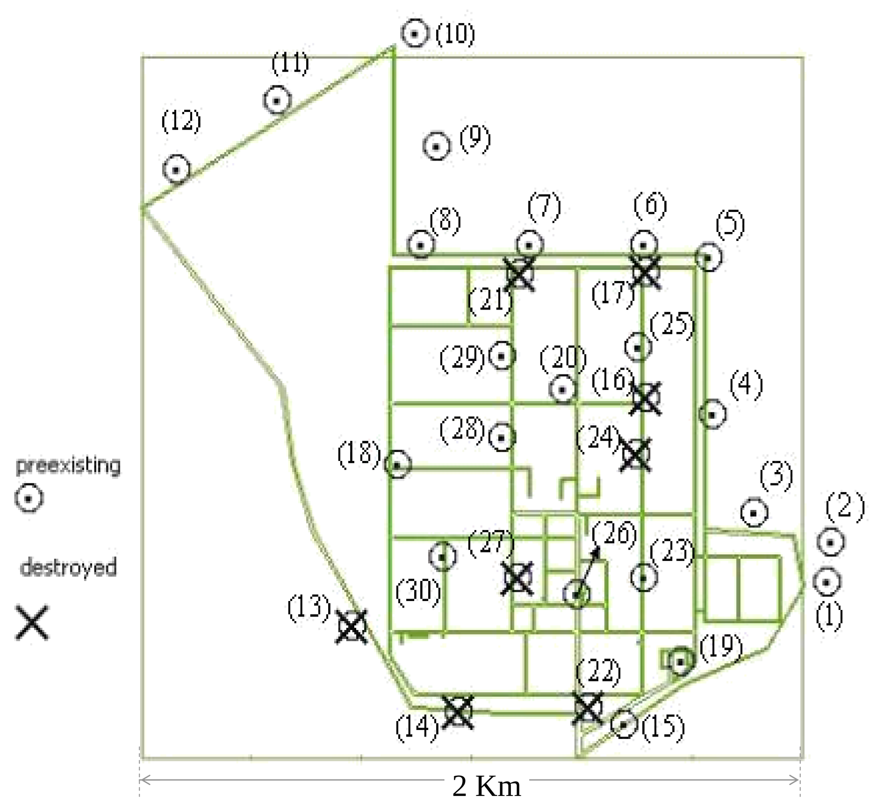
coffey geotechnics
SPECIALISTS MANAGING THE EARTH

An optimisation approach for groundwater monitoring network augmentation-
a ódetectionô monitoring ca

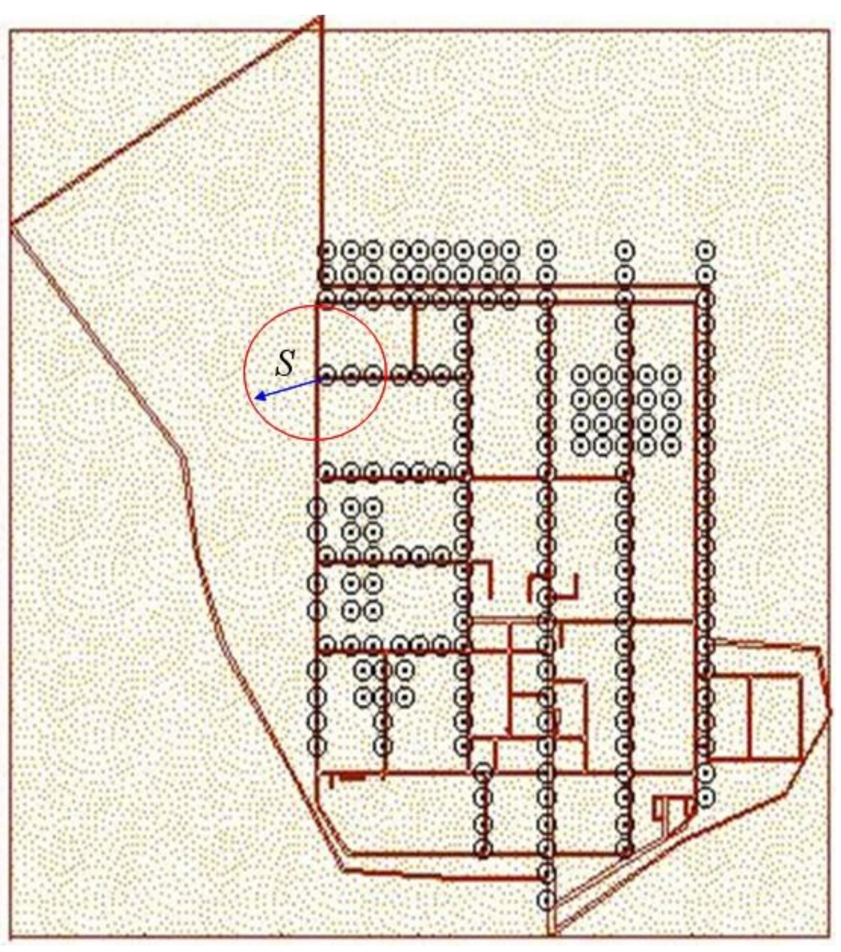
by: Kourosh Azimi

Background



- Preexisting network of monitoring wells had been installe lower the groundwater table. 8 of the 30 wells were broken.
- Samples of groundwater from some of the existing wells s free phase of hydrocarbon (visible LNAPL). Determination extent of contamination (i.e. mound(s) of floating hydrocarb the groundwater) beneath the refinery was the goal of the pr
- To gain further information on the spatial extent of the contamin augmentation of the network was deemed necessary.
- An integer programming approach, the Maximal Covering Loca Problem (MCLP), was adopted to optimise the augmentation.

Maximal Covering Location Problem (MCLP



Maximize coverage (population covered) within a desired service distance by locating a fixed number of facilities (Church and ReVelle, 1974). The mathematical formulation of this problem is presented below:

$$\text{Max } Z = \sum_{i \in I} w_i y_i$$

Subject to :

$$\sum_{j \in N_i} x_j \geq y_i \qquad (\forall i \in I)$$

$$\sum_{j \in J} x_j = P$$

$$x_j = (0,1) \qquad (\forall j \in J)$$

$$x_j = 1 \qquad (\forall j \in J_p)$$

$$y_i = (0,1) \qquad (\forall i \in I)$$

w_i : population at node i;

I : set of demand nodes in discretized network;

J : set of prospective nodes for siting facilities;

J_p : set of nodes j occupied by preexisting facilities;

$N_i : \left\{ j \in J \,\middle|\, d_{ij} \leq S \right\}$;

d_{ij} : the shortest distance from node i to node j;

S : covering distance threshold (maximal service distance);

x_j : 1 if a facility is located at site j; 0 otherwise;

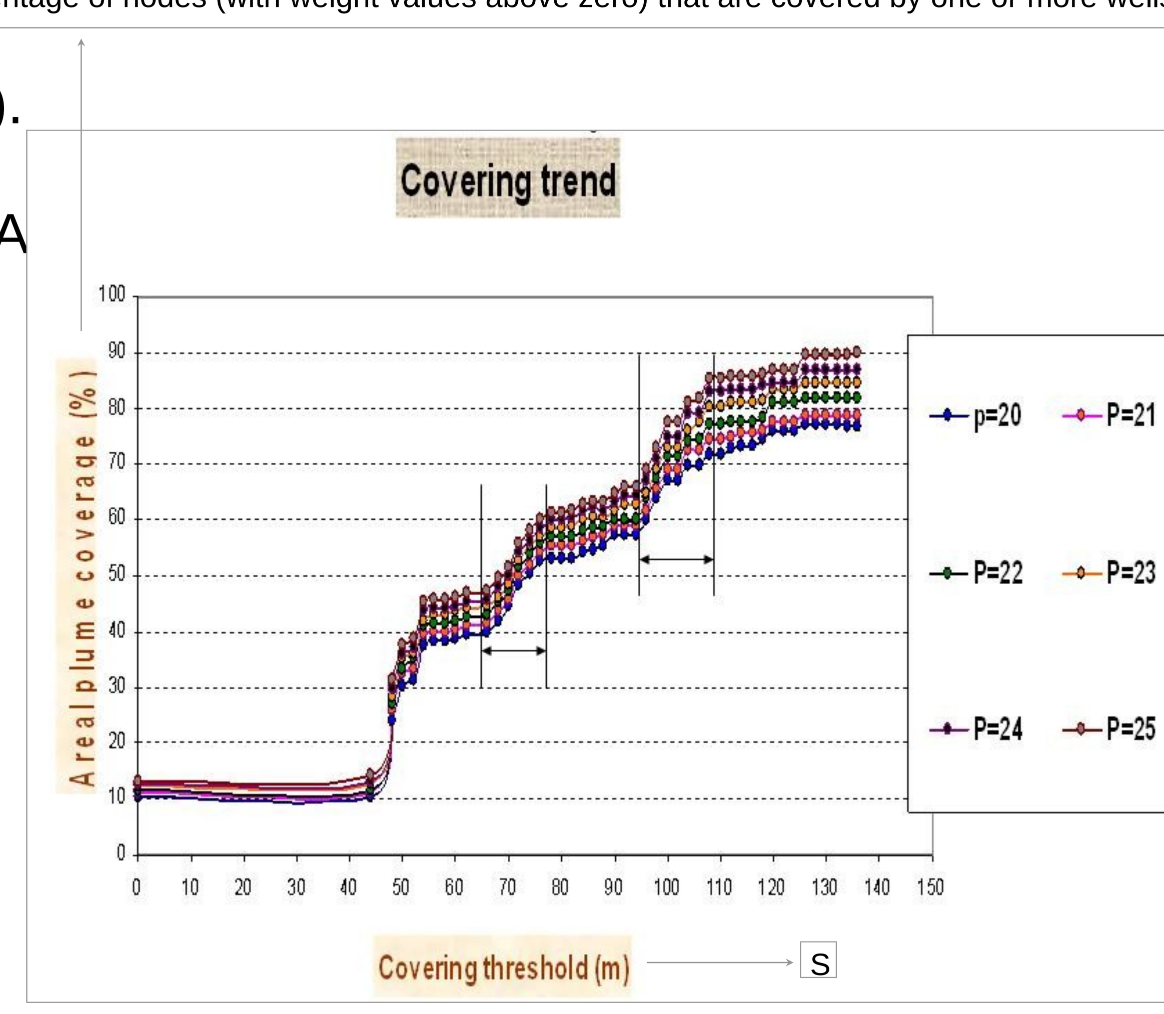
y_i : 1 if node i is covered; 0 otherwise;

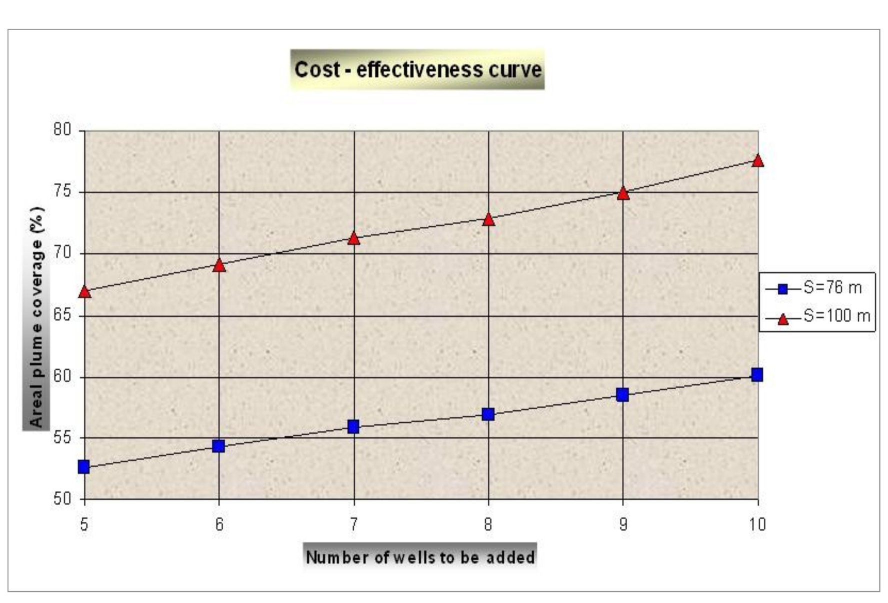
P : total number of facilities (pre-existing and added) to be located

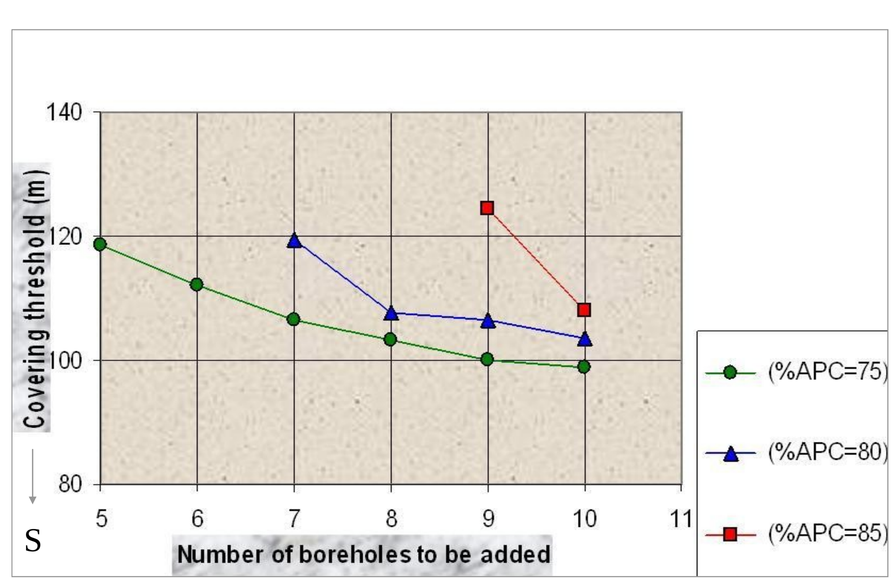
Implementation of the model

- Discretization of the study area into network of ódemandô n
- Nodal weights calculation (estimation via a stochastic interpolator in this case).
- Solution of the integer programming problem (Lingo with supports from MATLA
- Further analysis and implementation of the outputs.

Percentage of nodes (with weight values above zero) that are covered by one of more wells (nodes i for wi







Why the modelling was successful?

- Groundwater samples from 5 out of the 10 added monitoring wells showed free phase of hydrocarbon (i.e. captured the mound). Coverage of the mound by the augmented network was satisfactory.
- Clustering of added monitoring stations at areas with the highest weight (concentration) values was prevented. This was separately investigated through a on a purely geostatistical approach (i.e. óvariance reducti the optimisation (MCLP) approach.
- Direction of geostatistical anisotropy in the analyses carried out to delineate the extent of the mound (using the data from the augmented network) was in agreement with the groundwater flow.