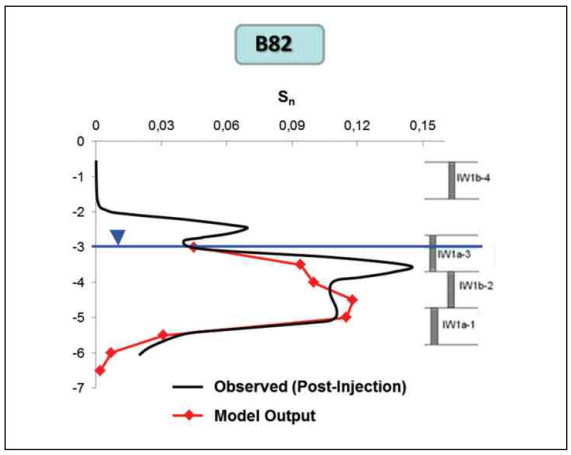
- Formation of micro-emulsion during Pilot SEAR

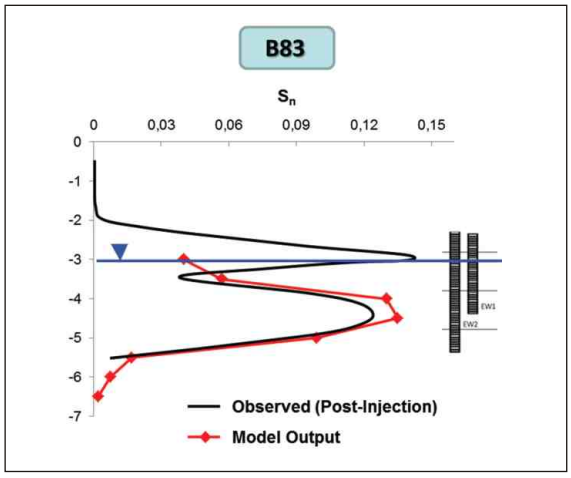


- Accumulated Oil during Pilot SEAR



- Post Oil Saturation in soil





The simulations indicate a removal of 130 kg oil on day 50 and approximately 400 kg after day 70. Simulations without surfactants show a removal of less than 1/10 of the removal achieved when using Ivey-sol® surfactants.

CONCLUSIONS

The UTCHEM model was able to simulate the Pilot SEAR, and injected fluids were contained within the pilot area. Further, the simulations estimated an approximate 10-fold (1000 %) increase of the oil concentration in the extracted ground water relative to a water injection without the use of Ivey-sol® Surfactants. The model also showed that the main process for mass removal during SEAR was production of a micro-emulsion.

The total removal during the Pilot SEAR was by UTCHEM estimated to be 100-400 kg oil compared to 25-50 kg by analysis and measurements of the effluents from the extraction wells, and 50-150 kg based on the change of oil saturation in the soil by analysis of soil samples.

The simulated post-SEAR oil saturation was similar to measured concentrations from post-study soil sampling. The simulations also indicate that most of the Ivey-sol® surfactants was removed during the pilot SEAR and the post pump & treat period.

The setup of the UTCHEM gave an insight into the processes and hydraulics during the pilot SEAR in comparison to a "Black Box" situation, where the remediation technology performance is only evaluated by process and monitoring data, after the remediation is conducted.

The performance of the pilot study provided important lessons of great value for both the design and the documentation of issues in the design and planning of future full-scale remediation.