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MODELLING OF THE SYSTEM FOR CLEANING UP FREE OIL PRODUCTS WITH THE APPLICATION OF THE MARS SIMULATOR***

1. THE OBJECTIVE AND TOOLS

The objective of the conducted computer simulations is the analysis of the LNAPL (Light Non Aqueous Phase Liquids) recovery by wells and piezometers with installed skimmers. The mathematical model calculations were conducted using the MARS programme (Multiple Areal Remediation Simulator) of the Drapen Aden Environmental Modelling, Inc. The programme solves the multiphase filtration equations by the finite elements method [2]. It permits conducting the calculations in an heterogeneous and anisotropic filtration field in transient conditions. The MARS simulator performs the flow calculations for a lighter-than-water, free oil product appearing on the water table – LNAPL (Light NonAqueous Phase Liquids). It estimates the volume of the free and residual LNAPL. The recovery level of the remaining LNAPL is forecast.

It is also possible to estimate the volume of the free and the residual oil and to periodically forecast the recovery level of the free LNAPL to be found in the ground and water environment.

2. THE MODEL PARAMETERS DESCRIPTION

The developed numerical model covers the area of 400 m × 400 m size. The model area was discretized with a quadrangle grid 40 × 40 (1600 nodes) with the 10 m step of the discretization grid.

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The following parameters defining the ground and water environment were introduced into the model: filtration coefficient, total porosity, the parameters defining the level of pore saturation with liquid: S – the ground pore saturation with liquid, S_m – the residual pore saturation with water, S_{or} – the maximum residual pore saturation with LNAPL in the saturation zone, S_{og} – the maximum pore saturation with LNAPL in the aeration zone, as well as the van Genuchten ground model parameters for soil (α parameter describing the inverse of the air entry suction and n describing pore-size distribution). These parameters define the ground with respect to its capability of binding liquid in the pore space.

The following values were taken into account in the modelling: the parameters characterizing the liquid phase [1, 3]: ρ_{ro} – the oil to water density ratio, η_{ro} – the oil to water dynamic viscosity ratio, β_{ao} – the air-oil surface tension ratio, and β_{ow} – the oil-water surface tension ratio. Taking the above parameters into account in the investigation shall permit the performance of the further modelling simulations.

The following initial boundary conditions were assumed in the model:

- 1st type conditions for water: assumed in the model corners (on the northern and southern model boundaries),
- 2nd type conditions for water: assumed in the grid nodes where the dewatering wells are situated,
- 2nd type conditions for oil products: assumed in the grid nodes, in which the activity of the boreholes extracting LNAPL was assumed

It was assumed that the aquifer is composed of Quaternary deposits such as medium or coarse sands. The value of the infiltration recharge was assumed to be 0.00045 m^3/d per nod.

3. THE MODEL SOLUTION

The model calculations were conducted to determine the volume of the free LNAPL on the water table and to estimate the size of the area affected by the designed extraction wells [5]. The optimum operation mode of the technological process was also proposed. It was assumed that the three dewatering wells: S-1, S-2 i S-3 were going to operate simultaneously with the cumulative volume being up to 3.0 m^3/h. In each well was generated a depression of 0.3 m to 0.4 m. The fuel was going to be extracted by skimmers from 24 boreholes located on the LNAPL spill area.

The forecast calculations performed with the application of the MARS multiphase filtration model permitted the selection of the calculation results best fitting reality and the presentation of the effective operations of the technological system. The most important model solution results for the technological system operations designed to extract the oil product are presented below. On the basis of the conducted model calculations it was estimated that in the initial period the LNAPL surface was approximately amount to 36,300 m^2 and the volume of the free LNAPL was approximately amount to 600 m^3. Based values used for the calculation are shown in the Figure 1.

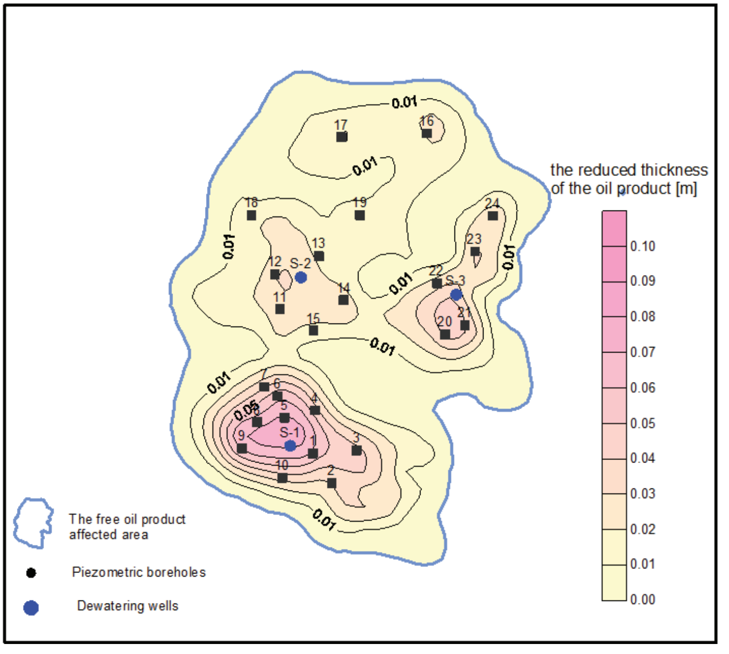

Fig. 1. The assumed reduced thickness distribution of the free oil product

The performed computer simulation revealed that in two months' time the system would effectively operate on the area of 14,300 m^2, what is approximately amounts to 40% of the LNAPL surface area. Zone of influence of the working system is presented in the Figure 2. The technological system operation presented in the proposed solution causes a decrease in the actual reduced thickness of the free oil product by approximately 0.01 m in the S-1, S-2 and S-3 wells' area of influence measuring cumulatively about 2800 m^2, which corresponds to app. 8% of the spill surface area.

The highest decrease in the actual reduced thickness by around 0.03 m occurred in the southern part of the spill in the S-1 well's area of influence measuring 240 m^2 (0.6% of LNAPL surface area).

In one year's time the system will cover the area of 17,000 m^2, which corresponds to about 47% of the LNAPL spill surface area (Fig. 3).

The technological system operation in the proposed solution causes the decrease of the actual reduced thickness of the free oil product by app. 0.01 m, mostly in the southern part of the patch in the area of the S-1 well's influence, partly in the centre in the area of the S-2 well's influence, and to a smaller extend in the area of the S-3 well's influence, on the cumulative area of app. 4300 m^2 corresponding to about 12% of the patch surface area.

The highest decrease in the actual reduced thickness by app. 0.03 m took place in the southern part of the patch in the area of the S-1 well's influence measuring 1000 m^2 (2.7% of the patch surface area).

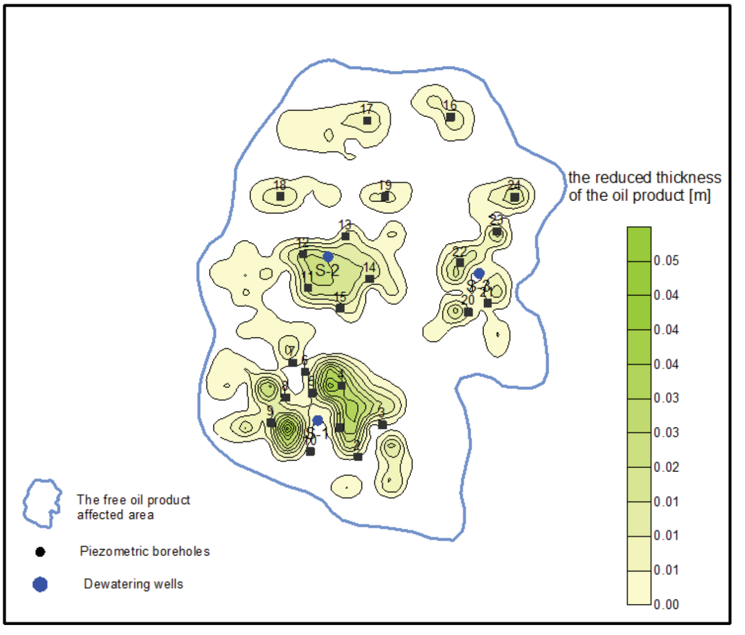

Fig. 2. Zone of influence of the working system after 2 months of operation

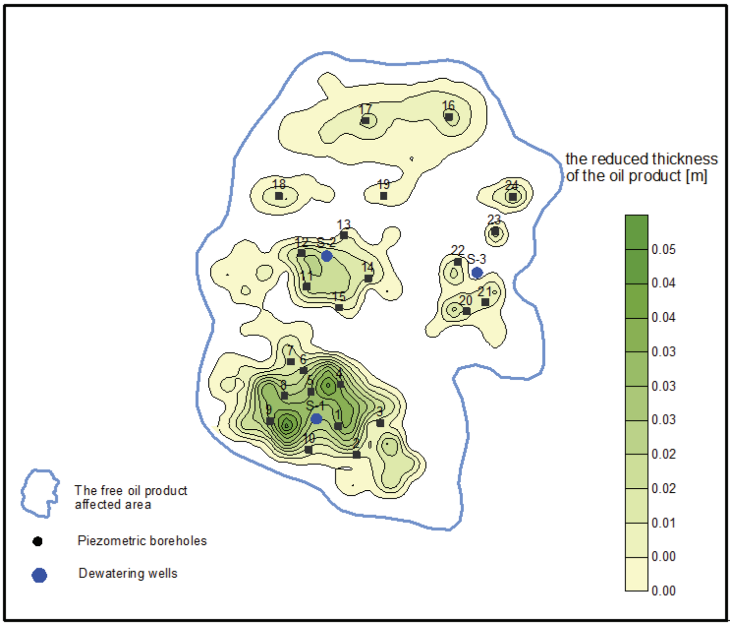

Fig. 3. The zone of influence of the LNAPL spill after 1 year of operation

4. CONCLUSIONS

1. Computer simulation is important to make optimal project of the continuous system operation, which will in effect cause the gradual decrease of the free oil product spill, with the mean LNAPL reduced thickness also gradually decreasing.
2. The analysis of the model investigation results allowed us to distinguish the most efficient LNAPL extraction boreholes, i.e. those numbered: 1, 4, 5, 8, 9, whereas the boreholes: 13, 19 and 15 are the least efficient ones.
3. The forecast calculations performed using the MARS multiphase filtration model permitted the analysis of the wells and extraction boreholes operation in selected calculation periods what is important to plan and minimize operational costs.
4. The conducted calculations should be treated as the demonstration of the capabilities of the multiphase filtration model.
5. More accurate verifications of the extraction systems operations require further modeling and development of new techniques to the measure parameters in the field.

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