Interreg North-West Europe
RAWFILL
European Regional Development Fund

How can geophysical methods help to characterize landfills?

Focus on Onoz landfill

David Caterina, Itzel Isunza Manrique , Frédéric Nguyen

Agenda of the presentation

- A short introduction to geophysics
- Landfill investigation
  - Context
  - Extension
  - Composition
- Landfill monitoring
- Take home message
- Landfill of Onoz

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A short introduction to geophysics: Objectives

Mapping spatial variations in:

- Lithology/waste type/density
- Water content
- Pore fluid or total dissolved solids
- Mechanical properties
- Metallic content

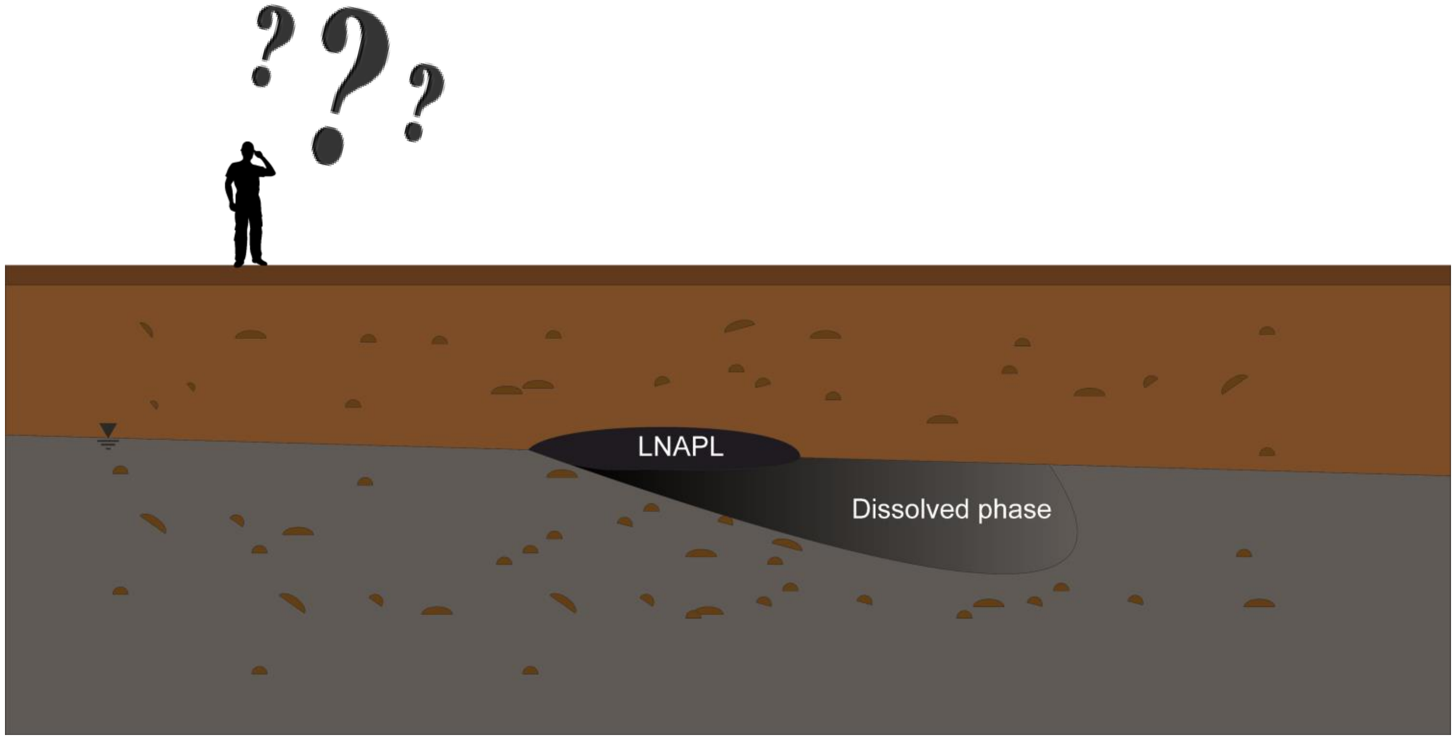
Monitoring changes in:

- Waste/contaminant mass
- Tracer concentration
- Amendement injection
- Compaction/density/porosity
- Gas production

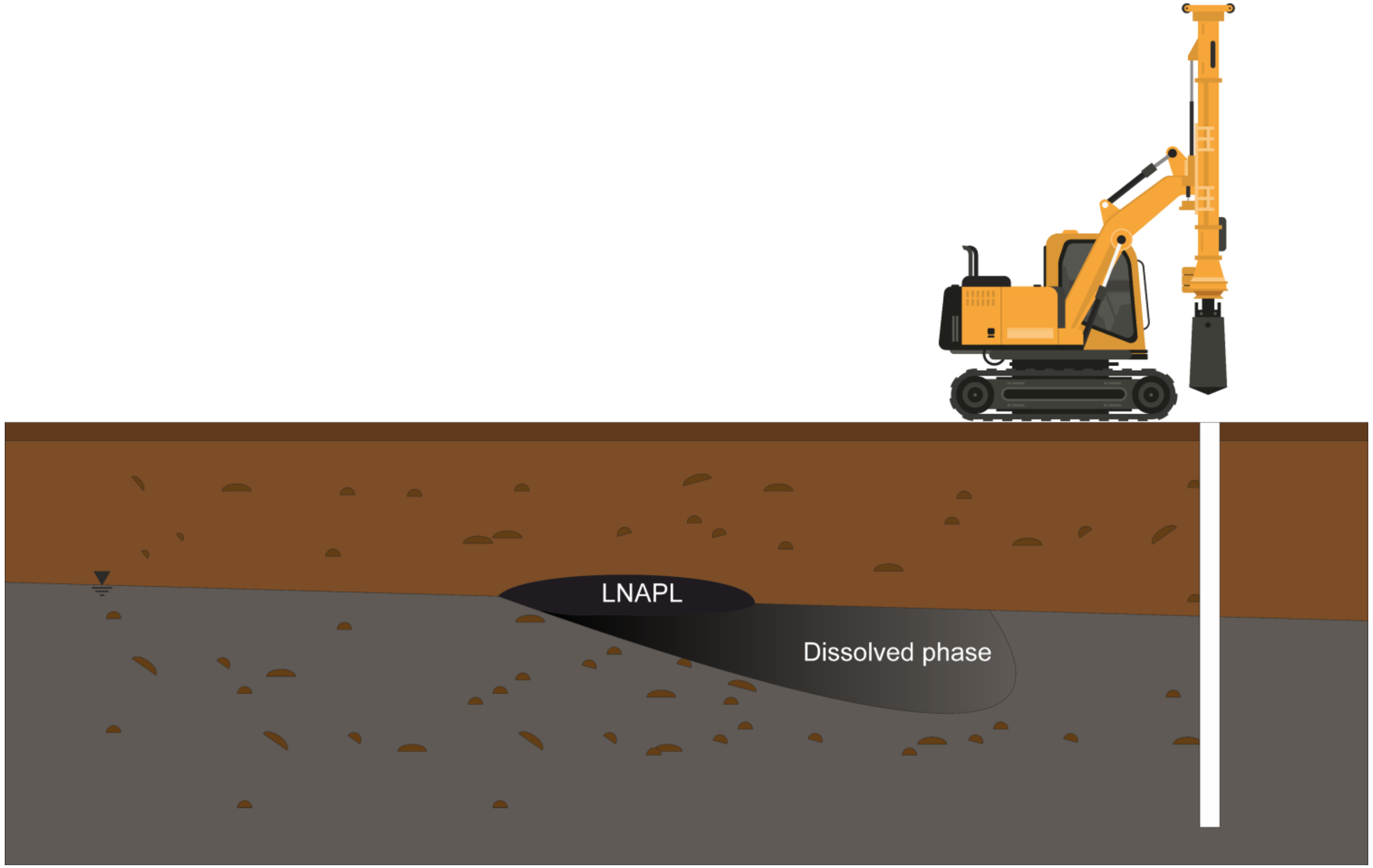
Translate the geophysical variations or changes into property of interest assuming a relationship.

Why geophysics?

Example: contaminant detection



Classical approach



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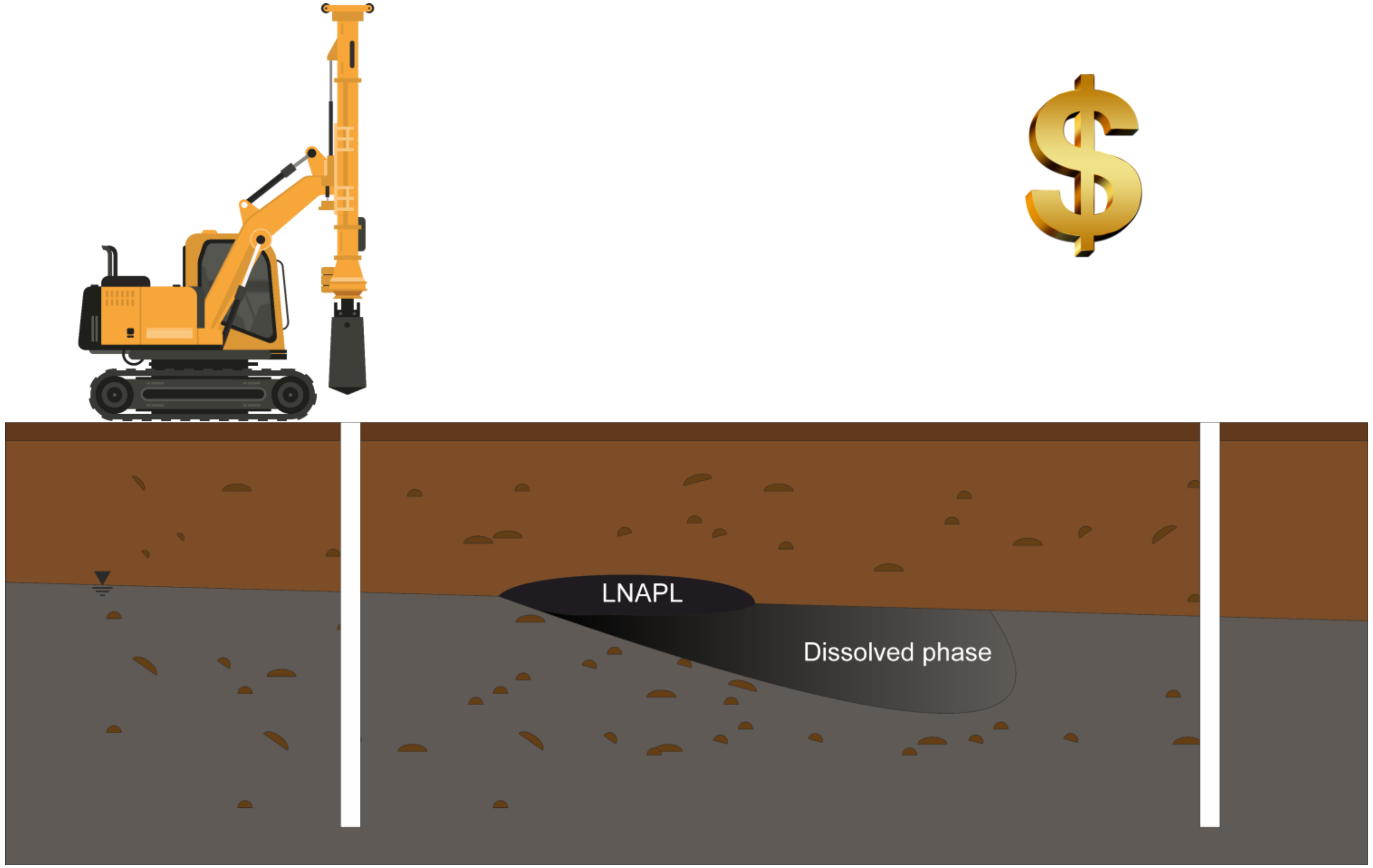

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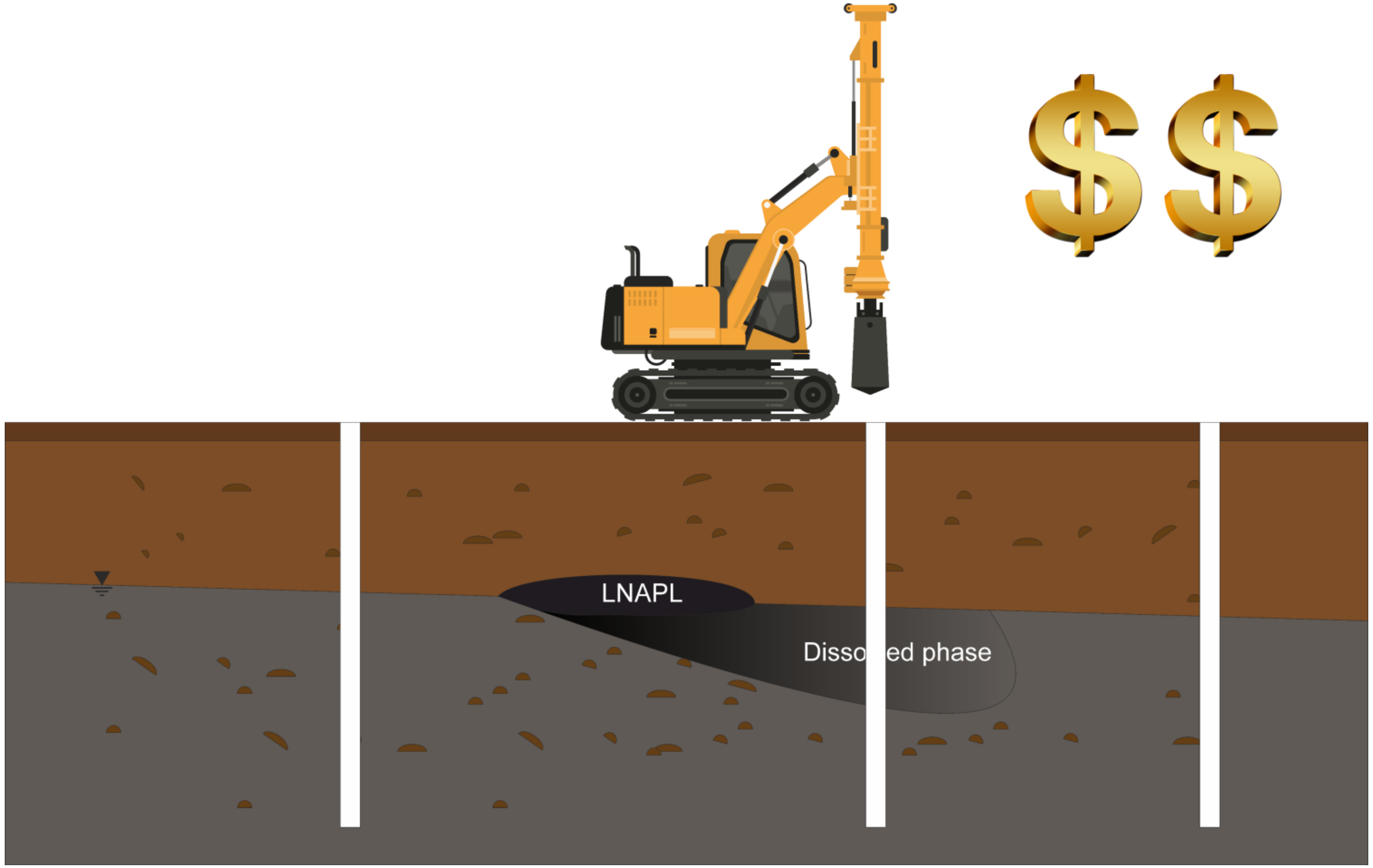

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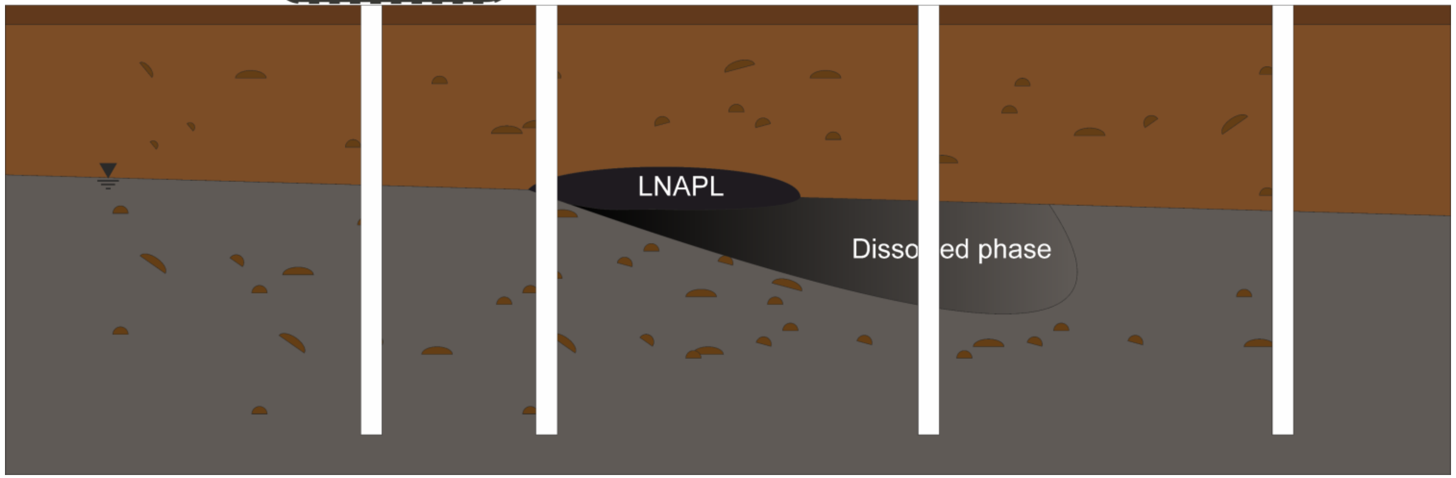
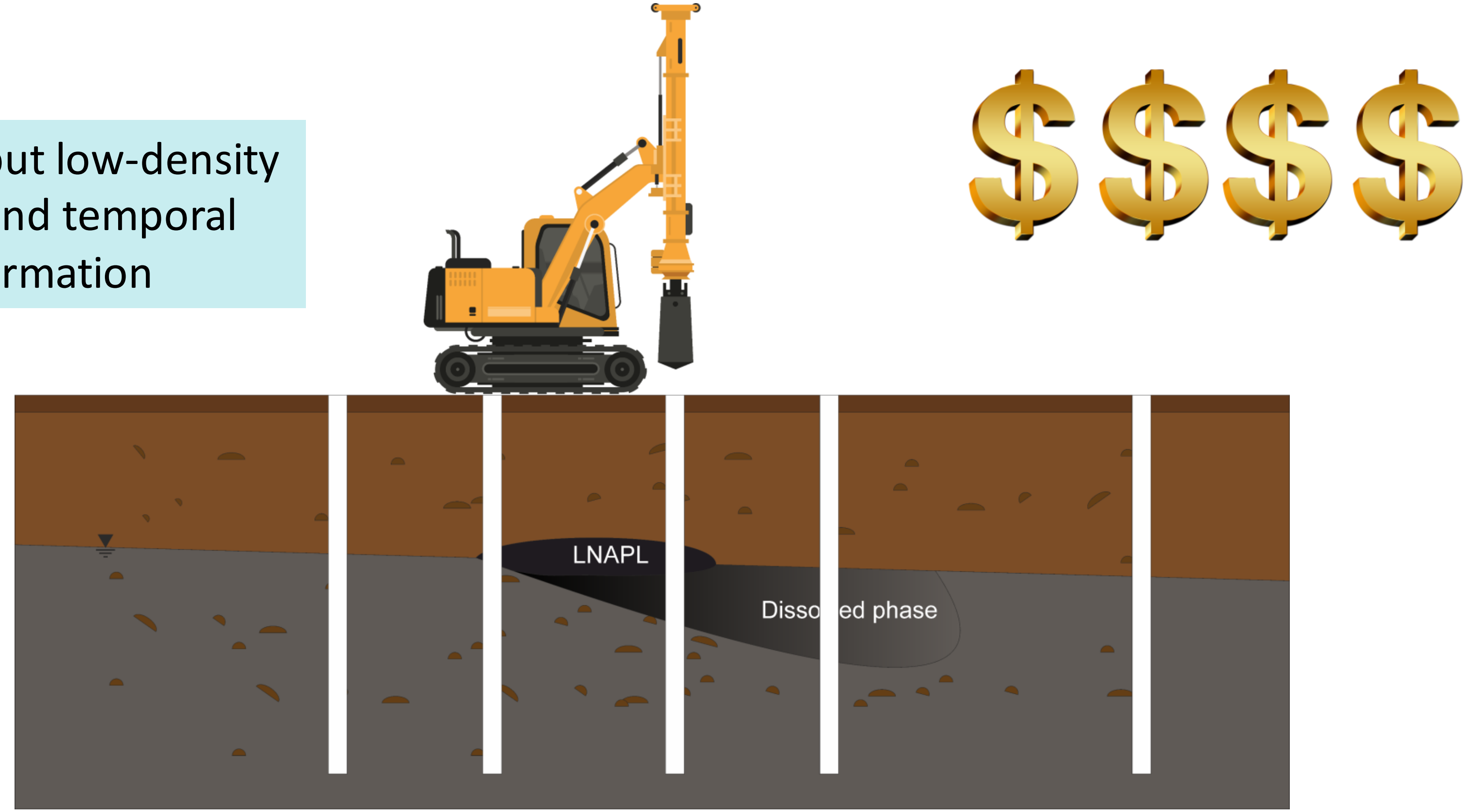
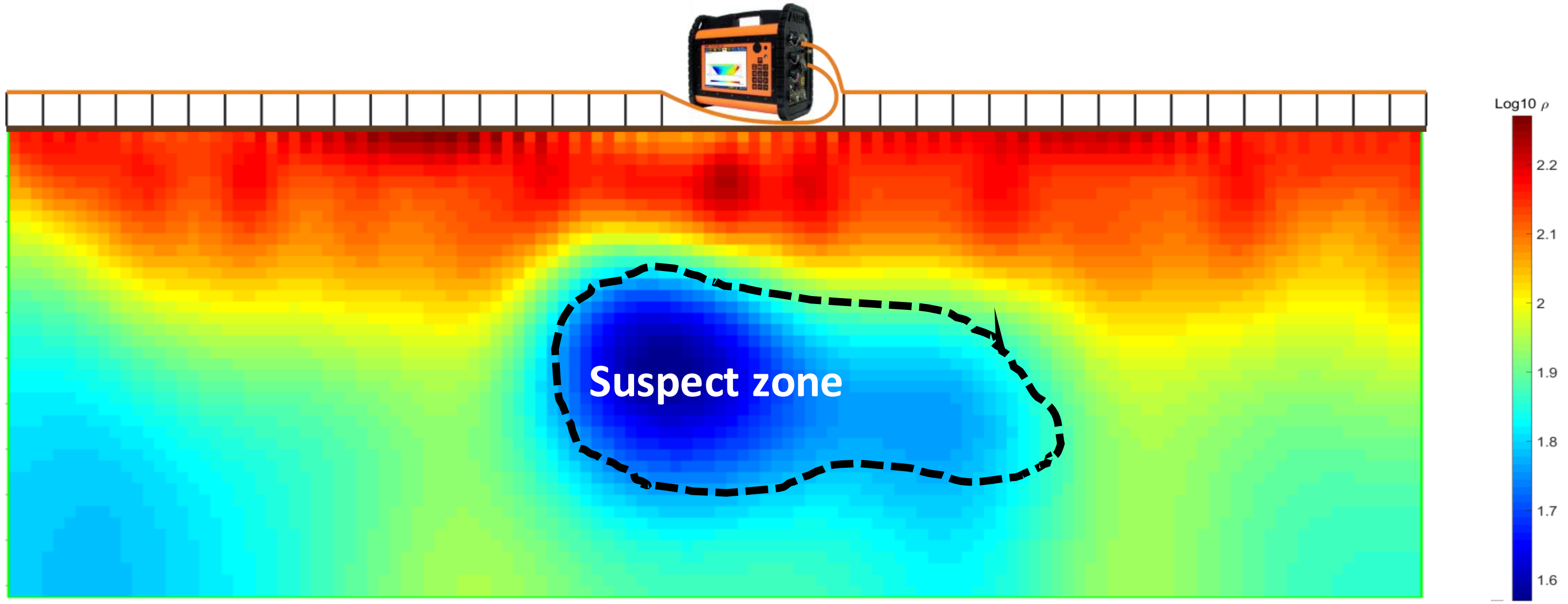


Classical approach

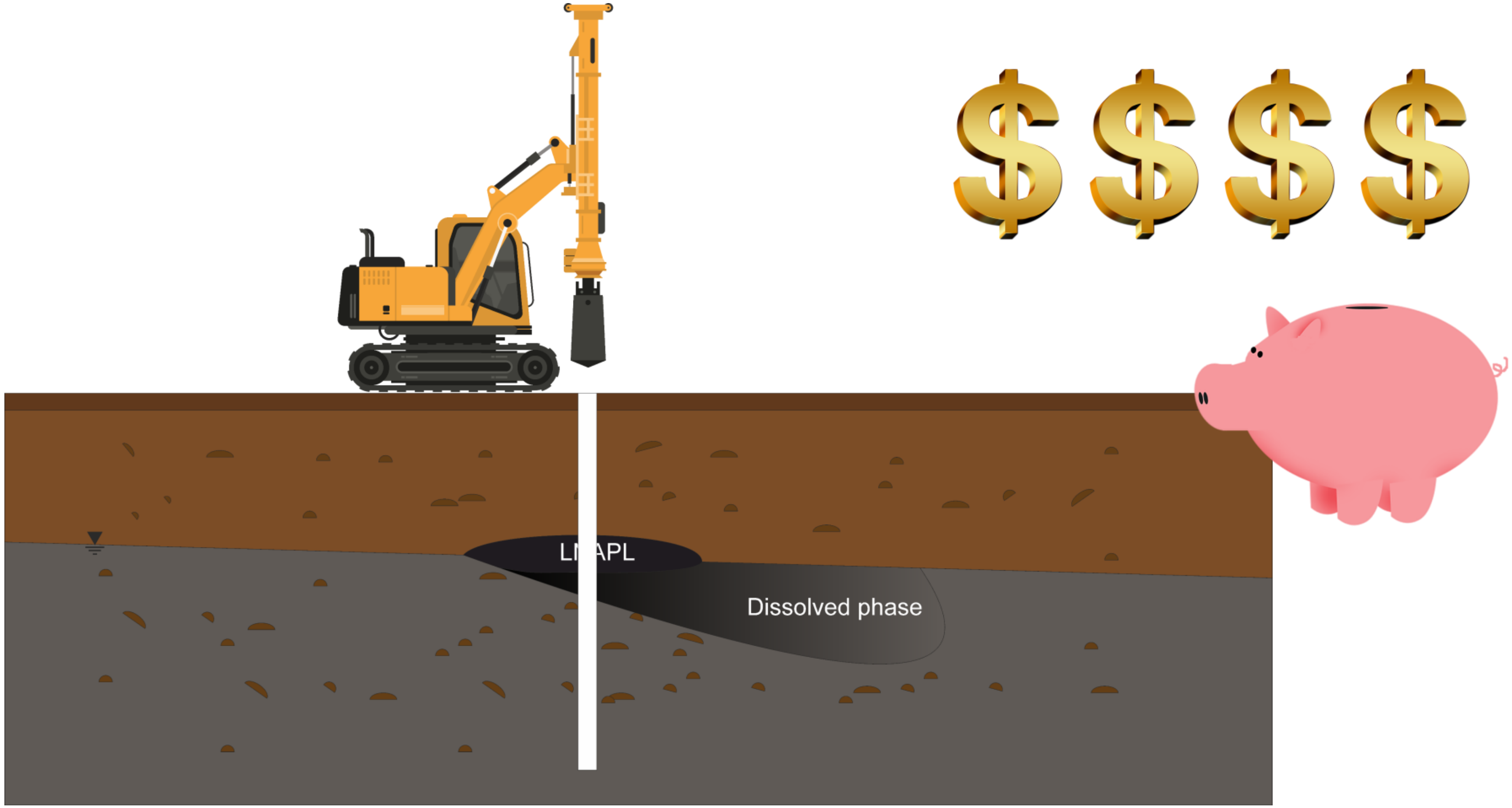
Accurate but low-density spatial and temporal information



With geophysics… (here ERT)



Focus on the geophysical anomaly



Pro and cons

- Non to minimally invasive
- Relatively low cost
- Large coverage
- See through technology

- Indirect information
- Resolution decreases with depth
- Prone to modeling errors (artefacts)

Most powerful when interpreted with other data

Different methods…

Different targets…

Method
Seismics (refraction, surface waves, reflection, ambient noise)
DC electrical resistivity
Induced polarization (IP)
Spontaneous potential (SP)
Ground Penetrating Radar (GPR)
Electromagnetic (EM)
Magnetic
Gravimetry
Borehole logging (caliper, gamma, sonic, flowmeter, TV)

A combination of different methods is recommended to reduce uncertainties

The main phases of a geophysical investigation and associated costs

- **Pre-investigation and feasibililty**
  - Set-up
  - Properties
  - Surveys
- **Measurements on site**
  - Data quality control
  - Possible interferences
- **Data processing and interpretation**
  - Image appraisal
  - Complementary data
- **Report synthesis**

- **Desk study**
- **Equipment preparation and depreciation**
- **Field study**
  - Transport to and on site
  - Data acquisition
  - Accomodation
- **Desk study**

A lot of pragmatism too: site access, logistics, near-surface objects (cables etc…)

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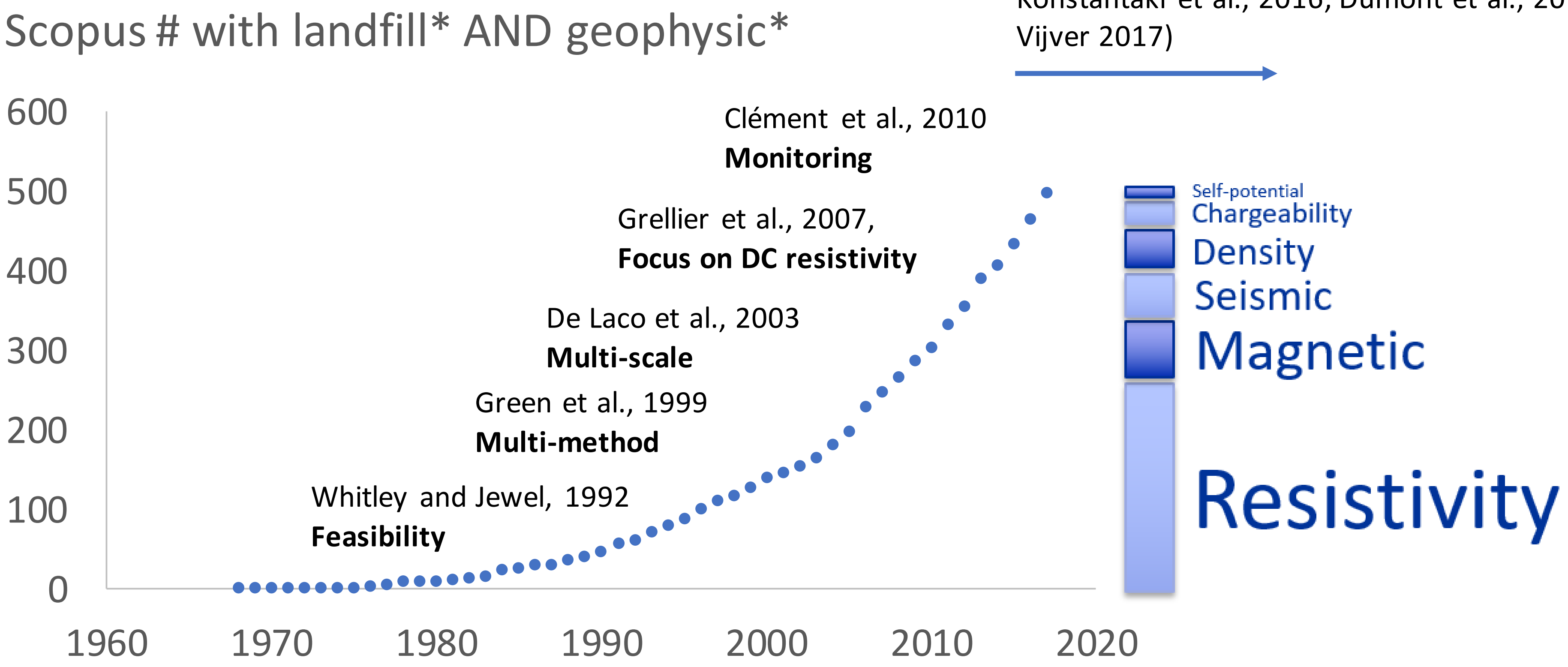
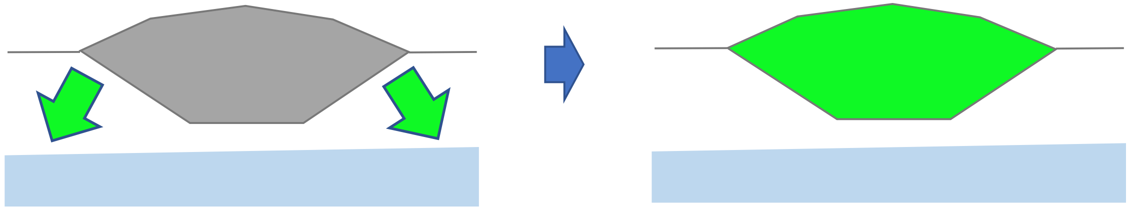
Applied geophysics and landfills

Book chapter by Soupios and Ntarlagiannis (2017)

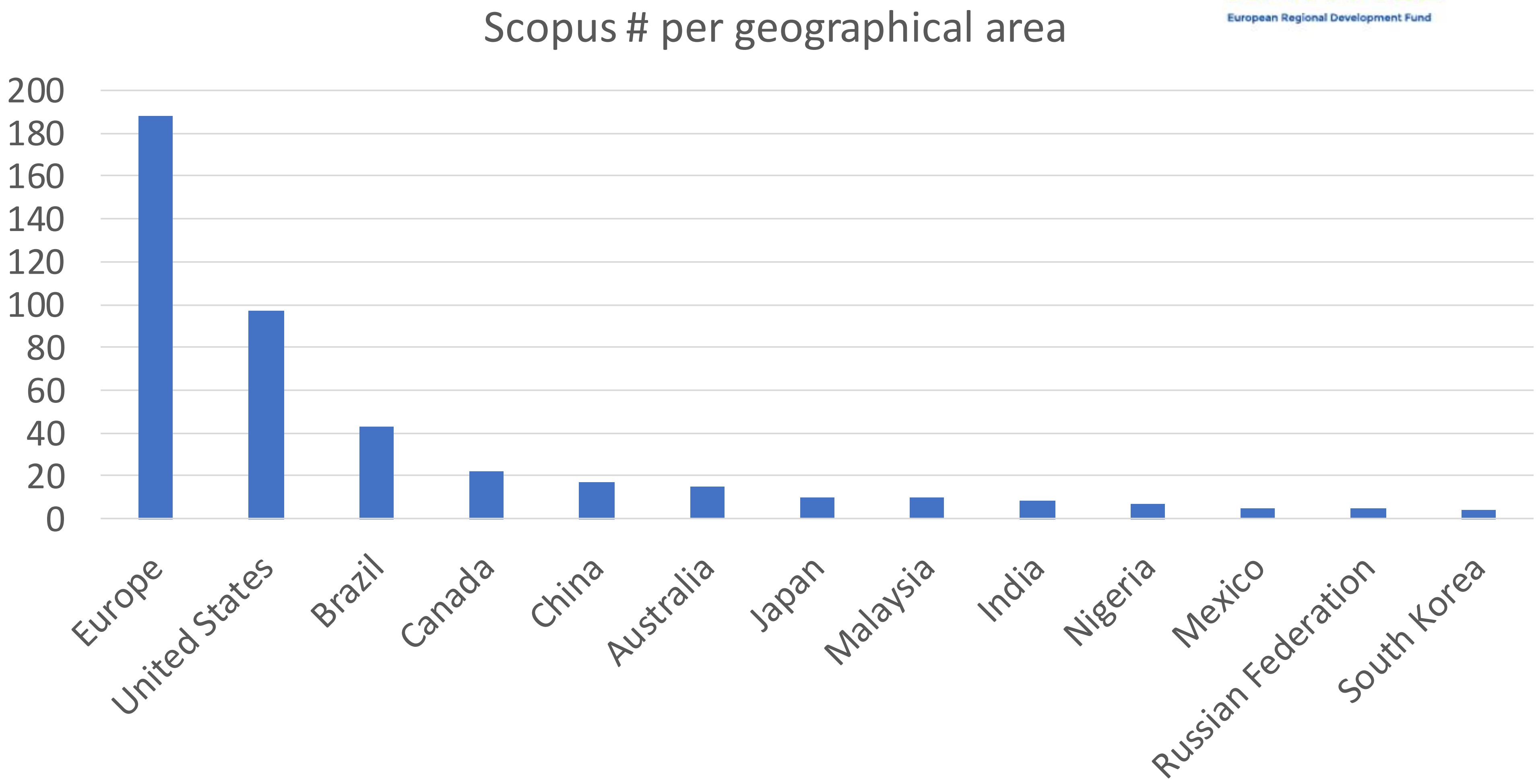
Dedicated development (e.g. Audebert et al., 2014; Konstantaki et al., 2016; Dumont et al., 2016; van de Vijver 2017)

Query performed 03/02/2018:
(TITLE-ABS-KEY(landfill* AND geophysic*))





Europe leads the way!



Physical properties of wastes: solid part

Municipal solid waste composition example :

- 2,5% - 3,5% metal → valuable
- 15-40% aggregates → recycled concrete
- Organic material → landfill biogas
- Plastic → alternative fuel

Electrical resistivity: 1 – 100 Ωm

Magnetic susceptibility : 0,02 SI

Density: 0,9 – 1,6

Dumont (2017)

Physical properties of wastes: liquid part

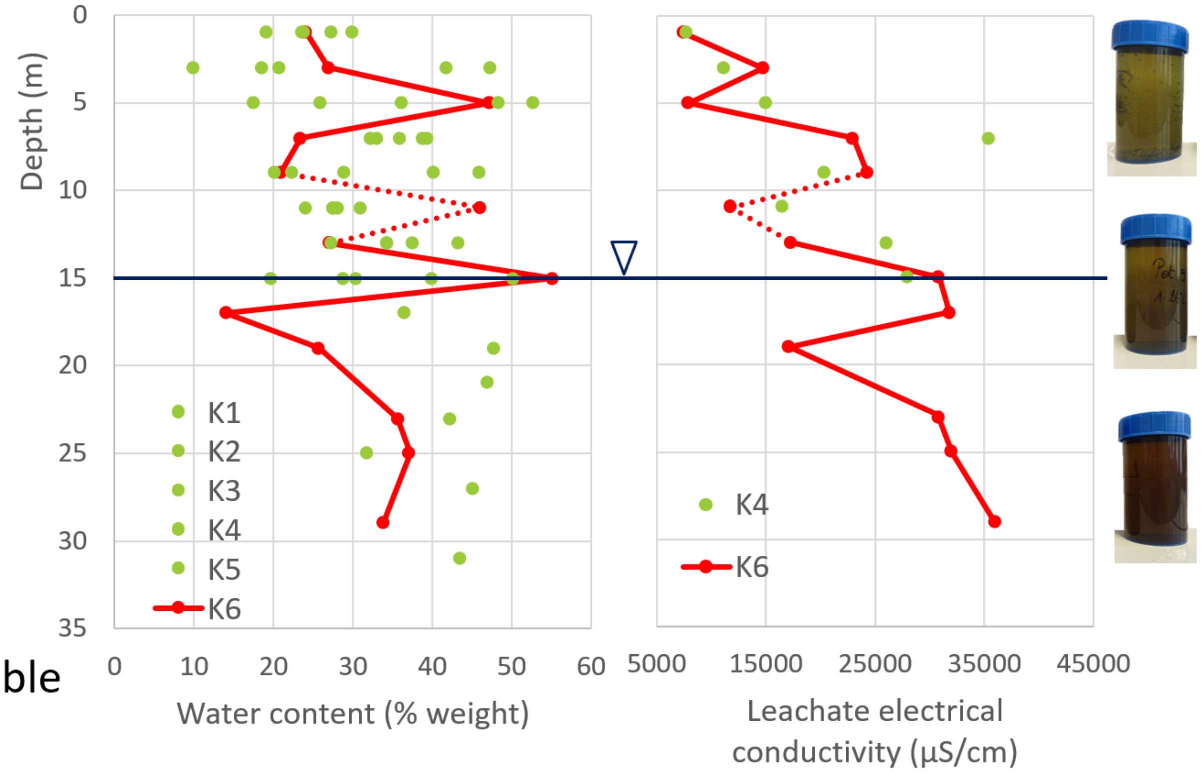
Water content

- Mass loss after drying
  10 – 55 % weight

Leachate conductivity

- Use of 15 tons press
  7000 – 35000 µS/cm

➔ occurrence of perched water table
➔ saturated zone at 15 m depth



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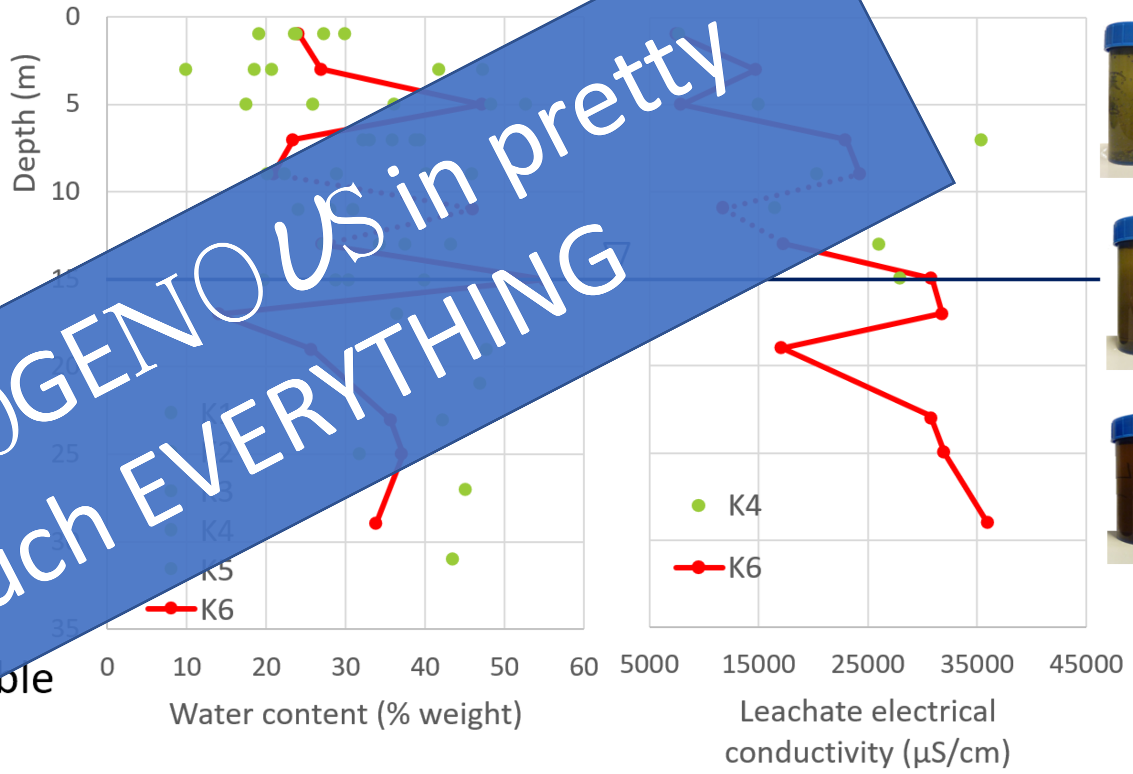

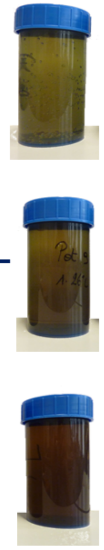

HETEROGENOUS in pretty much EVERYTHING

Physical properties of wastes

Generally, geophysical properties contrast well with the surrounding environment

- Leachate ionic strength and temperature increase > low electrical resistivity (0.5-30 Ωm)
- Metal scraps and redox reactions > high chargeability and self-potential (100s mV/V, 100s mV)
- Ferromagnetic objects > κ 2-4 orders of magnitude larger than sedimentary rocks
- Low compaction > lower density 1-2 t/m^3 and lower elastic moduli (Vp~180 m/s to 1450m/s)

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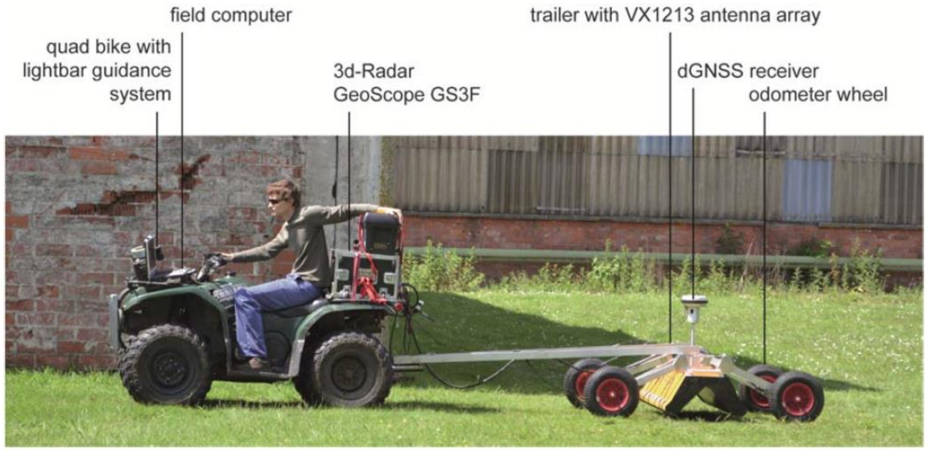
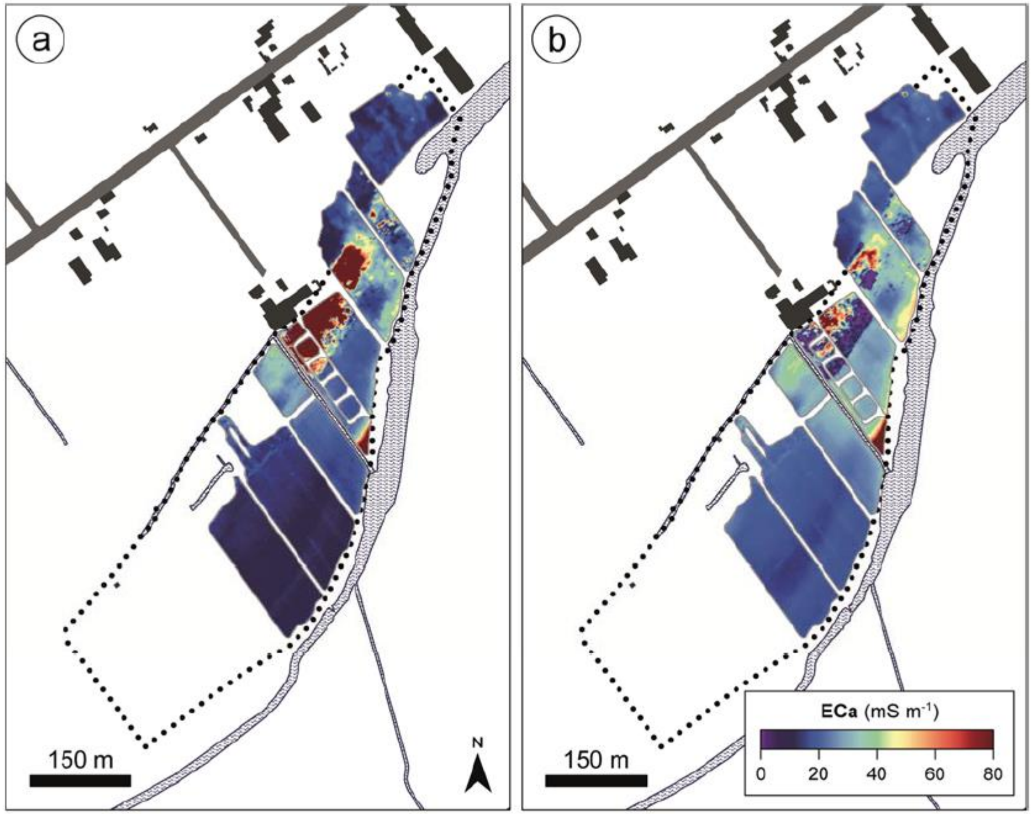
Landfill investigation: extension



Average driving speed 7.3 km/h



loamy sandy soil background

Van de Vijver PhD, 2017

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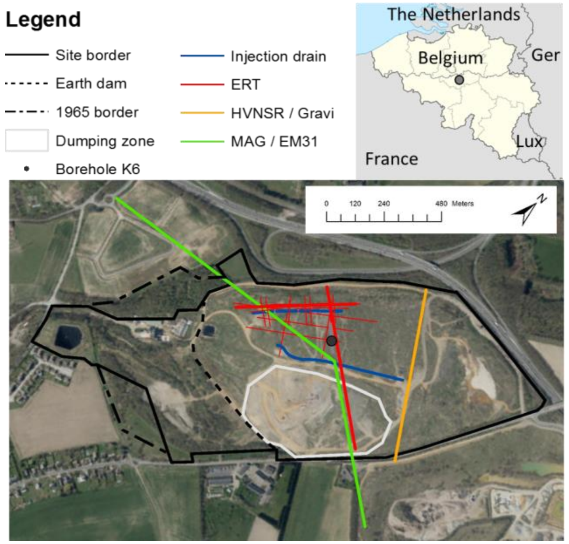
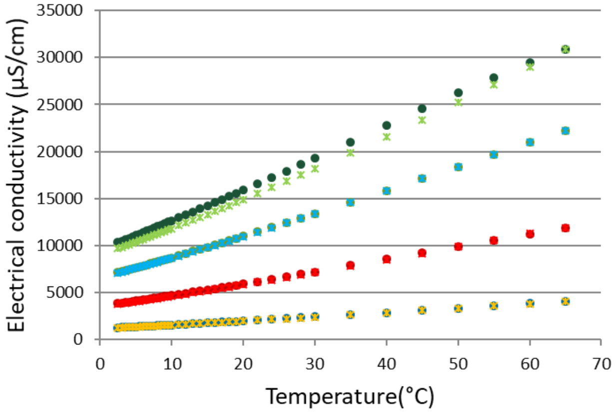
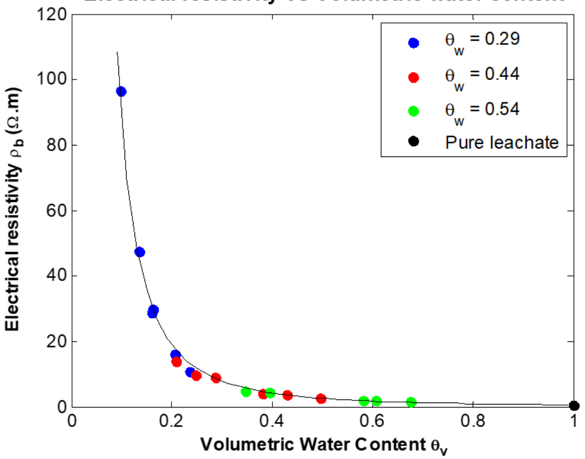
Landfill investigation: Composition

Towards quantitatvie spatial distribution **of leachate property : petrophysics**







$$\rho_b = 1.53 * 0,40 * \theta_v^{-2.101}$$

$$\frac{\sigma_T}{\sigma_{25}} = 0.19(T-25)+1$$

(Dumont et al., 2016)

Landfill investigation: Composition

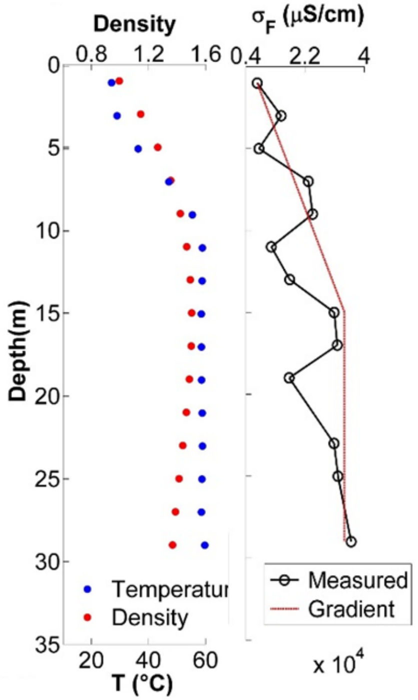
- Towards quantitative spatial distribution **of leachate property**

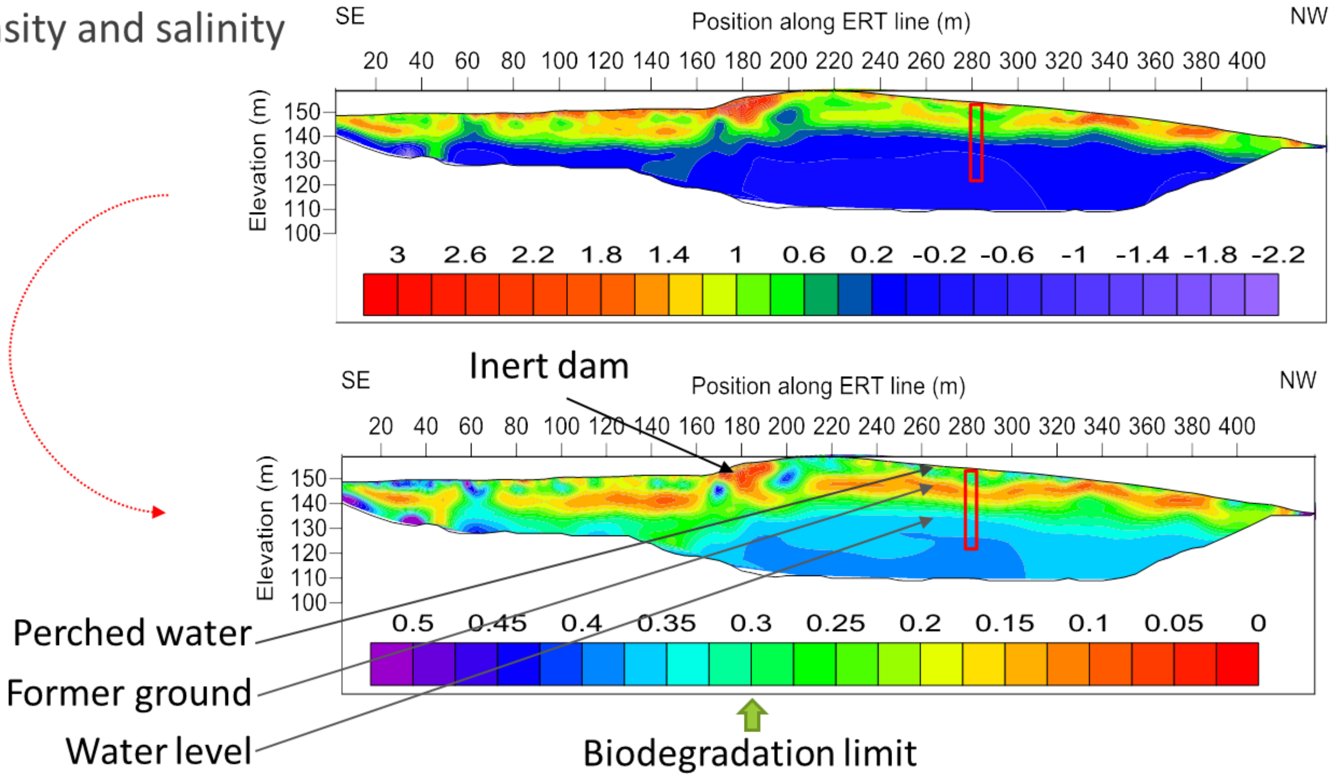
$$\rho_b = 1.53 * 0{,}40 * \theta_v^{-2.101}$$

$$\frac{\sigma_T}{\sigma_{25}} = 0.19(T - 25) + 1$$

(Dumont et al., 2016)

Correction of temperature, density and salinity





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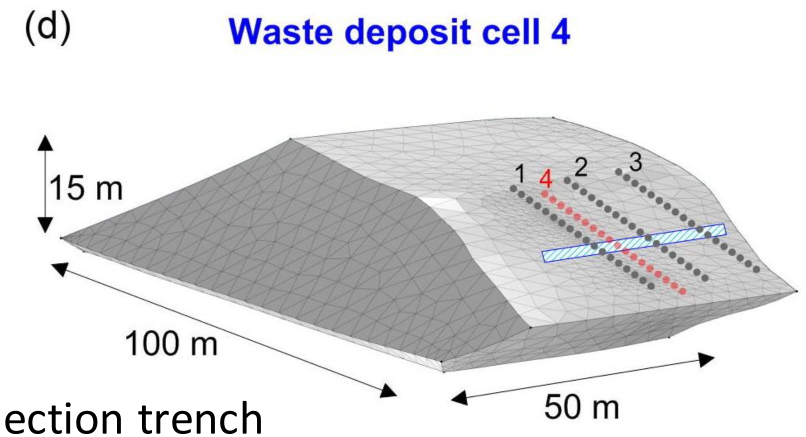
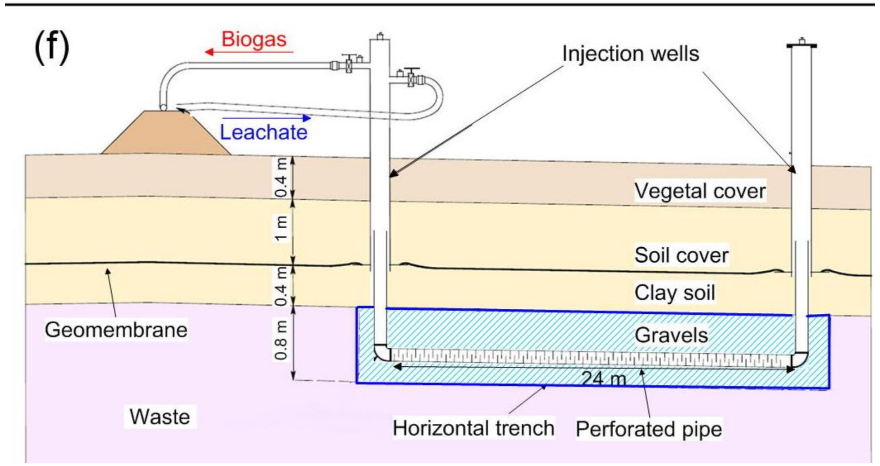
Landfill monitoring



Injection trench

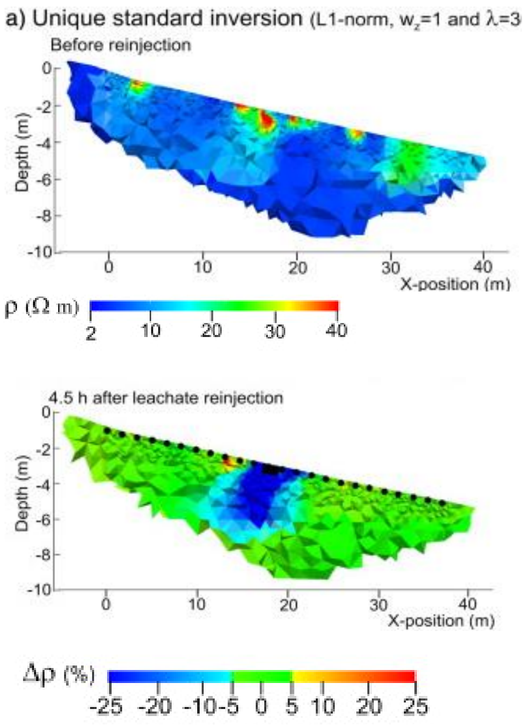


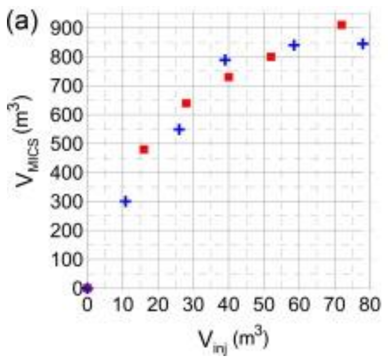
Les Champs-Jouault experimental site

- Household waste, non-hazardous industrial waste

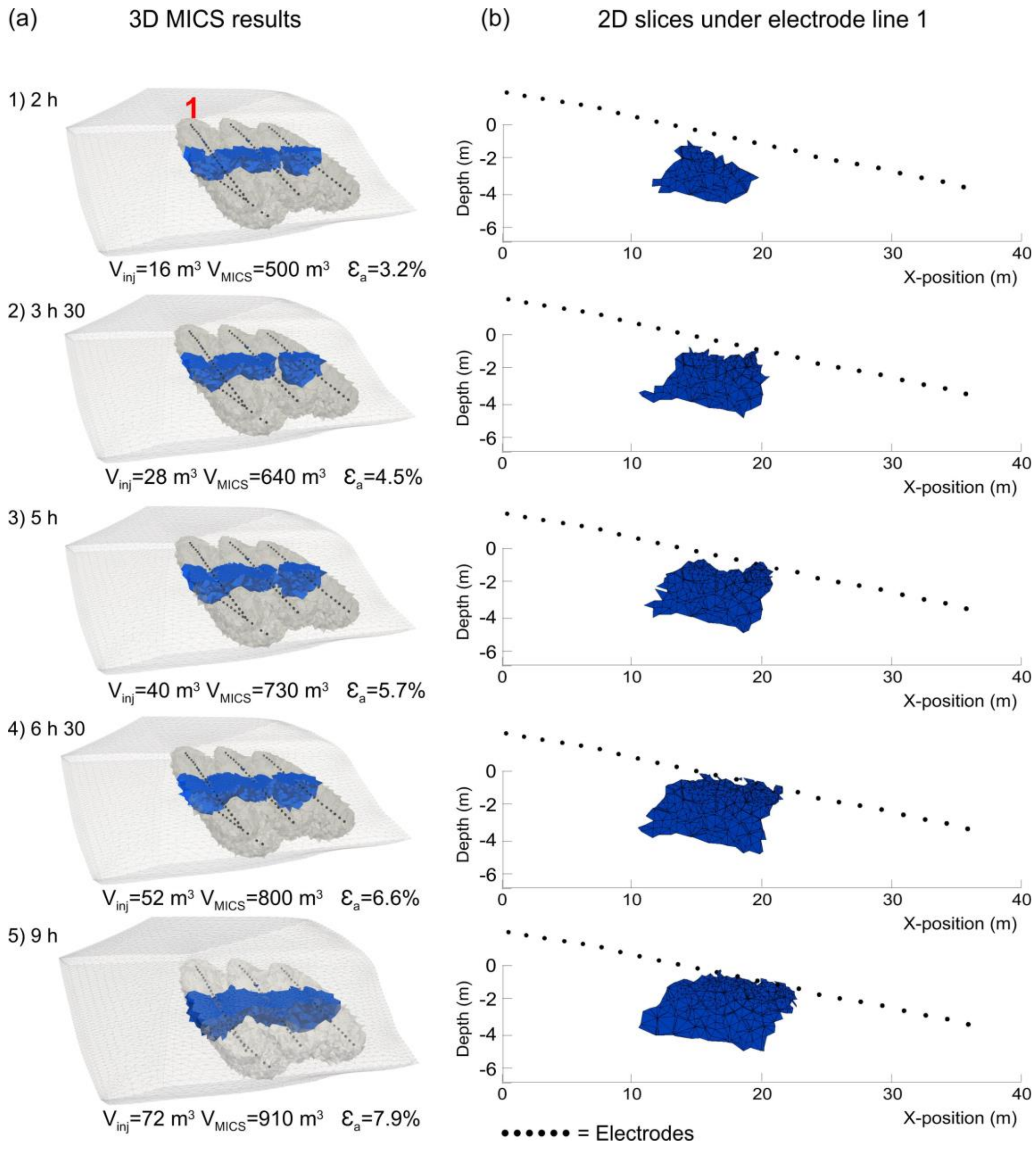
(Audebert et al., 2014)

Landfill monitoring





(Audebert et al., 2014; 2016)



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Take home message

- **Not a silver bullet** (no universal response), it needs to be assisted by complementary data
- **Go/No go pre-feasibility** using pre-modeling should be standard procedure

<u>On landfills :</u>

- Landfills Hor./Vert. delimitation is demonstrated > **multi-methods very efficient**
- For composition quantification: requires **careful and dedicated processing** and **laboratory petrophysics**
- Geophysical **monitoring** can follow **leachate injection, membrane leaking**
- To follow **biodegradation is more challenging** in the long term

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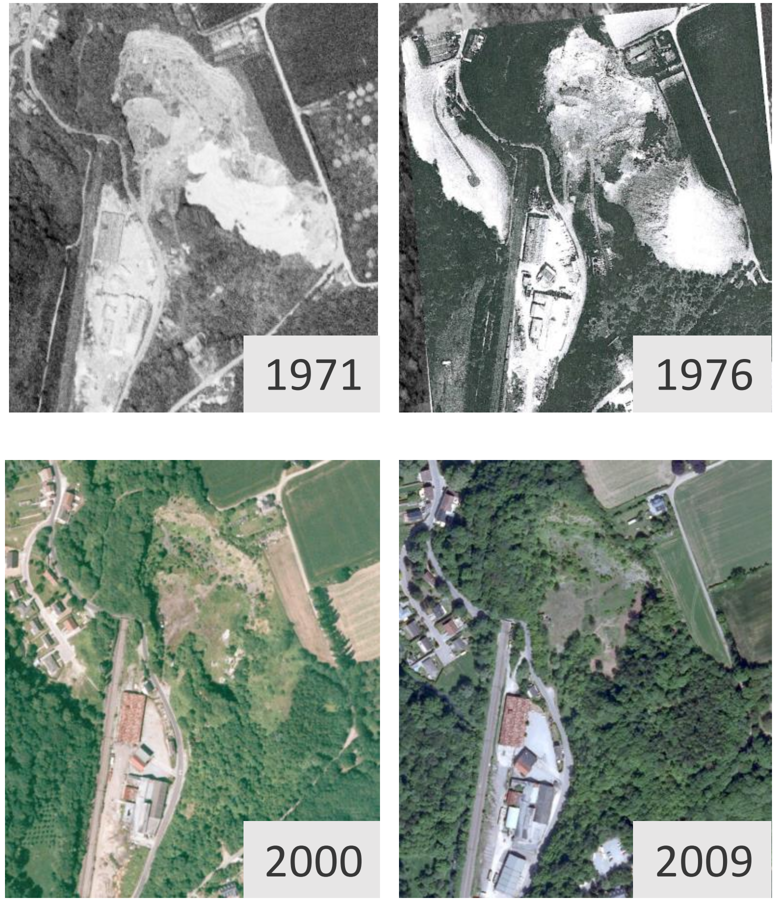
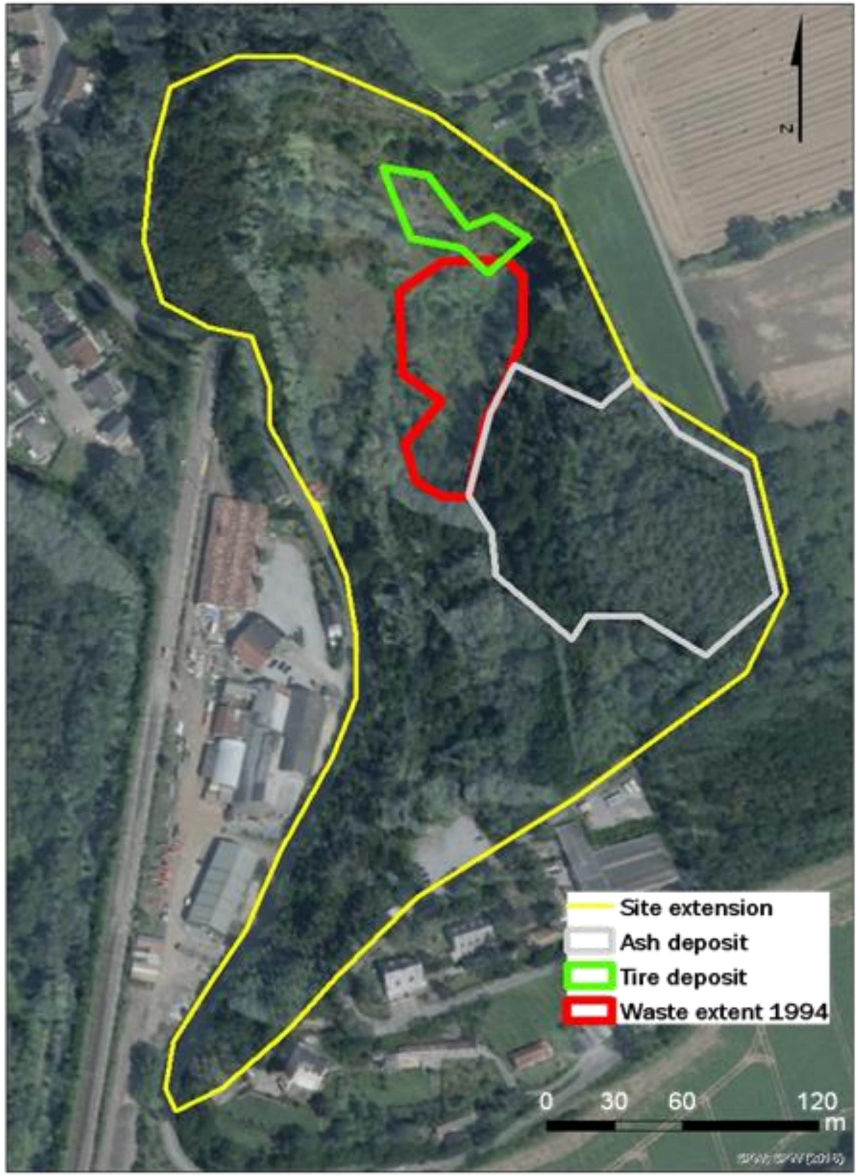
Site overview

History:

- 1902-1967: Quarry, limestone extraction
- 1967-1976: Deposit ashes & lime
- 1982-1987: waste from construction sector, tyres, rubber...
- 2004: 750t of tires removed by SPAQuE



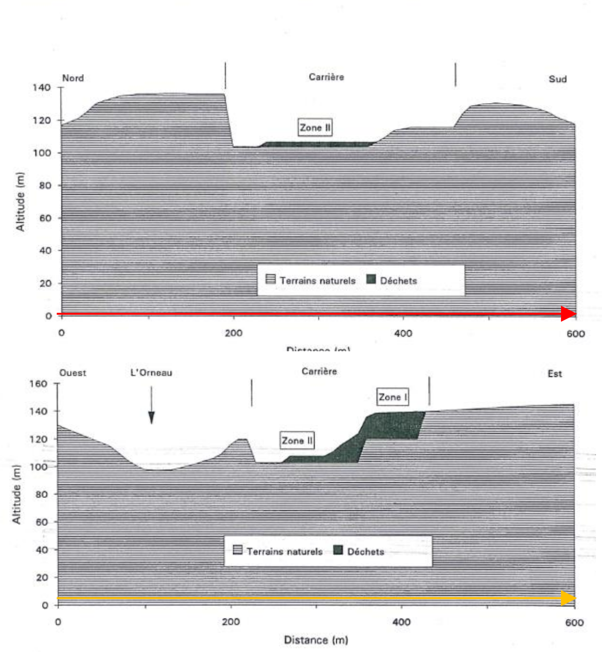

N
Site extension
Ash deposit
Tire deposit
Waste extent 1994
0 30 60 120
m

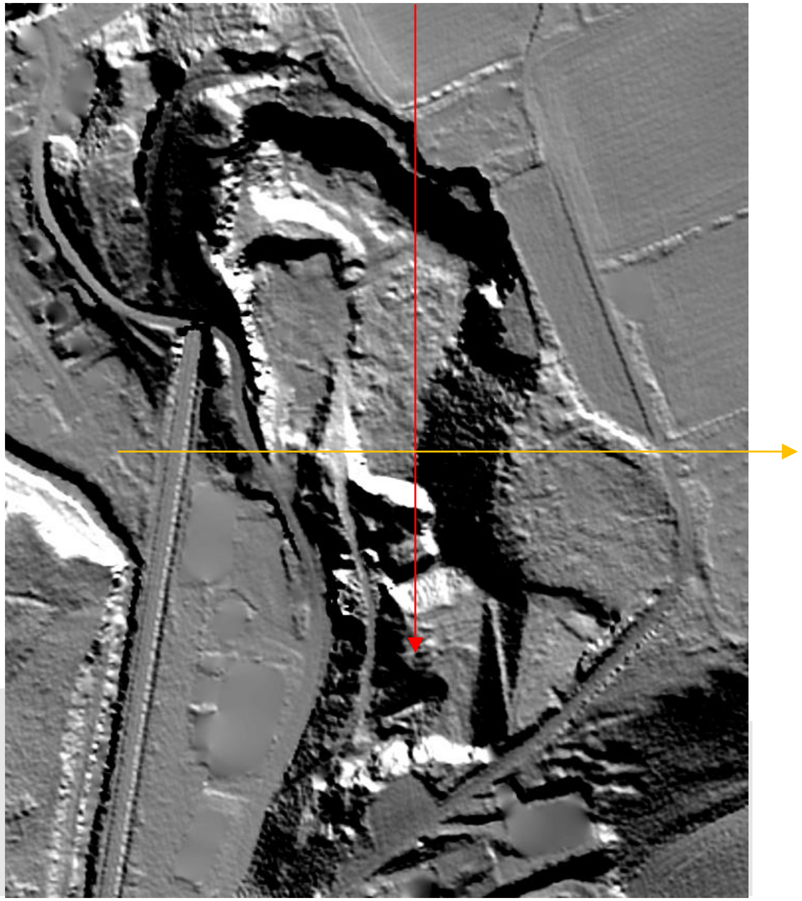
Today…

Site description

Site elevation

- 20 m of ashes in the upper part
- 4-? m of waste + lime in the bottom part





Goal of the first survey:

1. Estimate extension and boundaries of the waste
2. Identify ashes and lime
3. Leachate?

Methods – Survey design

Mapping methods:

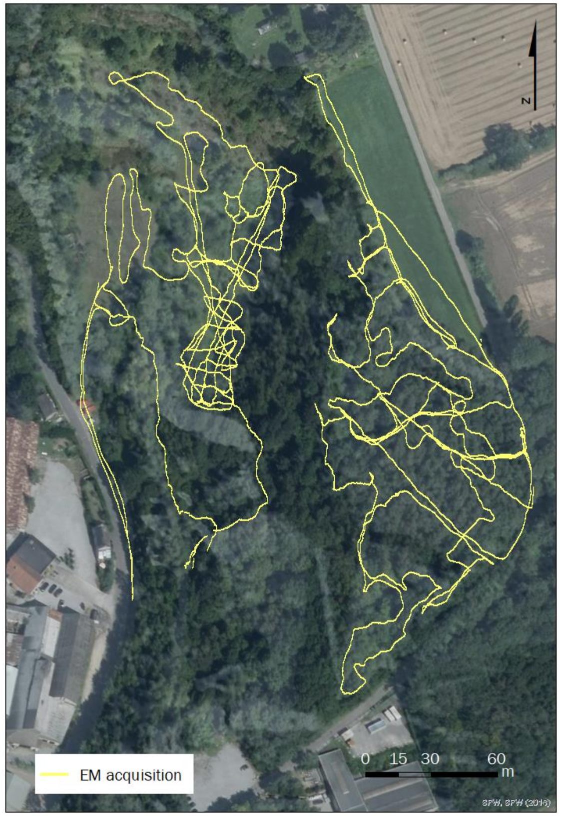
- Electromagnetic survey (EM)

Profiling methods

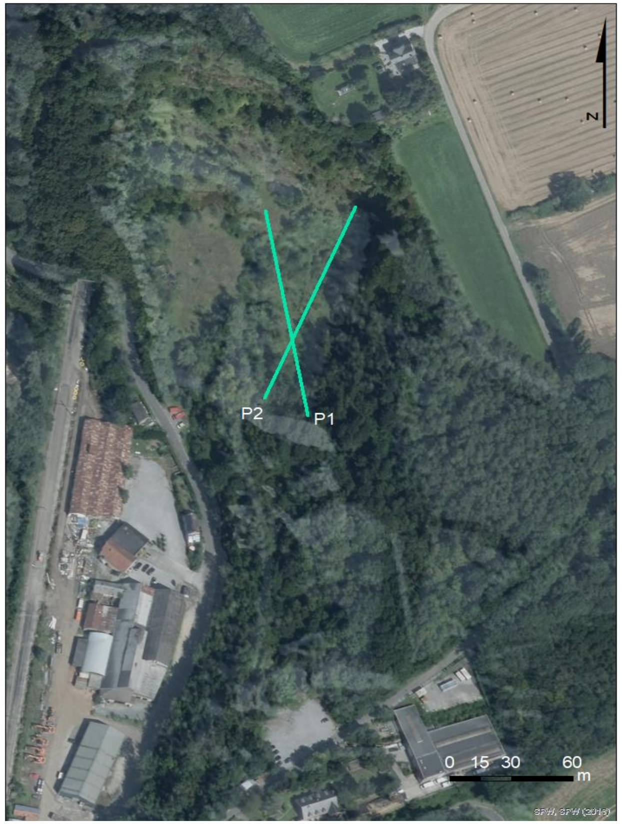
- ERT/ IP

Fieldwork done - covering

EM survey

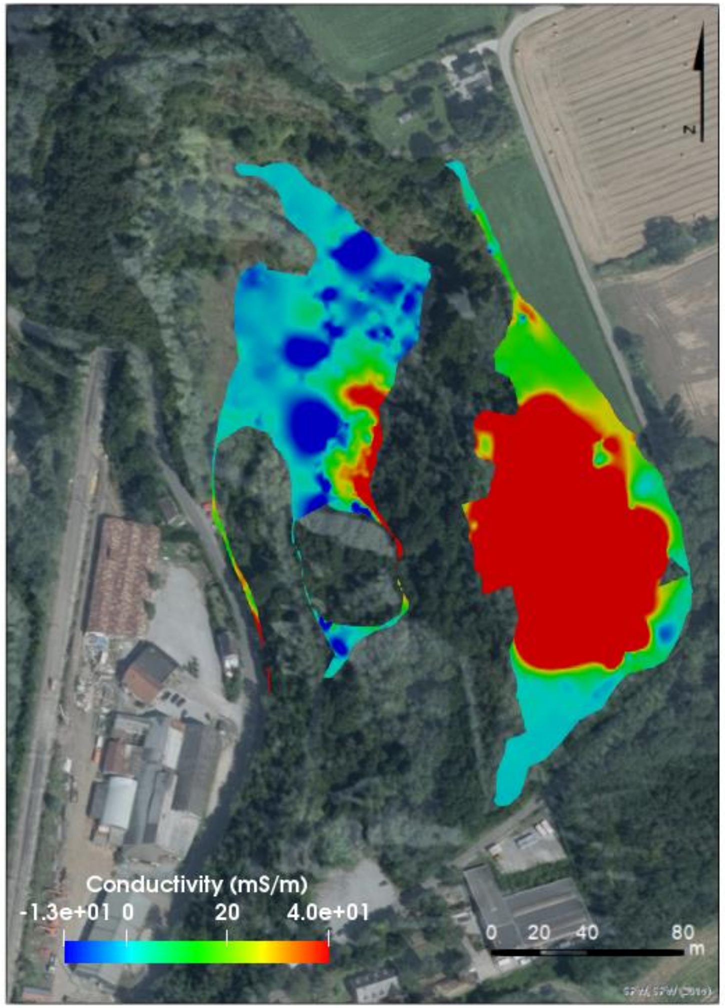


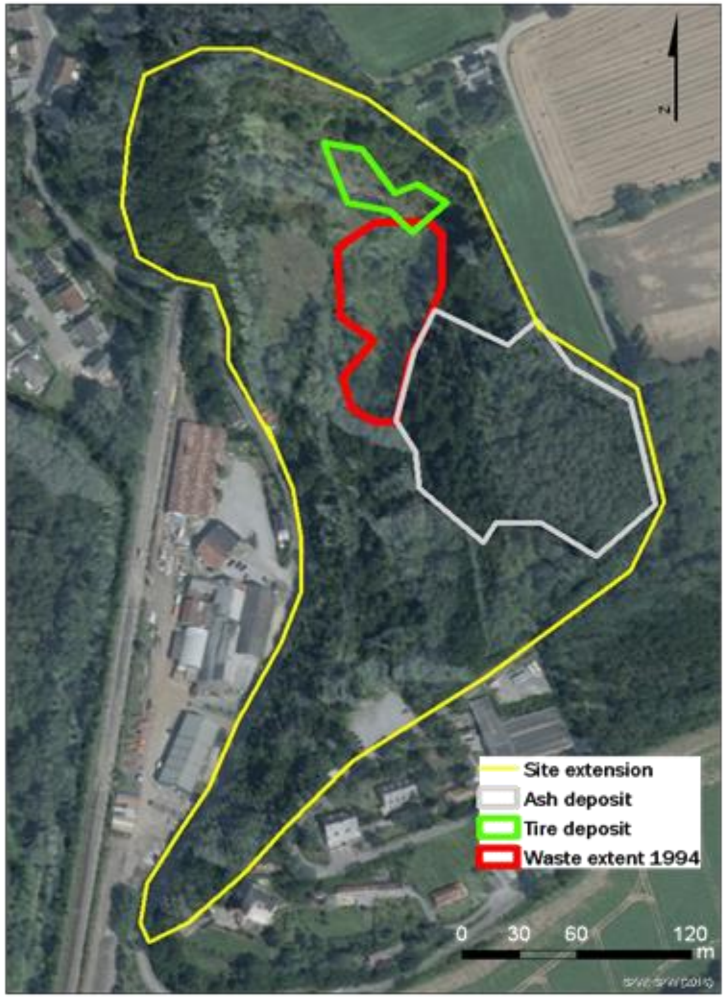
ERT/ IP



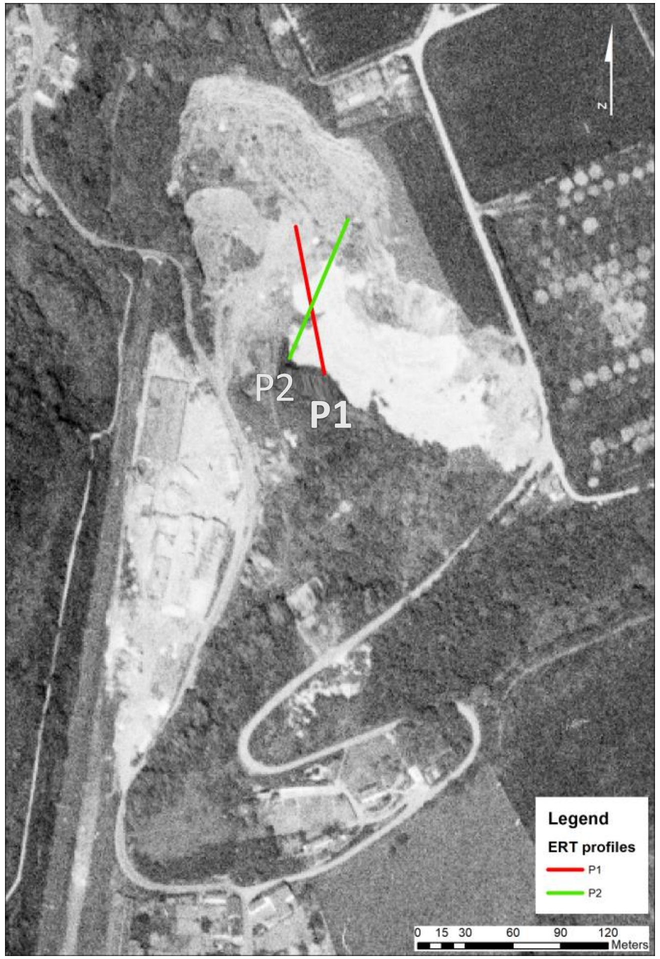
Results EM

Conductivity

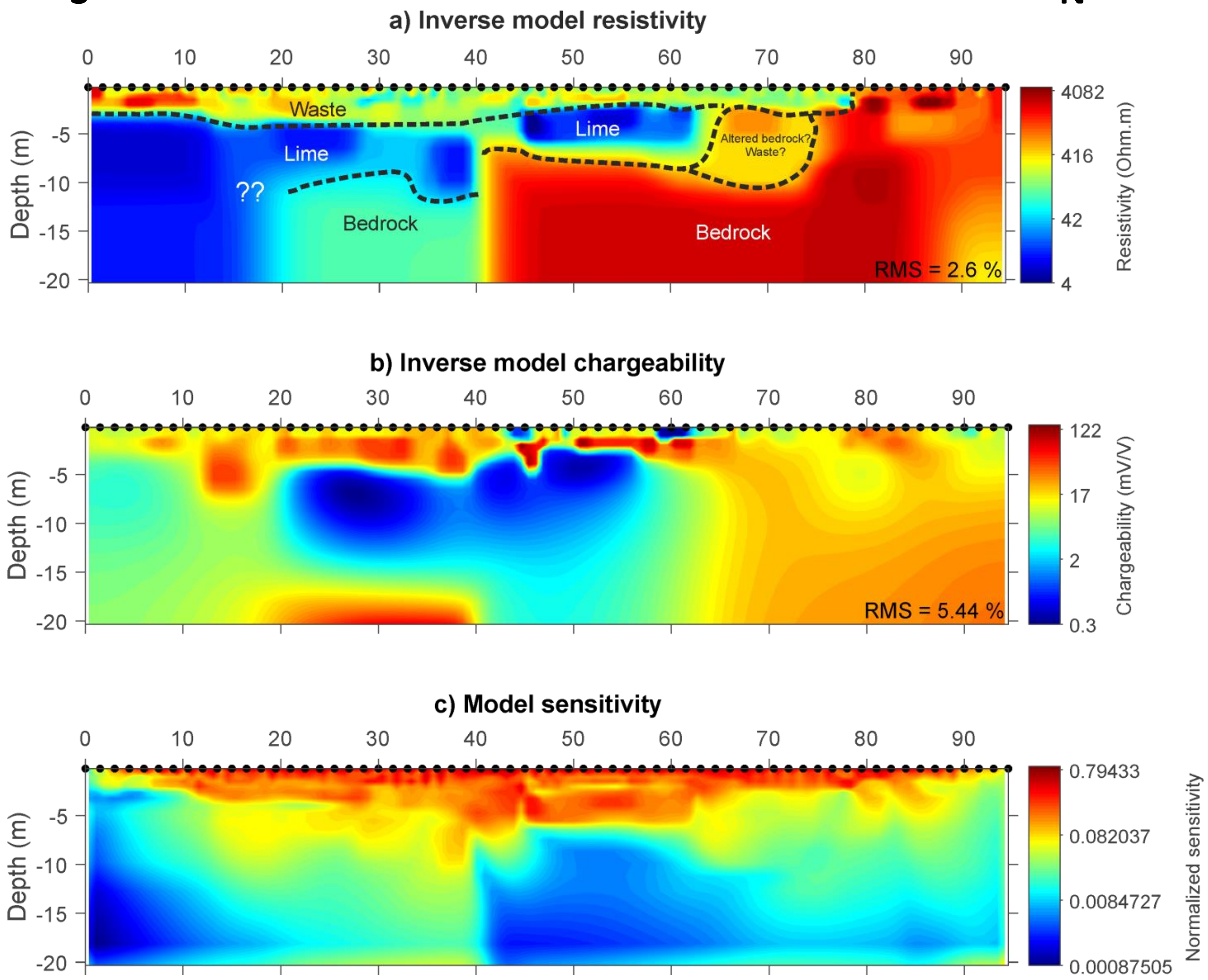




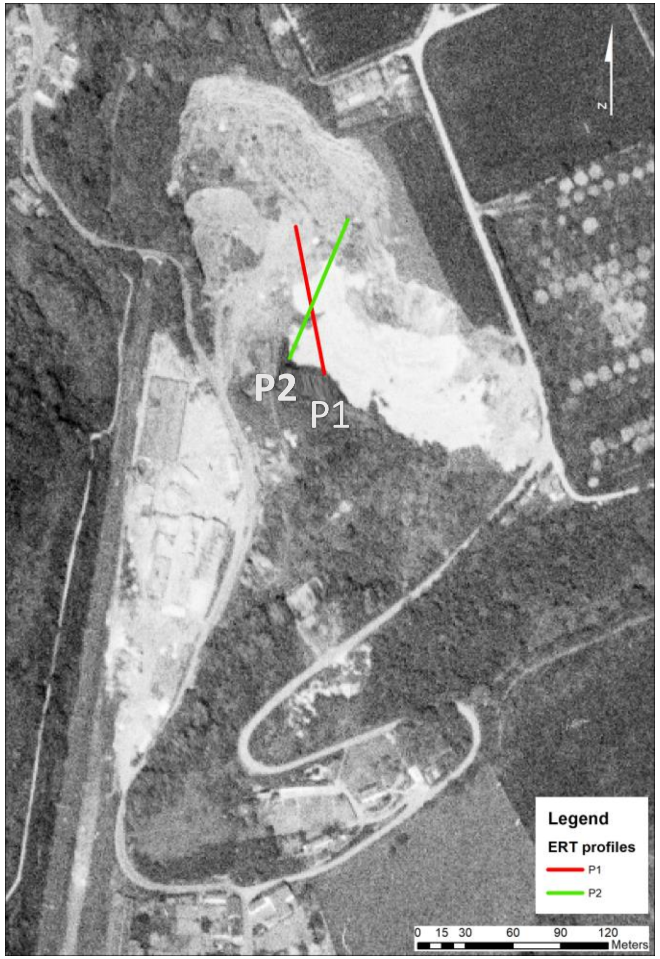
Results ERT/IP

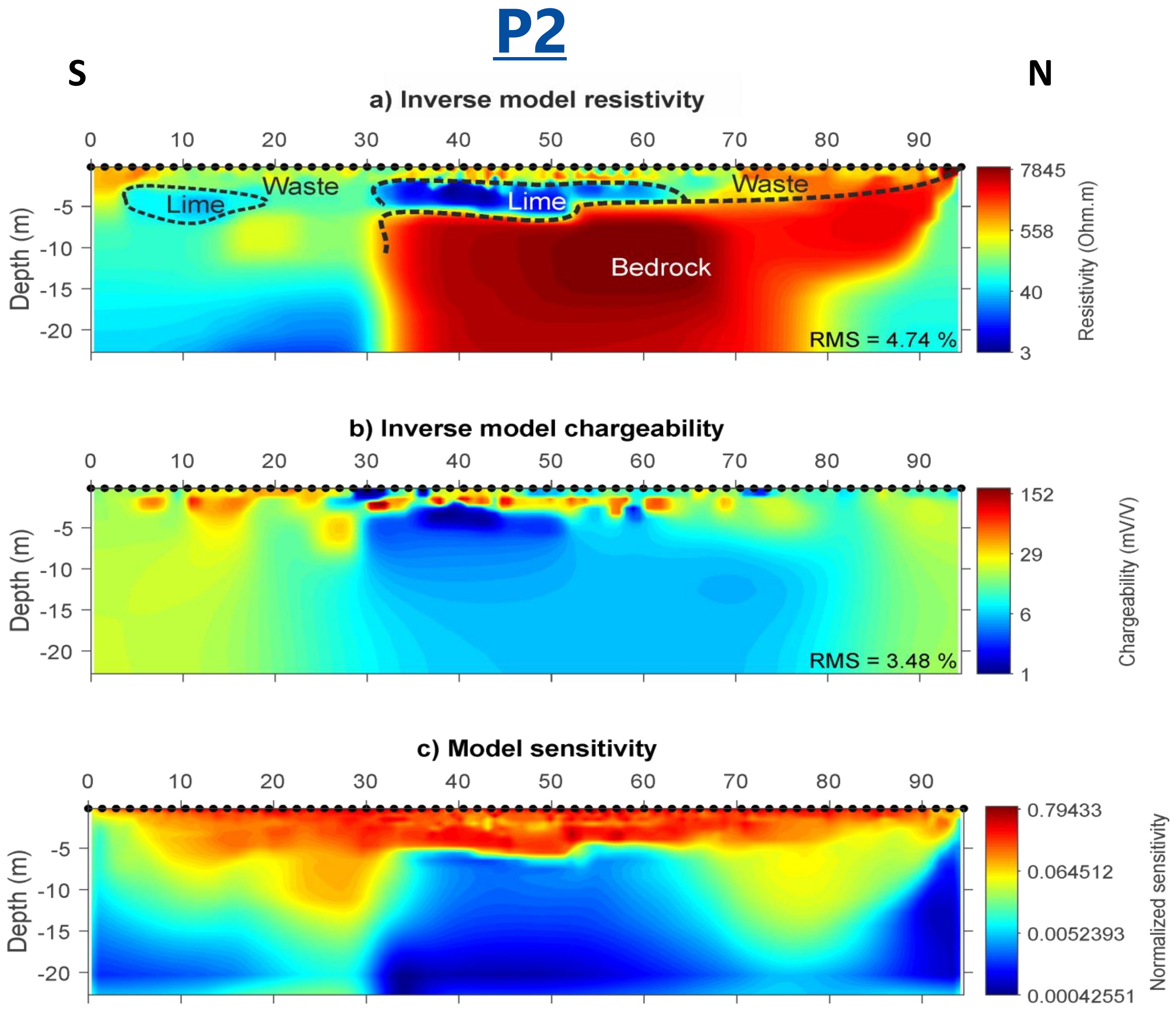


P1



Results ERT/IP





Preliminary conclusions

- The lateral extent of the zone containing the ashes is clearly visible in the EM images

- ERT models allow to clearly highlight the boundary between the limestone bedrock characterized with high electrical resistivity and the lime/waste deposits. The depth of lime lenses still need to be check

→ <u>To be confirmed by boreholes/trenches</u>

Interreg

EUROPEAN UNION

North-West Europe

RAWFILL

European Regional Development Fund

Thank you!

Raw materials recovered from landfills

The Interreg North-West Europe Project is coordinated by SPAQuE and unites 8 partners from 4 EU regions.