Application of time-lapse electrical resistivity tomography and groundwater simulation models to monitor the transport of organic contaminants under unsaturated and saturated conditions

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Outline

- Olive Oil Mills waste's (OOMWs) contamination
- Survey area
- Geophysical measurements
- Geochemical analysis
- Finite Element subsurface FLOW system (FEFLOW) simulation model

Olive Oil Mills' waste (OOMW) contamination

Olive Oil Mills Waste (OOMWs)

- Olive oil production generates a large amount of solid waste and wastewater with high organic load (phenols) and inorganic constituents.
- Disposal of OOMWs is in uncontrolled, unprotected and poorly constructed shallow evaporation ponds thus resulting in soil, surface water bodies and groundwater contamination.

OOMW deposition pond

Characteristics		Characteristics	
Moisture content, %	87.6	Total phenols, g/kg	12.4
pH	5.00	Total Mg, %	0.23
E.C., mS/cm	7.29	Total Na, %	0.18
Total Organic matter, %	22.0	Total Cu, mg/kg	32.4
Total organic Carbon, %	12.2	Total Fe, %	1.41
Total P, %	0.20	Total Zn, mg/kg	36.6
Total Ca, %	0.67	Total Mn, mg/kg	82.1
Total K, %	0.59	Total B, mg/kg	7.1
Total N, %	0.31		

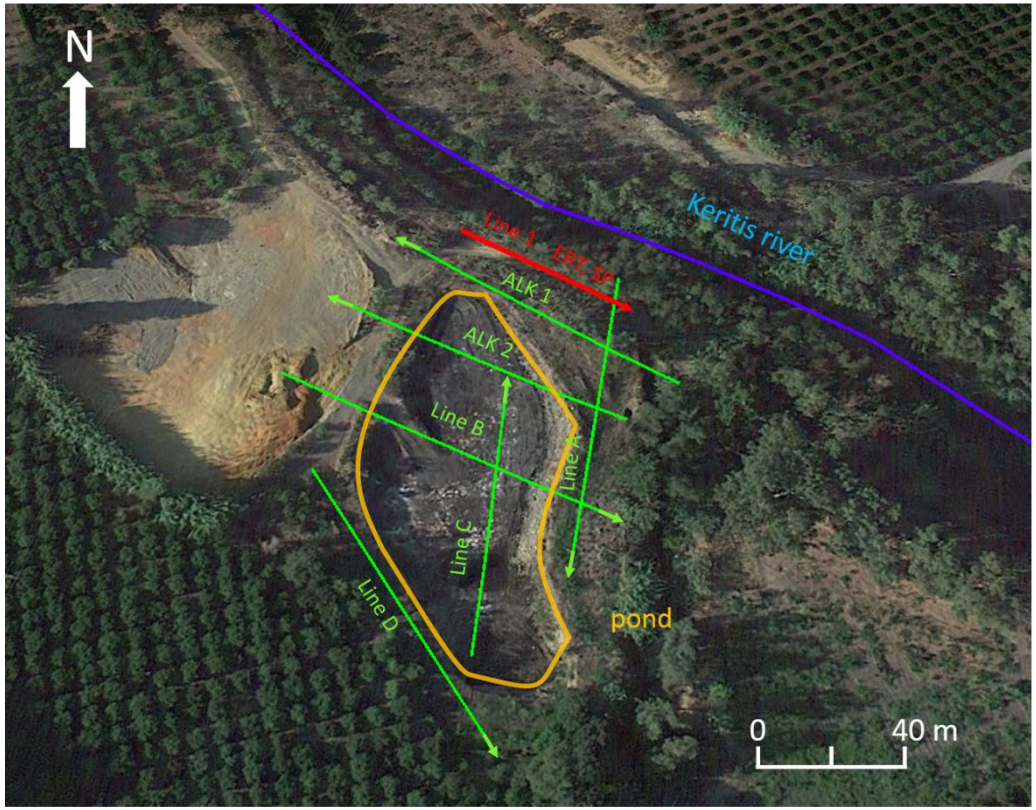
Characteristics of OOMW

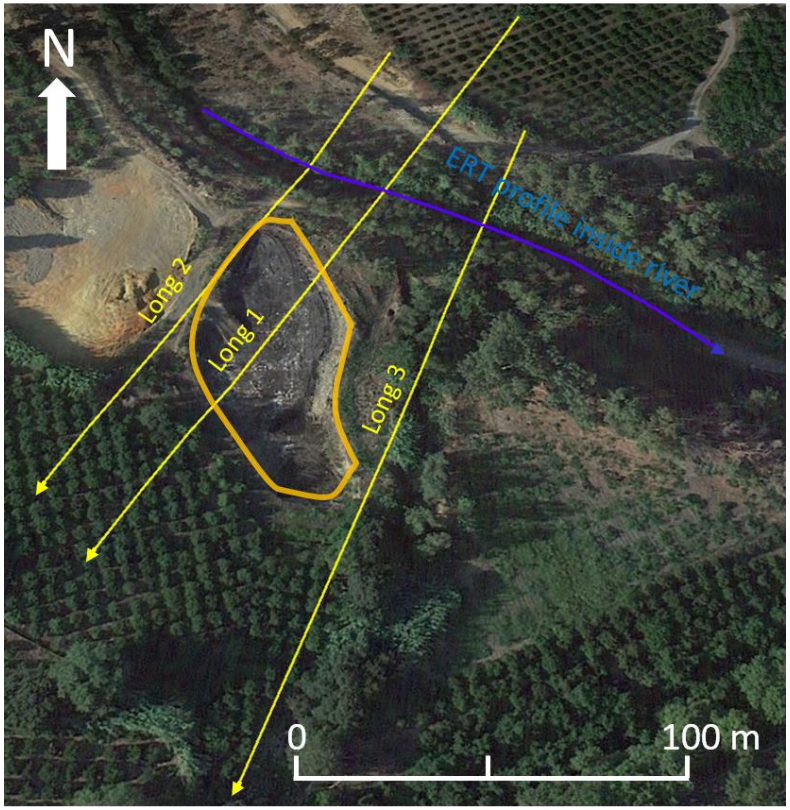
Kavvadias et al., 2016

Survey area

Survey area located in the north-western part of Crete Island (Greece)

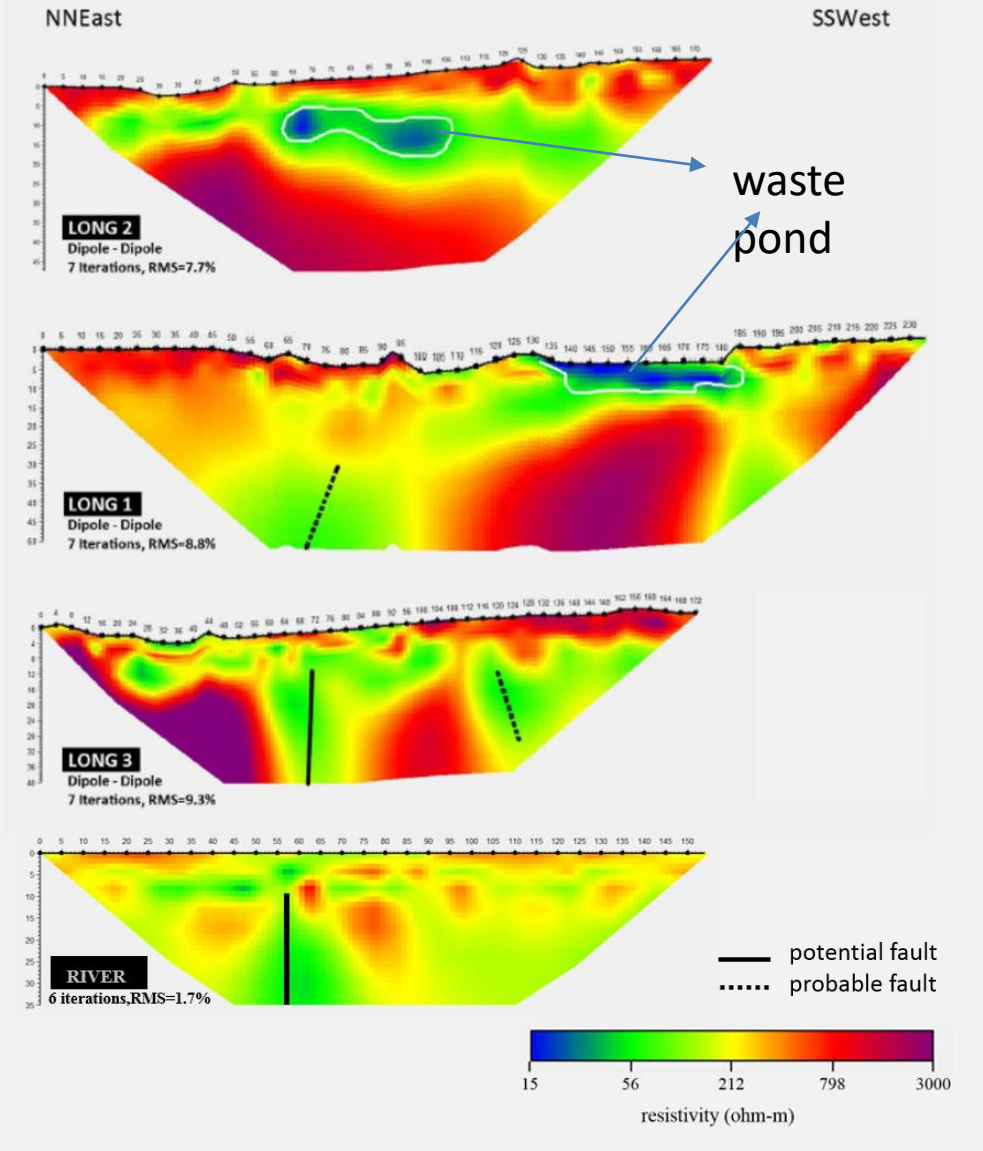
Geophysical measurements: ERT and SP surveys

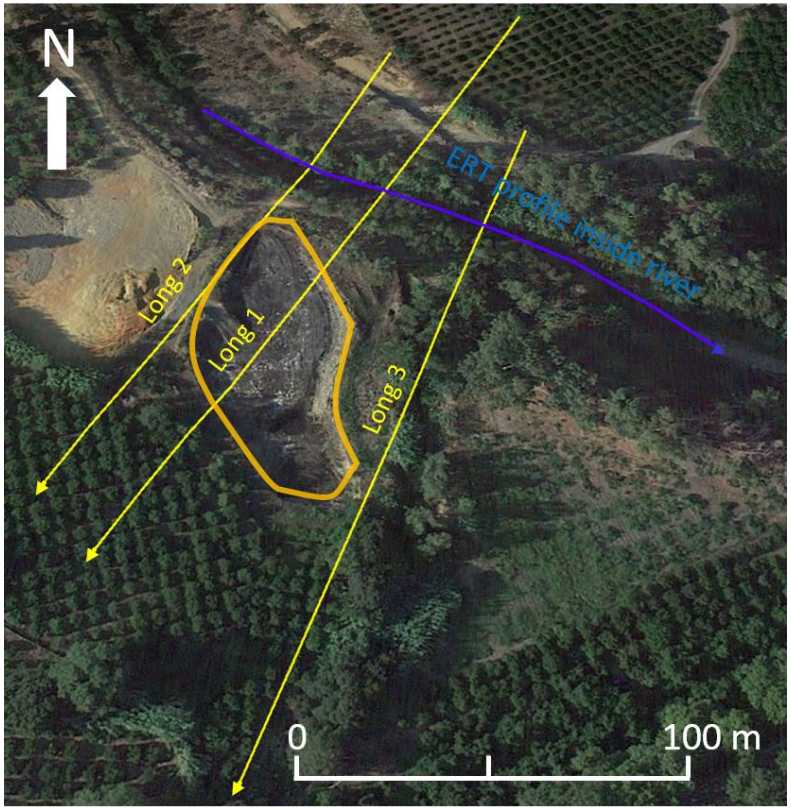




ERT measurement profiles

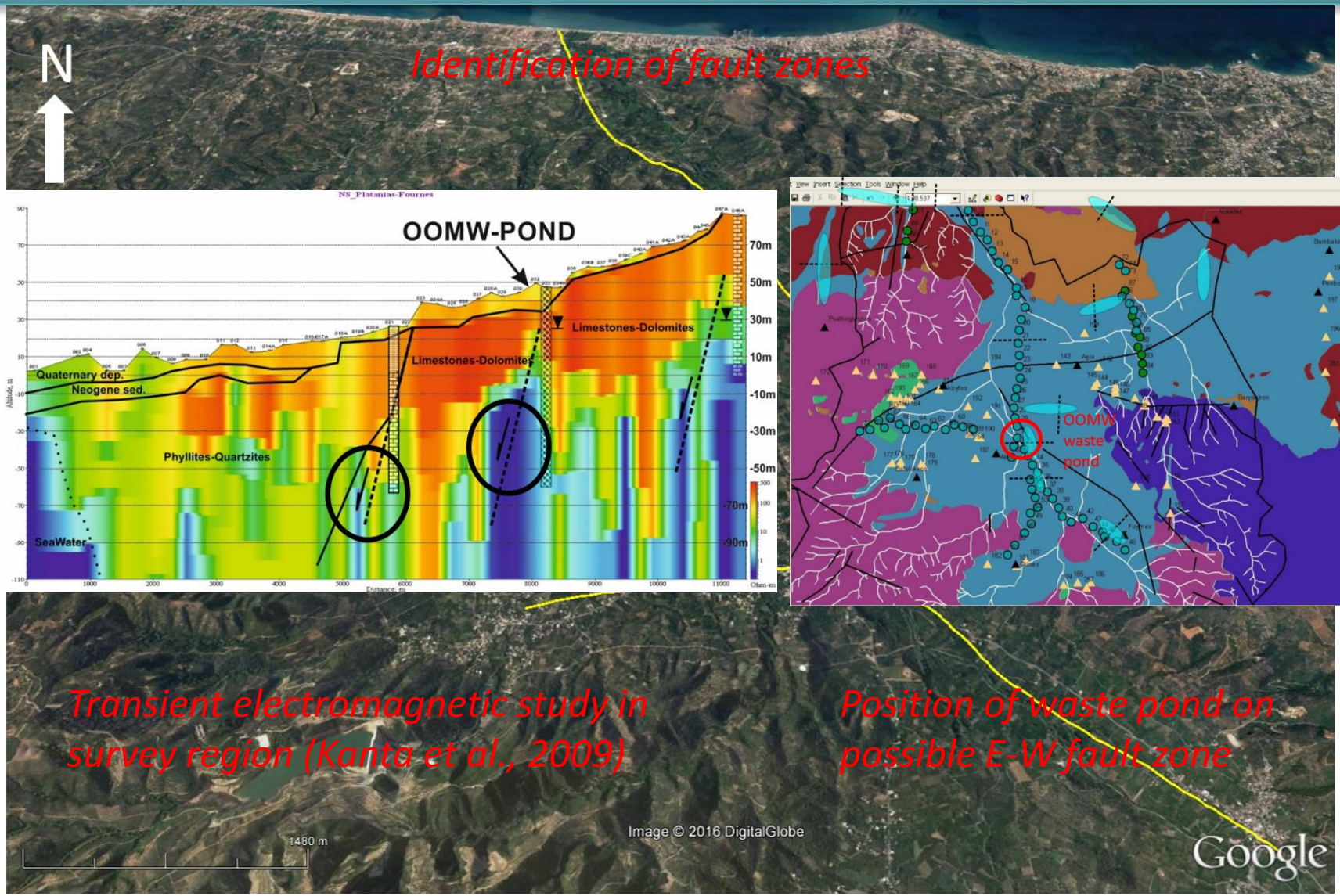
2D ERT measurement profiles



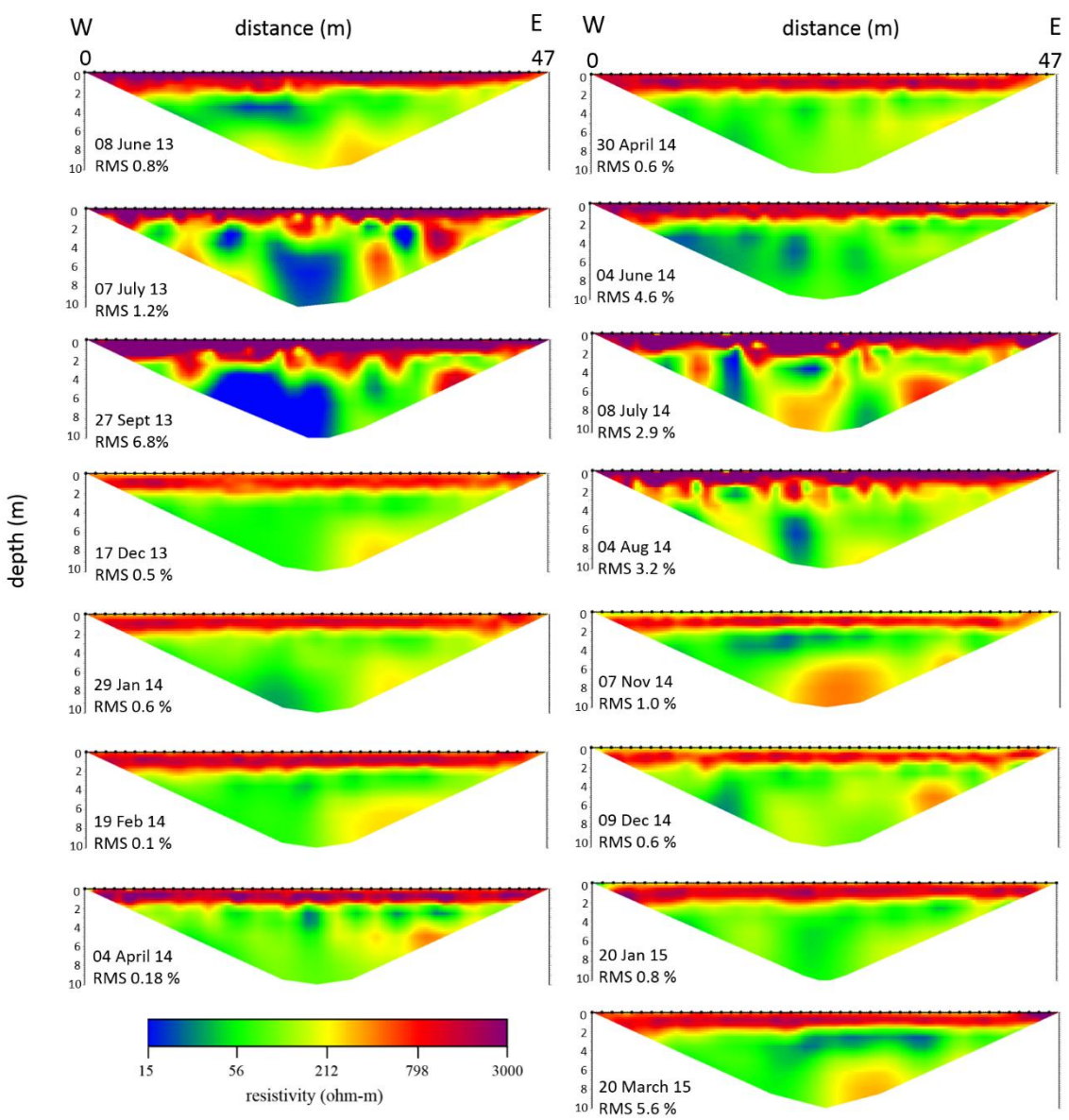


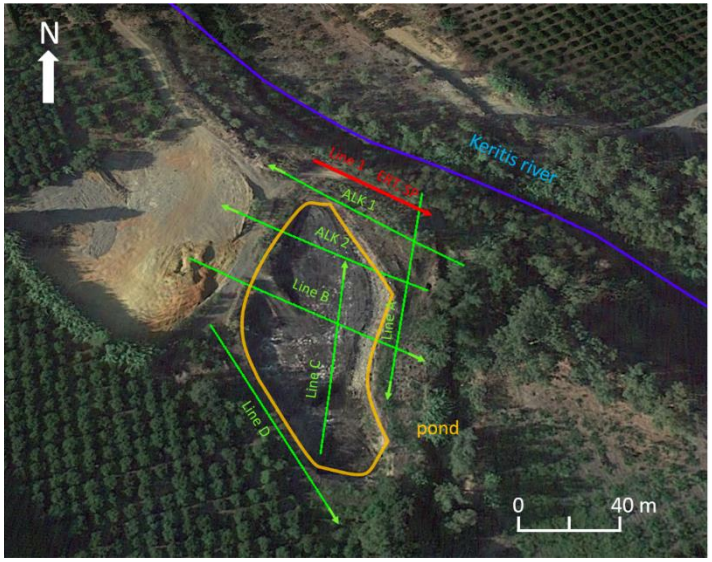
Simyrdanis et al., 2016

Transient electromagnetic study in survey area



Time evolution of the resistivity values along the Line 1



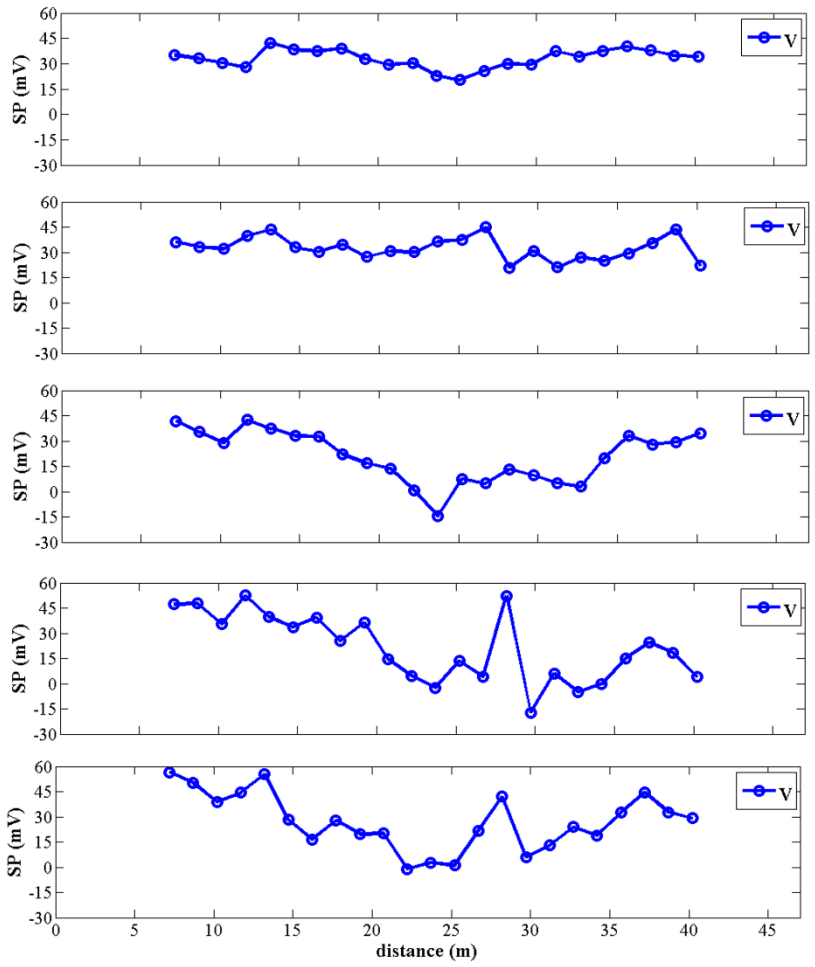


inversion results of "Line1" from June 2013 till March 2015

Test site characterization: SP and ERT profiles (Line 1)

green line: SP profile
yellow line: ERT profile

Self-potential measurements along the line 1



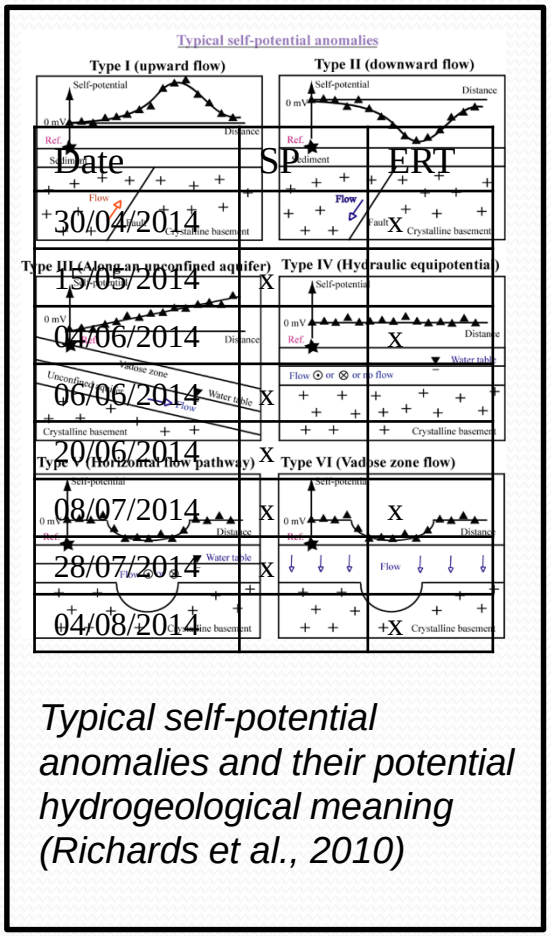
15 May

06 June

20 June

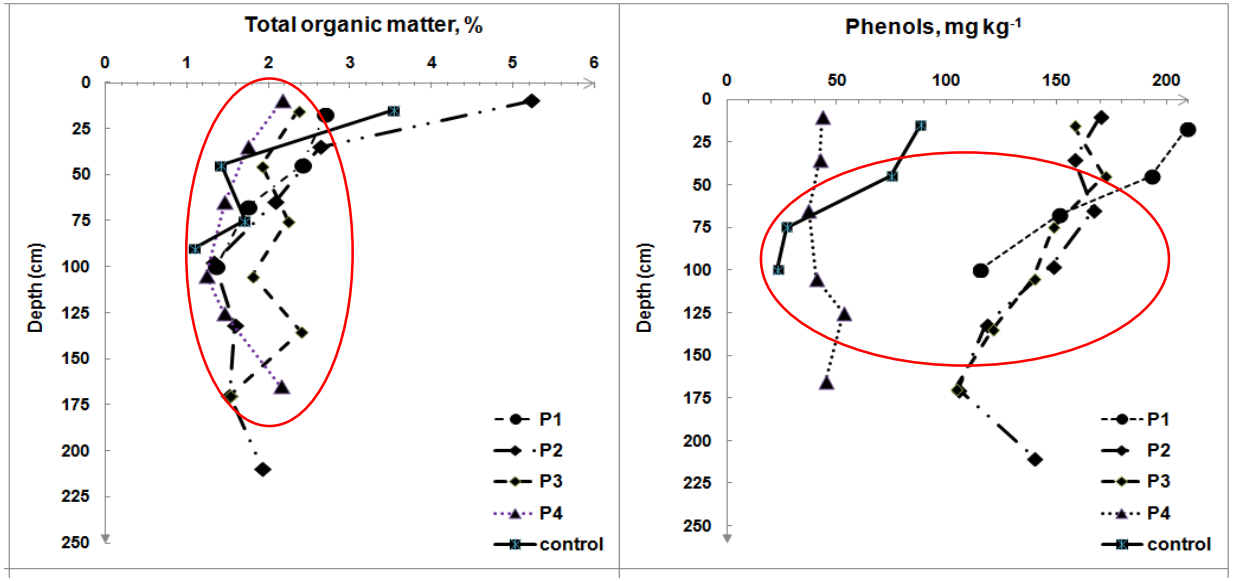
08 July

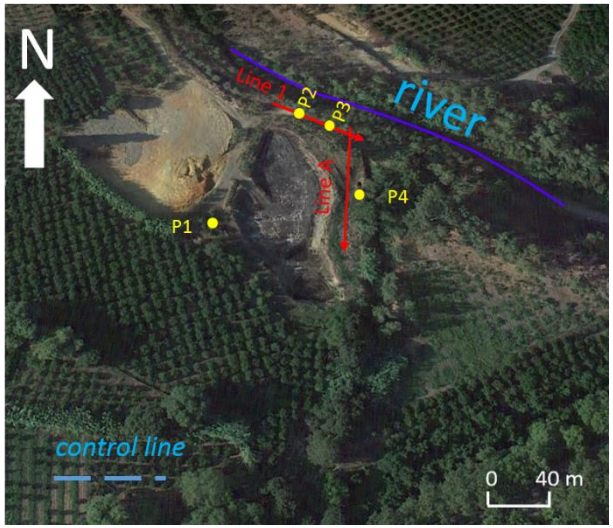
28 July



Typical self-potential anomalies and their potential hydrogeological meaning (Richards et al., 2010)

Geochemical analysis



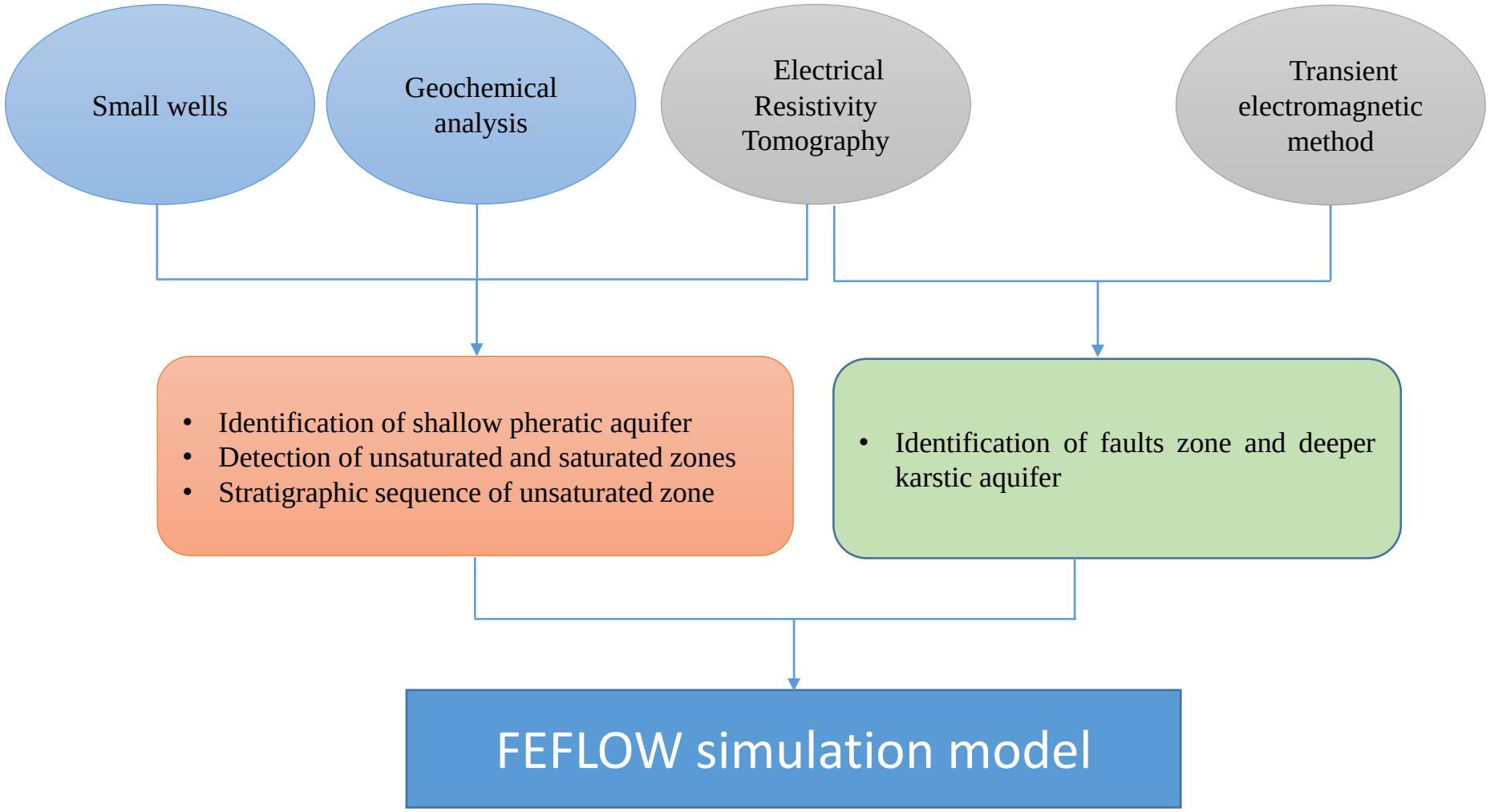


Changes of available organic matter and phenol with soil depth across P1-P4 and control line in the vicinity of pond

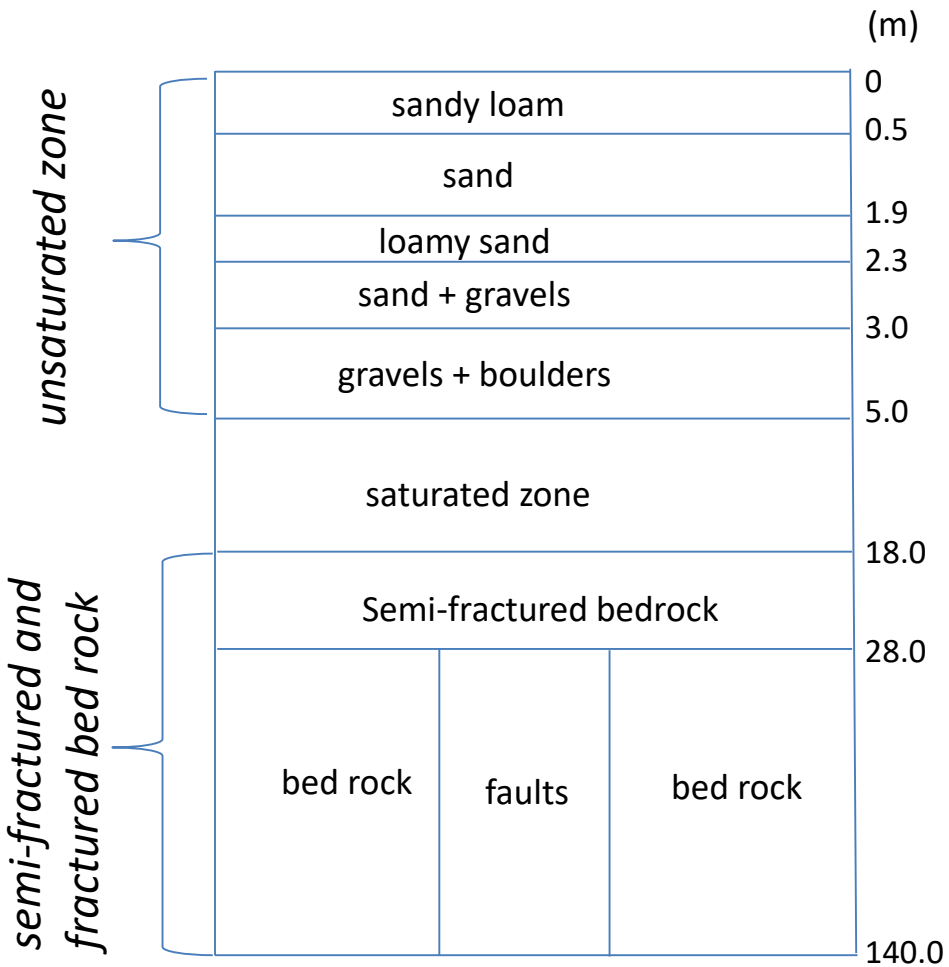
Kavvadias et al., 2016

- reduction in organic matter in soil samples with depth
- phenols were generally above the threshold value (40 mg kg^{-1})

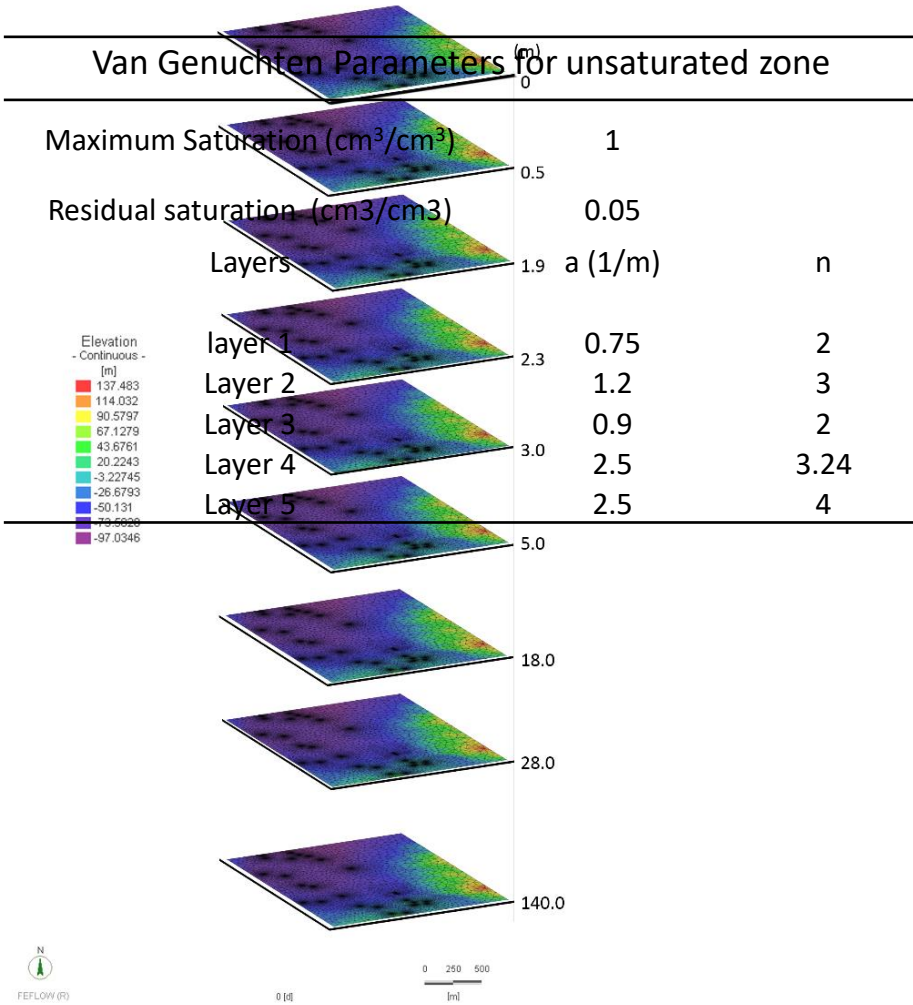
Finite Element subsurface FLOW system (FEFLOW) simulation model



Conceptual model

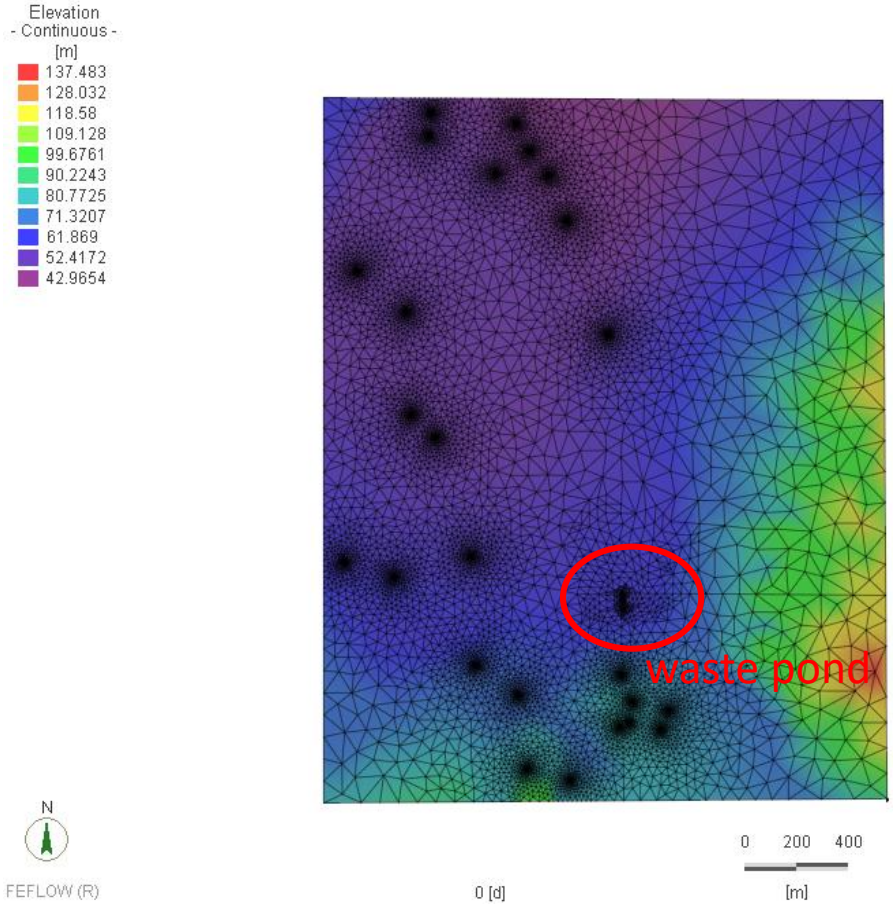


Van Genuchten Parameters for unsaturated zone		
Maximum Saturation (cm^3/cm^3)	1	
Residual saturation (cm3/cm3)	0.05	
Layers	a (1/m)	n
layer 1	0.75	2
Layer 2	1.2	3
Layer 3	0.9	2
Layer 4	2.5	3.24
Layer 5	2.5	4



Conceptual model for FEFLOW modeling

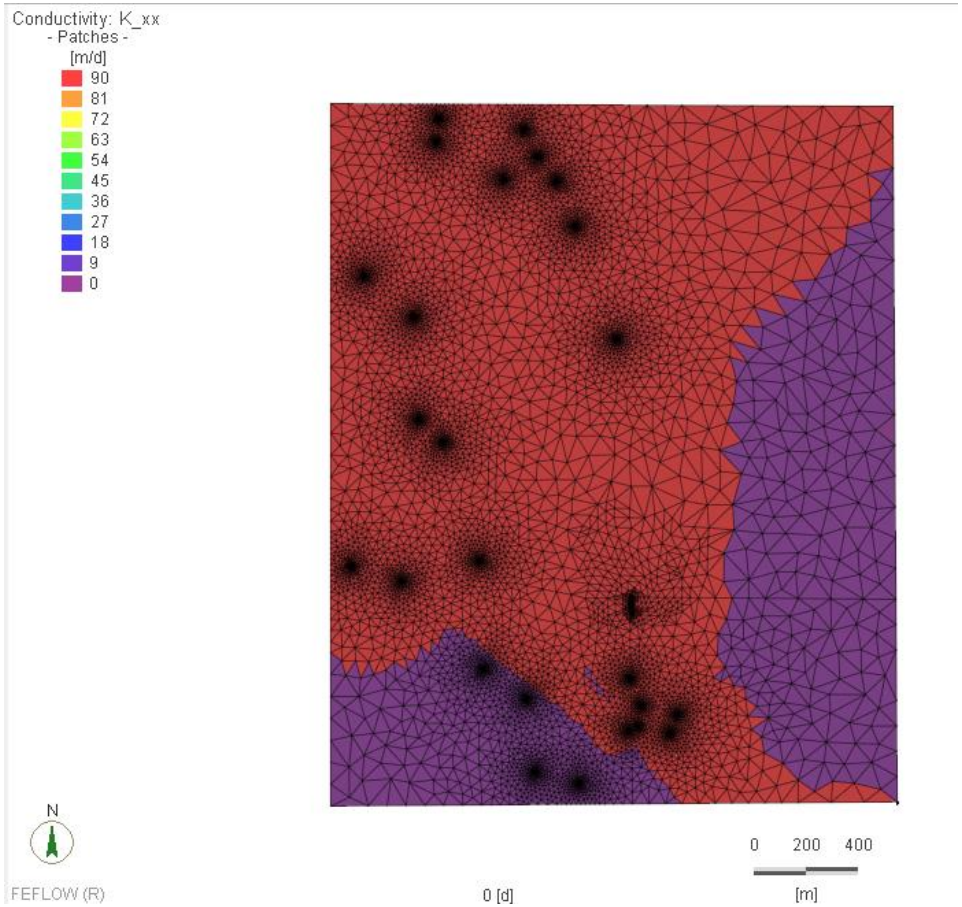
FEFLOW model development

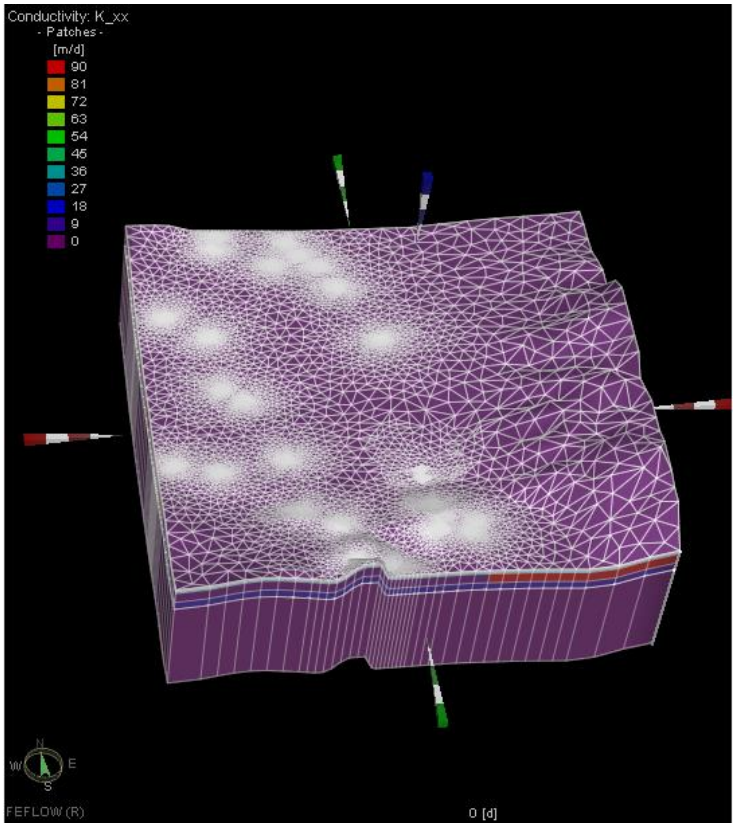


Horizontal discretization of model:

triangular finite element mesh consisting of 109476 nodes and 192168 elements.

Hydraulic conductivity

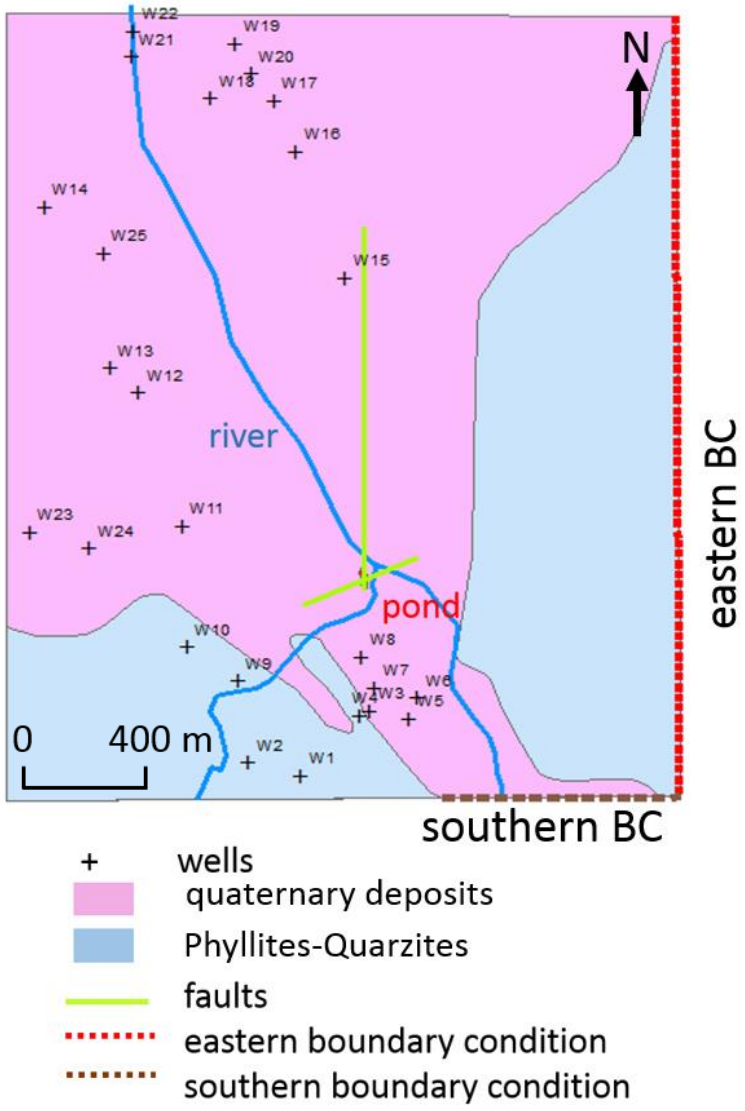




spatial distribution of hydraulic conductivity for saturated zone in 2D and 3D view

Hydraulic conductivty of saturated zone assigned after Nikolaidis and Karatzas, 2007, while for unsaturated zone the conductivity has been assigned based on soil type

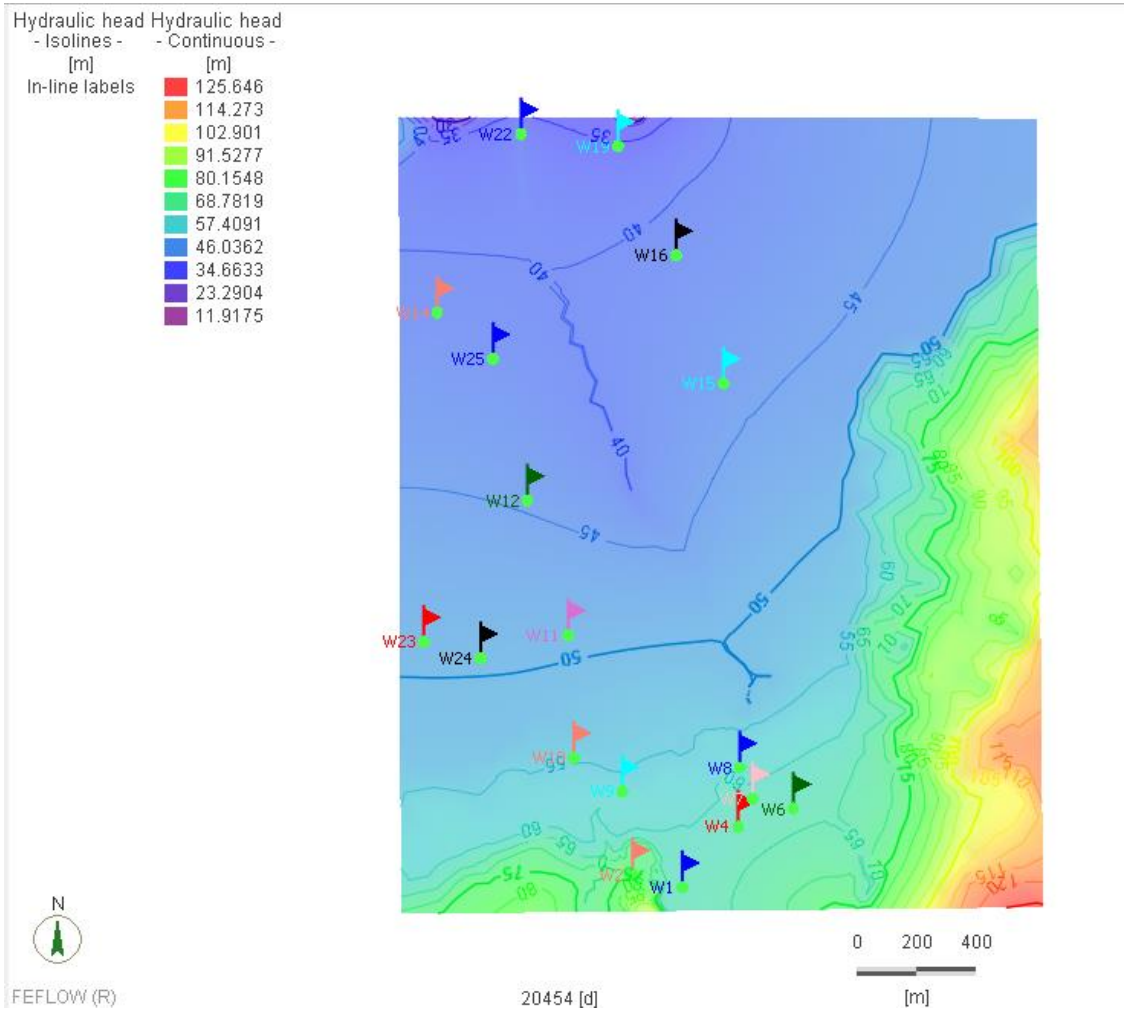
Project area for modeling



- Pond is used for waste deposition since 1940.
- Initial hydraulic heads are assigned for model from previous information of water table in study area.
- 1st type boundary condition is set for the river.
- 2nd type boundary condition is set for eastern and southern part of model domain based on the fluid flow (influx) from nearby Karstic springs.

Study area with location of wells, faults and flow boundary conditions

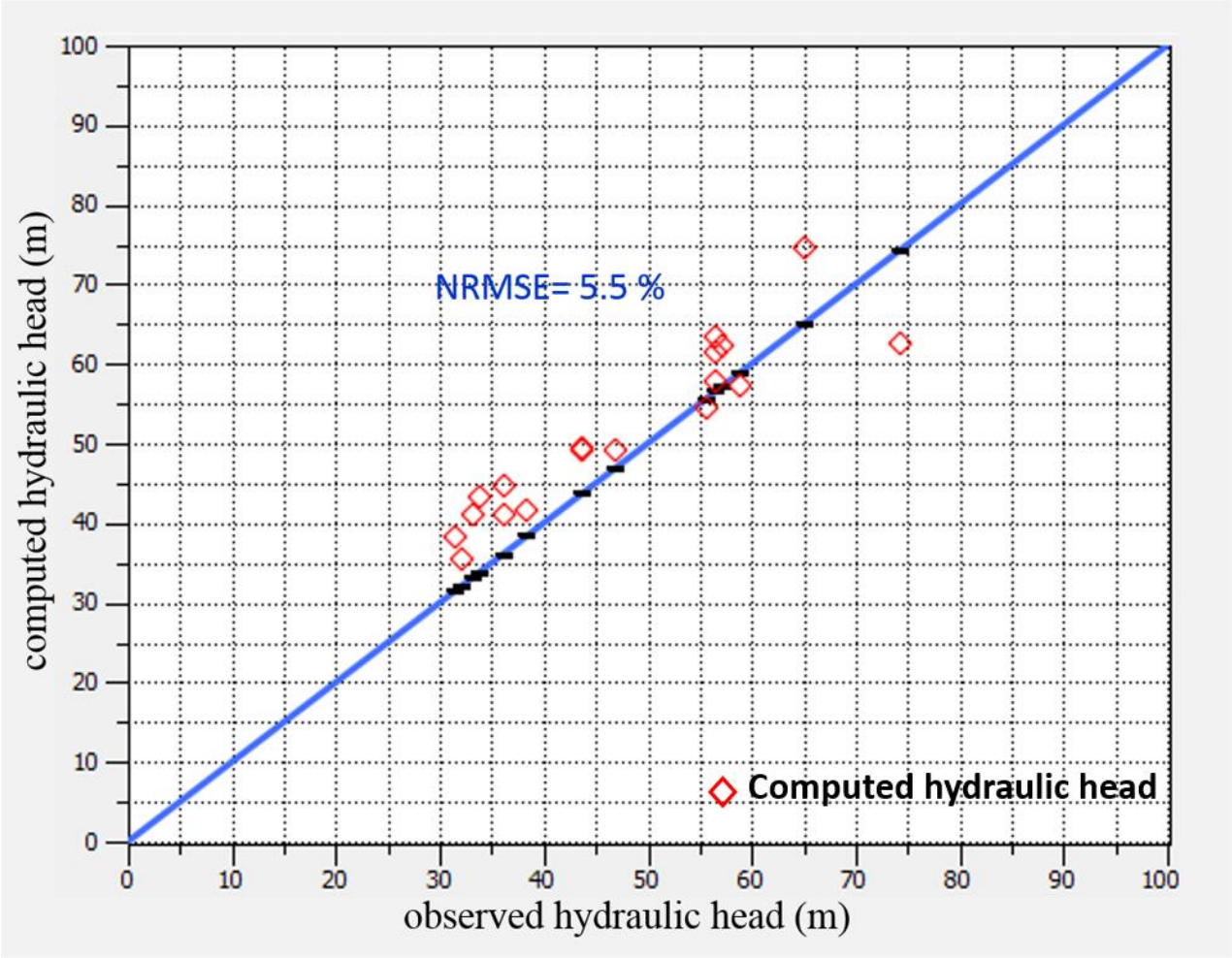
Flow calibration results



- The calibration of the flow was based on the hydraulic head measured in 18 wells.
- The lateral influx rate on the southern and eastern model boundary is varied during the calibration procedure.

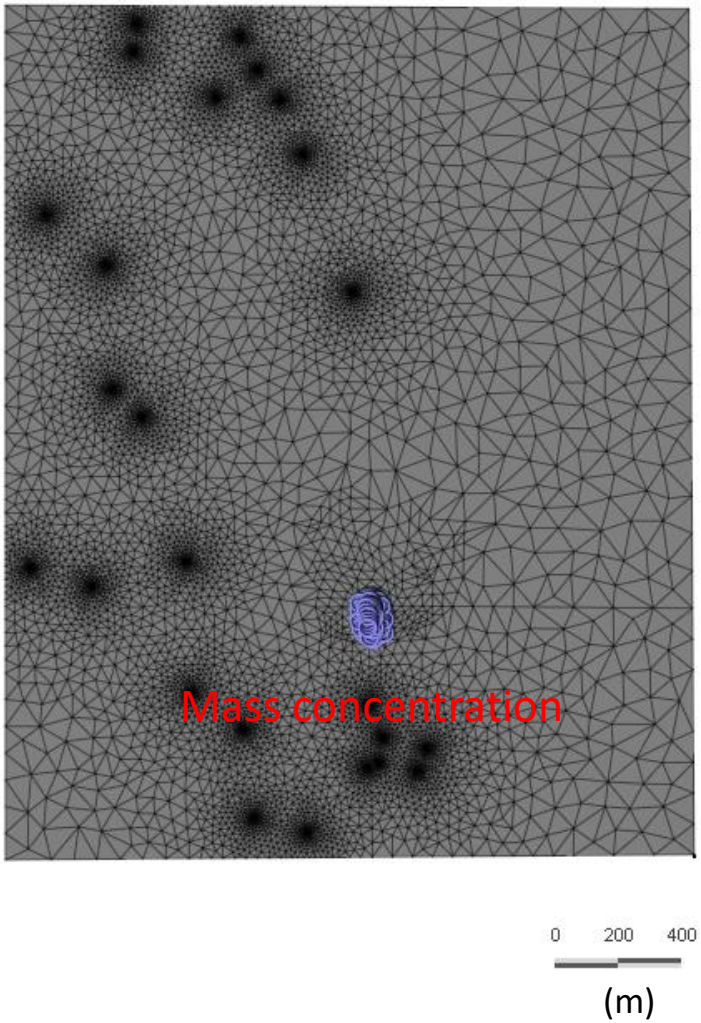
Hydraulic head distribution for model layer 6 (saturated zone)

Flow calibration results



Comparison of measured and computed hydraulic head values

Mass transport



- Phenol is selected as the main contaminant because of strong toxicity and high concentration in OOMW (Moraetis et al., 2011; Seferou et al., 2013)
- 1st kind boundary condition is set for mass concentration.
- Porosity values for each layer is defined from literature.

Conclusions & perspectives

- Time-lapse monitoring of the Olive Oil Mills' Wastes using geoelectrical methods is able to identify possible anomaly sources related to organic contaminant and to describe their time evolution.
- Integrated use of geophysical imaging techniques and numerical modeling is proposed to model the transport of OOMW under unsaturated–saturated conditions and very complex geological/tectonic formations.
- Geophysical techniques (ERT and TEM) provided a priori information for groundwater simulation model
- The flow calibration results for the survey area shows an agreement between measured and computed values
- *The study for the mass transport of the OOMW is in progress*