Geophysical approaches for landfill ground model development

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Talk overview

- What was the RAWFILL project?
- Near surface geophysical methods
- A landfill case study (Emersons Green)
- Ground model development

The work presented here was funded by **The RAWFILL project:** supporting a new circular economy for **RAW** materials recovered from land**FILL**s

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

assainir · valoriser les sols spaque

SAMEN MAKEN WE MORGEN MOOIER OVAM

LIÈGE université

BGS British Geological Survey

atrasol SUSTAINABLE CONSULTANT

BAV Bergischer Abfallwirtschaftsverband

LES CHAMPS JOUAULT S.A.S.

Cleantech Flanders Powered by VITO

Why was the RAWFILL project conceived

- Potential Recover and valorise raw materials from landfills
  → transition towards "circular economy"
- Reclaim land
- Reduce soil and groundwater contamination – environmental risks
- Reduce the costs of the after-care activities of landfills
- Produce green energy
- Reduce GHG emissions
- In order to "mine" landfills you need to be able to characterised them well first

CONTEXT

Landfills → change in Paradigm

Environmental impacts

Health issues

Land use restrictions

Post Management

Opportunity

Recover large volumes of resources:

- Materials
- Energy
- Land area

LANDFILL MINING

PAST → FUTURE

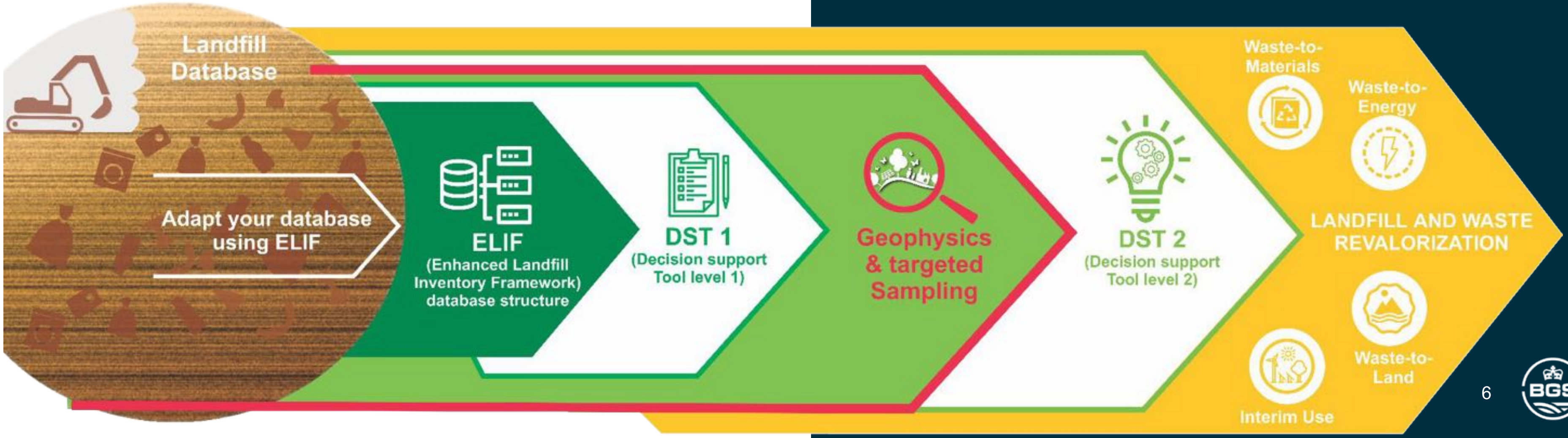
CONTEXT

Barriers

- Lack of knowledge about recovery potential (materials and energy) in terms of volume, content, extraction feasibility and environmental impact
- Expensive traditional exploration methods

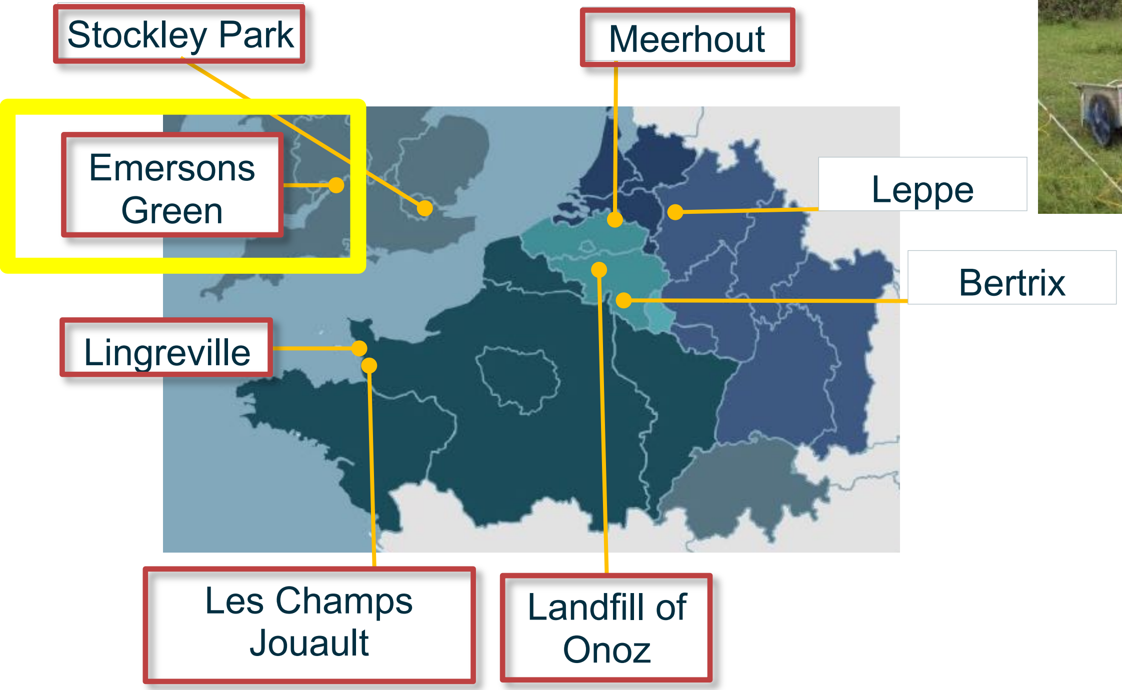
Goals of RAWFILL project

- Create landfill (LF) inventory framework & Decision Support Tool to rank Landfill Mining projects
- Develop improved LF characterisation with geophysical imaging and targeted sampling



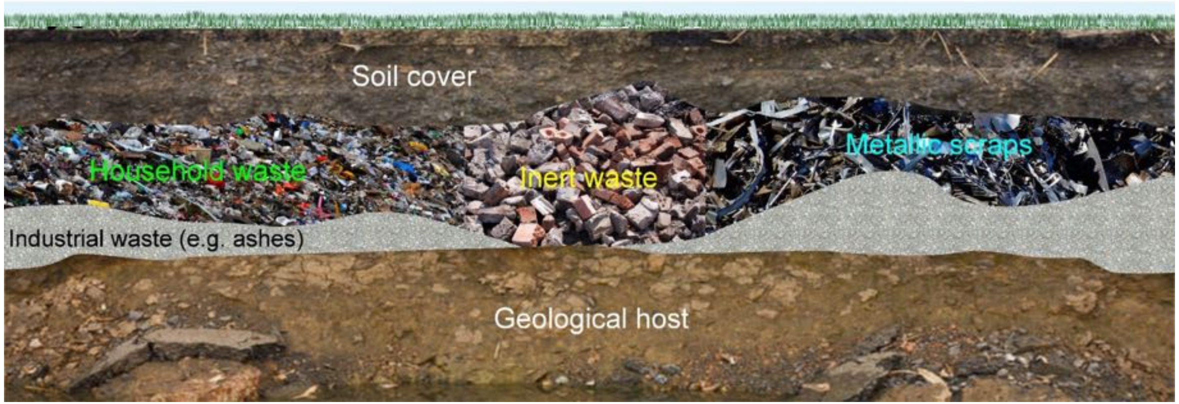
CONTEXT

RAWFILL test sites



Why geophysics?

- High heterogeneity of landfills



Why geophysics?

Good spatial characterization can be costly and lead to higher cross-contamination risks.

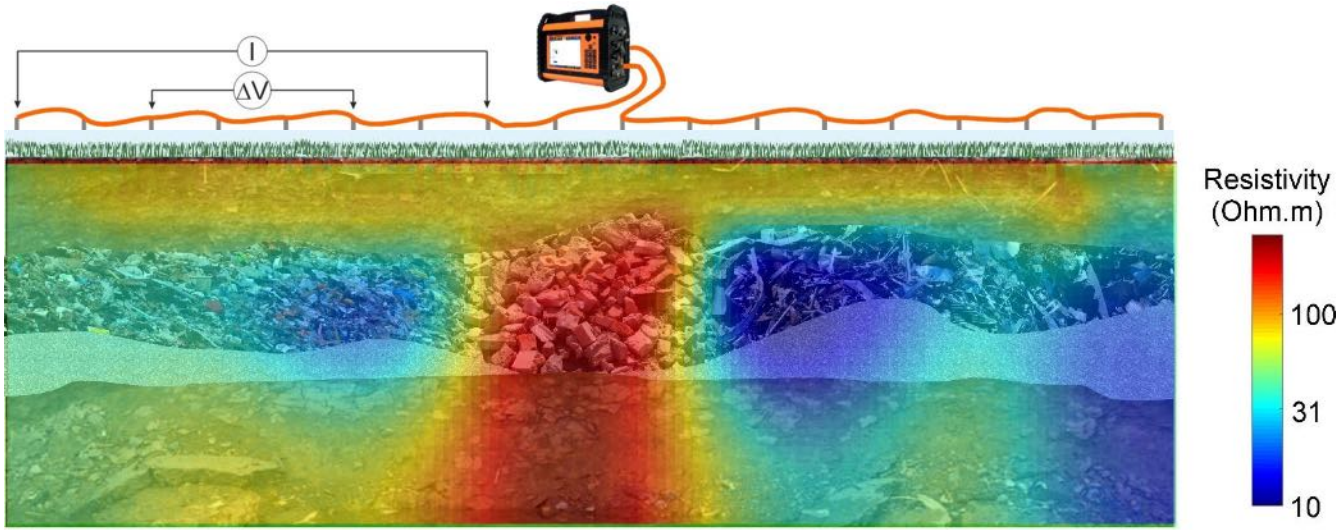
Why geophysics?

Advantages:

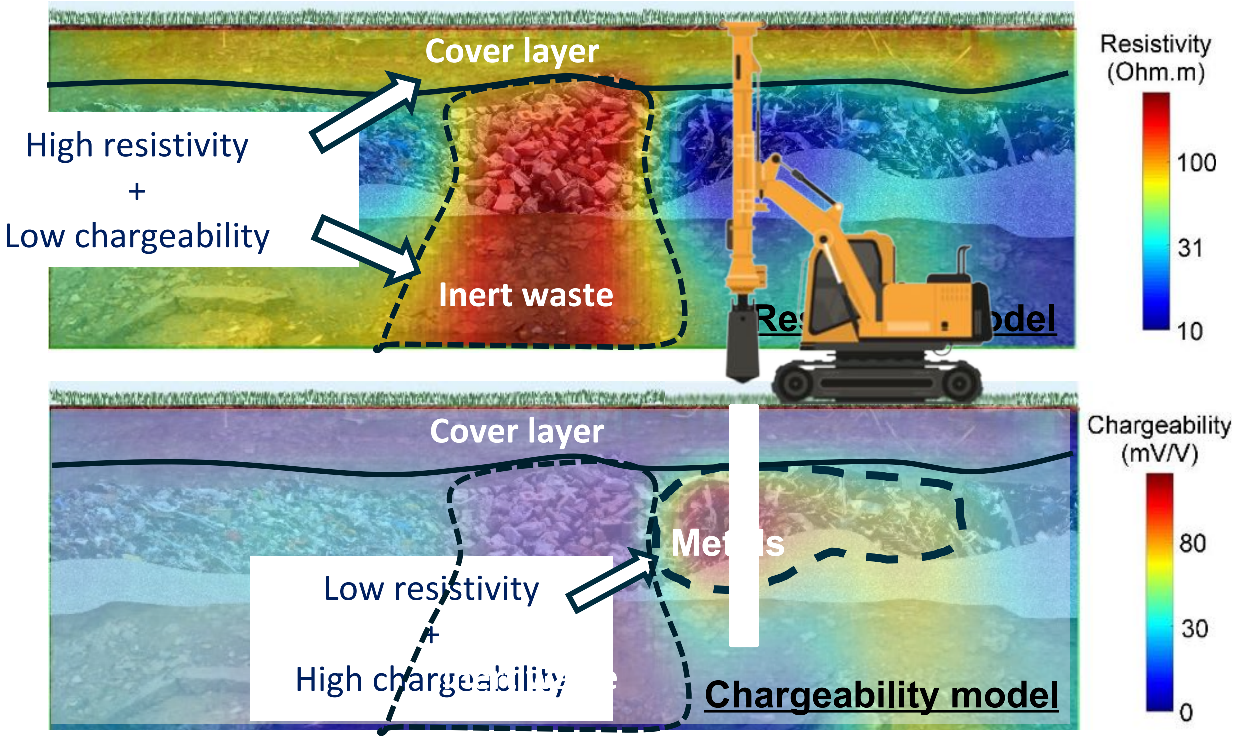
- Non-invasive
- Quasi-continuous spatial coverage
- Relatively low cost

Disadvantages

- Indirect information
- Non-unique solutions
- Smooth blurred images
- Distortions & artefacts



Geophysics: increase certainty



- Combine complementary geophysical methods to reduce ambiguities
- Apply target sampling for validation and calibration
  - Lower costs
  - Reduced risk of damaging structures, contamination and exposure to hazardous material

Proposed workflow

Archives & inventory report
- Gather and summarize all available information
  → Build conceptual model
  → Assess knowledge gaps

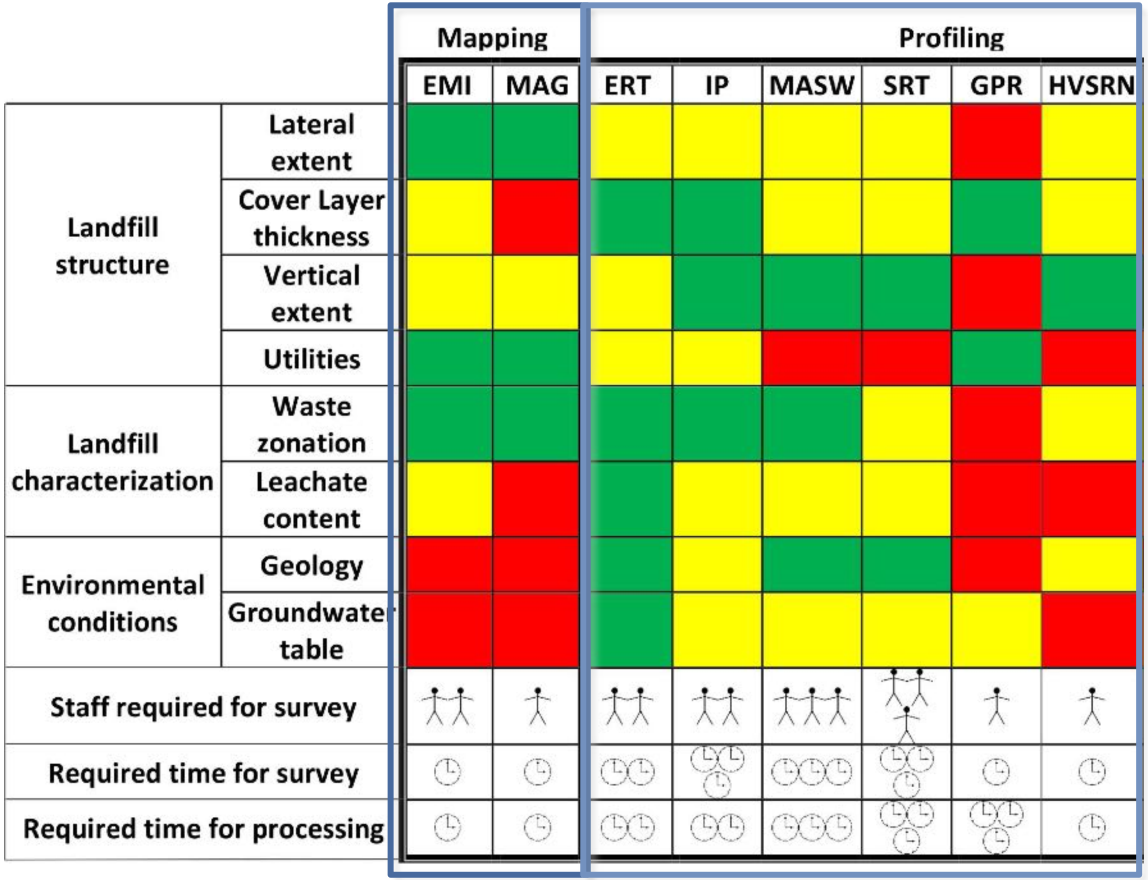
Geophysical characteri-zation
- Use complementary geophysical methods planned according to the conceptual model
  → Interpretation of geophysical results and detection changing properties

Calibration & validation
- Targeted sampling
  → Build sampling plan according to geophysical results
  → Verify and calibrate geophysical measurements to refine conceptual model

Resource model building
- Build a Resource Distribution Model based on refined conceptual model

Additional measurements required?

Geophysical methods



Geophysical methods

- Measure different/complementary geophysical properties
- Have different advantages and disadvantages

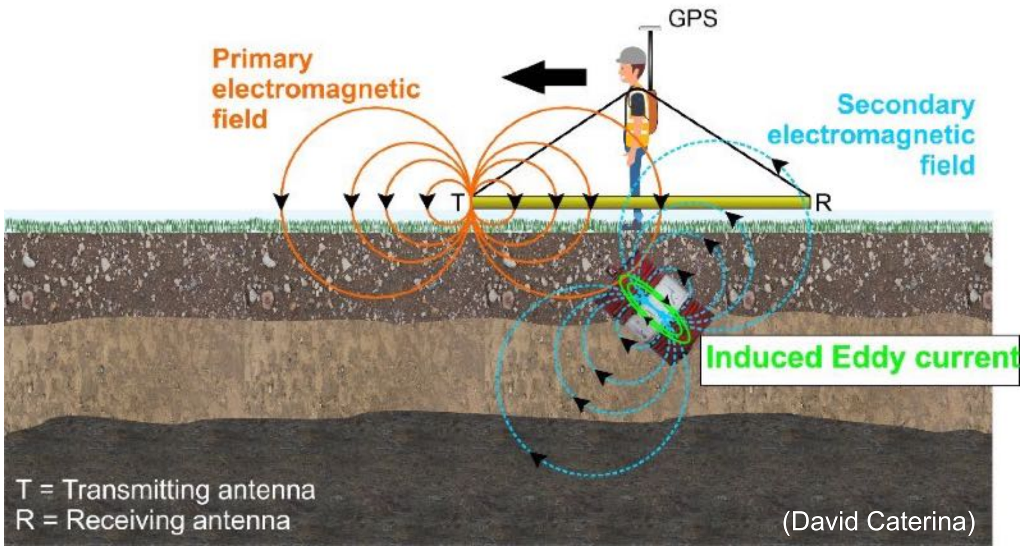
Mapping methods:

- Provide a wide spatial coverage
- Relatively easy to deploy and acquire data

Profiling methods:

- Provide more detail and vertical resolution
- Require more staff time for fieldwork and processing

Electromagnetic Mapping (EM)



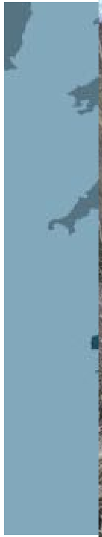
Parameters measured:

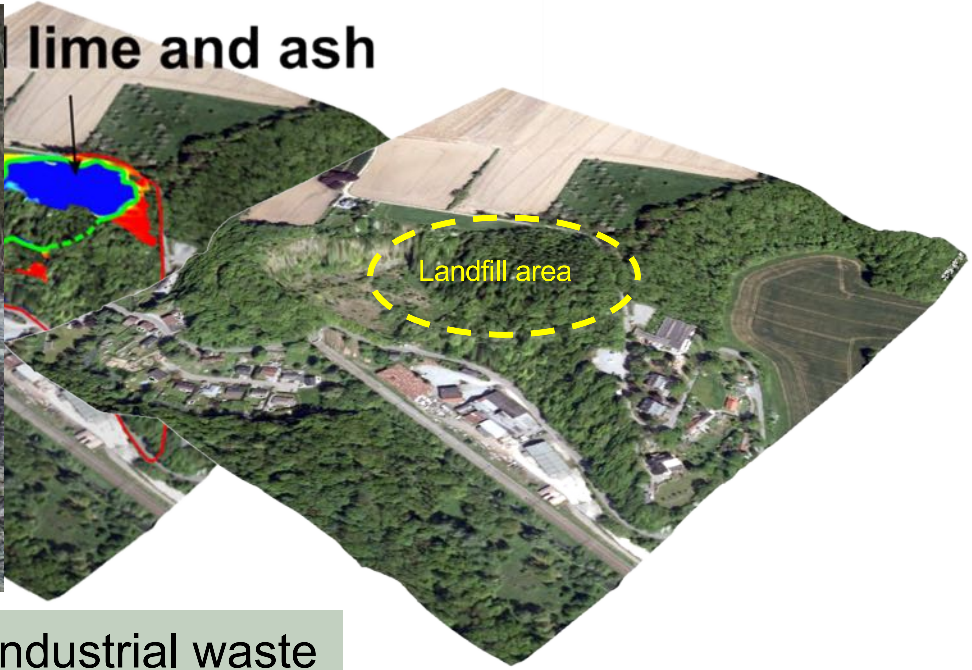
- Electrical conductivity
- Magnetic susceptibility

Sensitive to:

- Leachate content
- Pore fluid conductivity
- Metal content

Electromagnetic Mapping: Delineating landfill extent

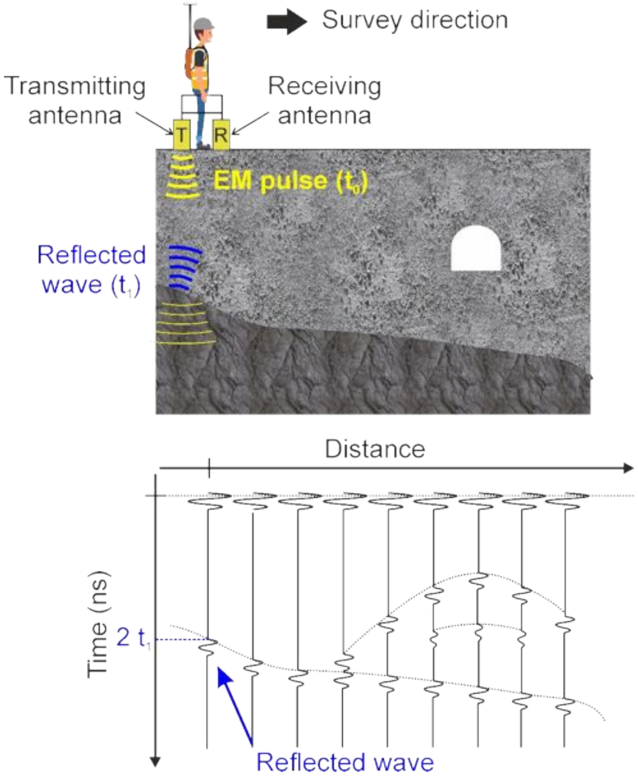




Low

- Mainly industrial waste

Ground Penetrating Radar

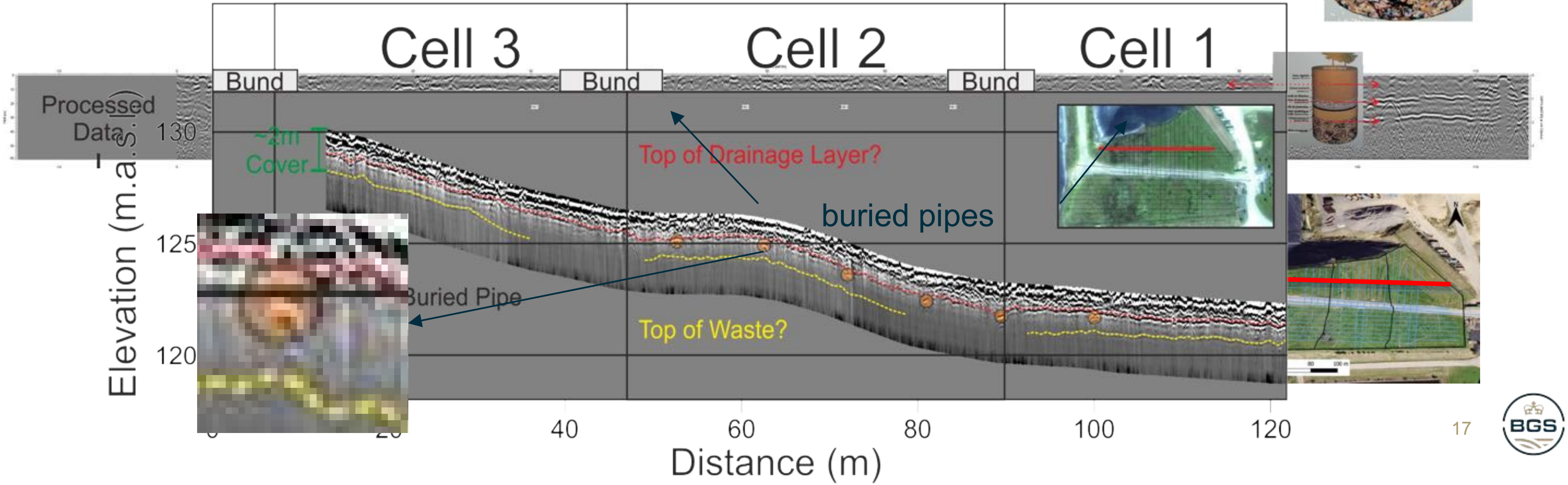


Dependent physical Property:

- Permittivity; conductivity
- Signal attenuates fast in very conductive material such as waste
  - mainly used to detect cover layer thickness

Ground Penetrating Radar: Delineate Cover Layer

- Imaging buried pipes
- Two interfaces corresponding to:
  - Boundary between 2 type of material in the cover layer
  - The top of the waste



Magnetics

Parameters measured:

- Earth’s magnetic field intensity
- Magnetic susceptibility

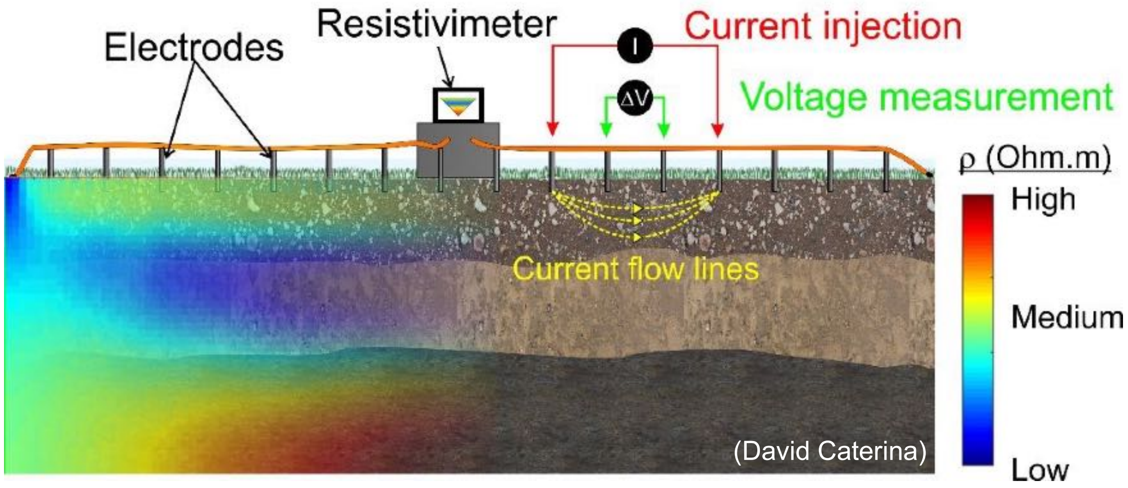
Sensitive to:

- Metallic items
- Metal content

Magnetics: Delineating landfill extent

- Municipal solid waste

Electrical Resistivity Tomography (ERT) Induced Polarisation (IP)



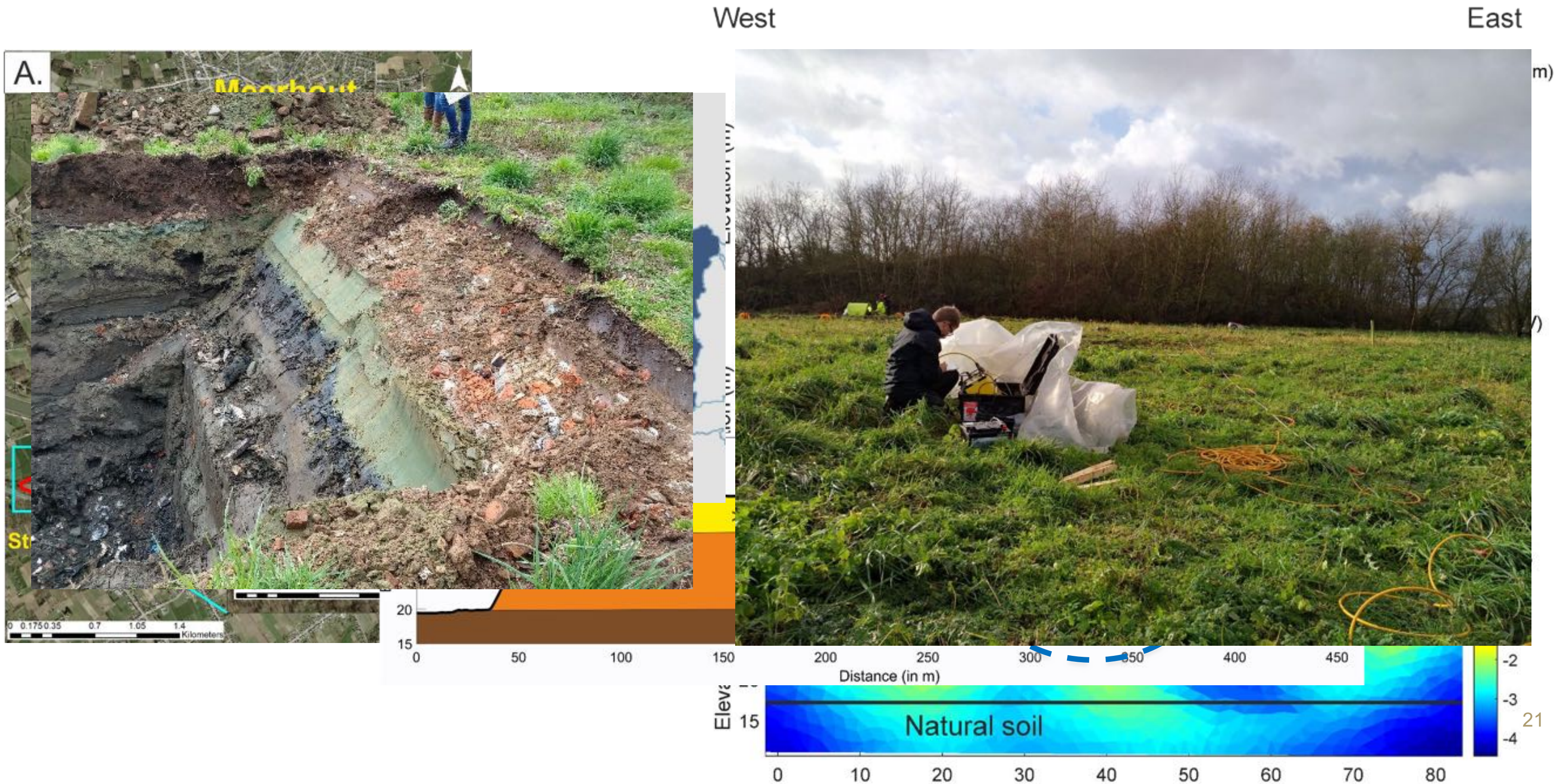
Parameters measured:

- Electrical resistivity (ERT)
- Chargeability (IP)

Sensitive to:

- Leachate/water content
- Pore fluid composition
- Metal content
- Size and shape of grains/pore space
- Connectivity of pores

ERT/IP: Zones of different composition & saturation

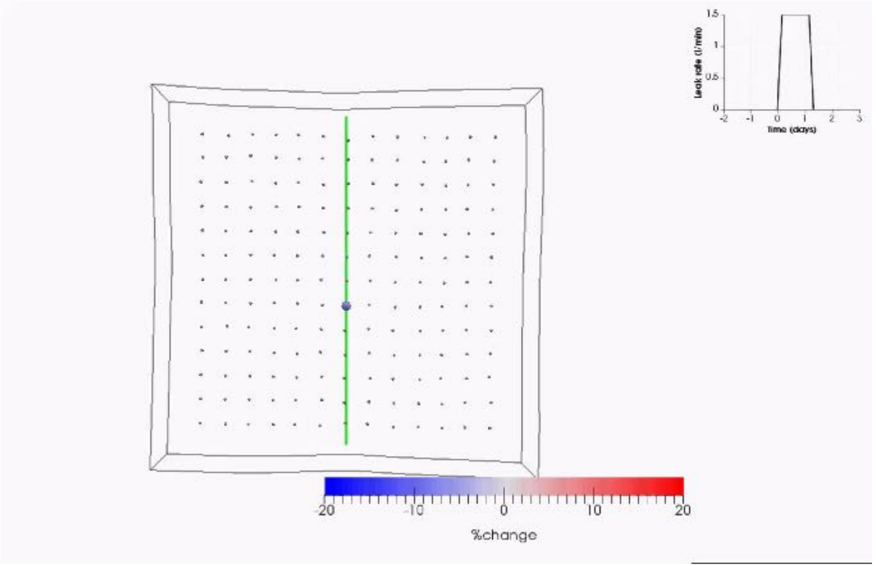


ERT/IP: HDPE membrane limits applicability

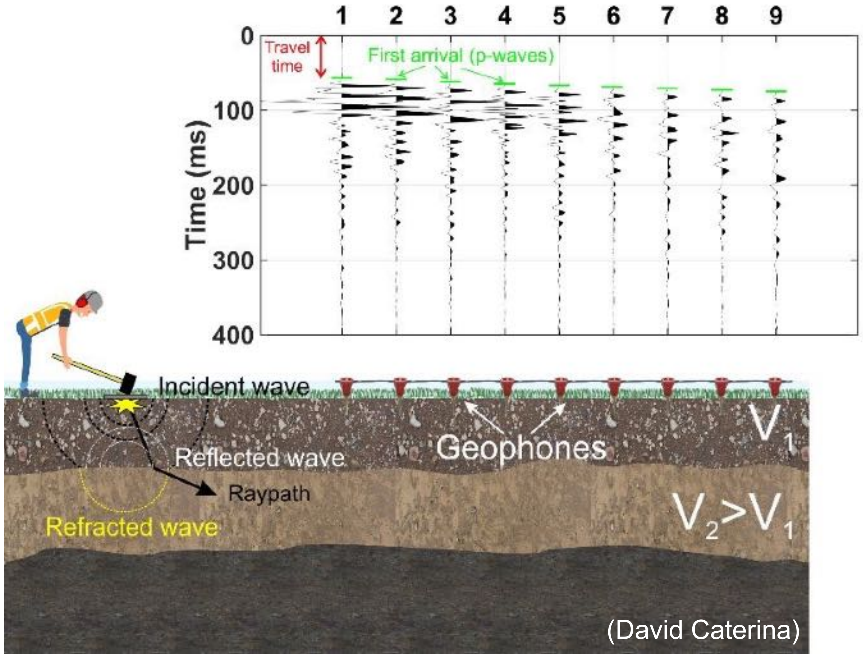
- If waste is completely isolated by HDPE-membrane is inaccessible to ERT/IP measurements

ERT in a monitoring context

- Sensitive to changes in resistivity.
  - Can detect changes in moisture content associated with rainfall.
  - Detects changes to pore fluid conductivity (leachate migration for example).



Active Seismics



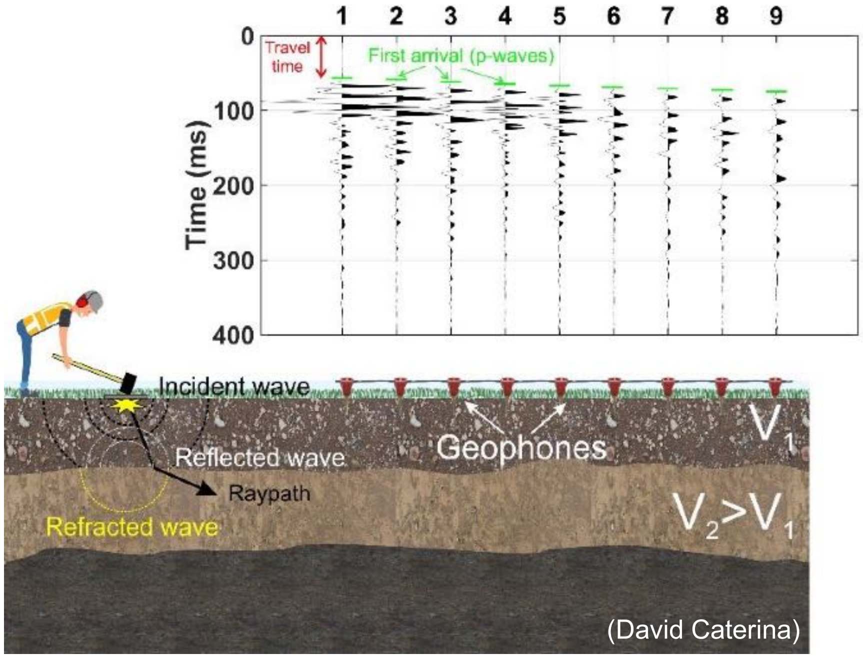
Parameters measured:

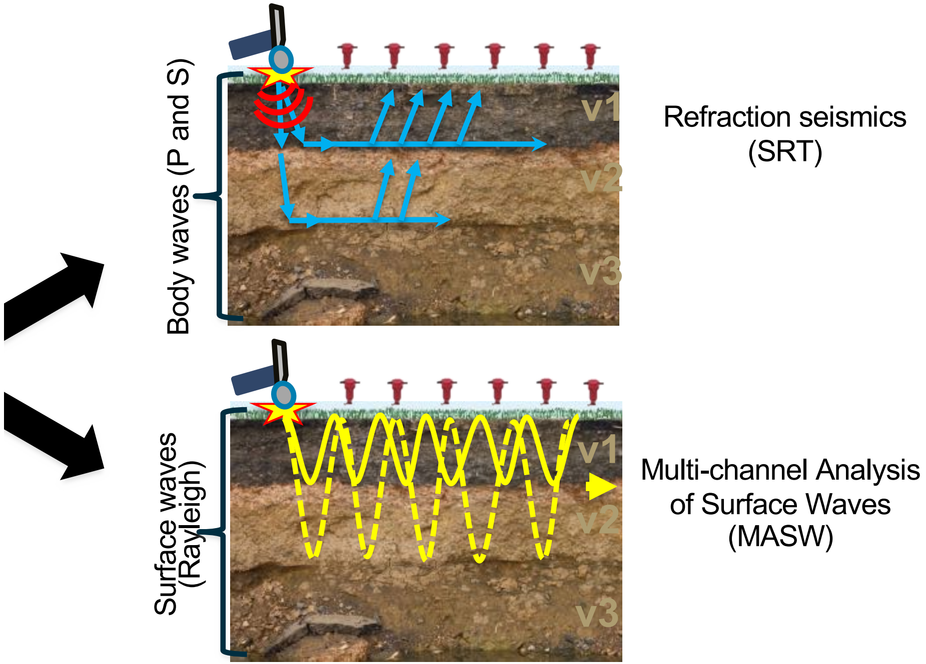
- Propagation velocity of seismic waves

Sensitive to:

- Ground stiffness, elasticity and density (mineral content, lithology, porosity pore fluid saturation and degree of compaction)

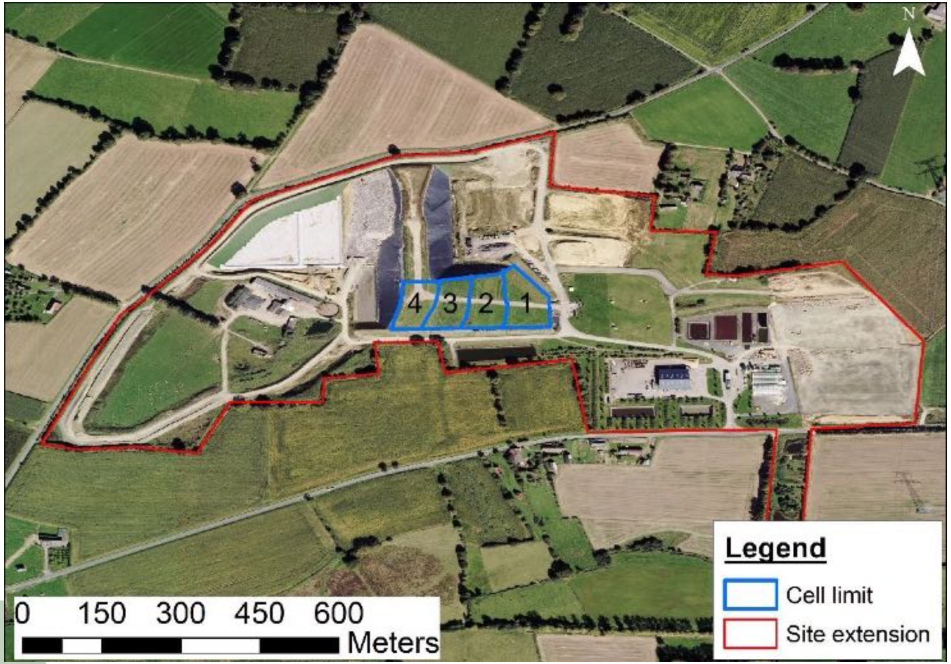
Active Seismics





Interreg North-West Europe RAWFILL

Active Seismics: Delineate landfill base



- Municipal solid waste
- Active landfill with several waste cells

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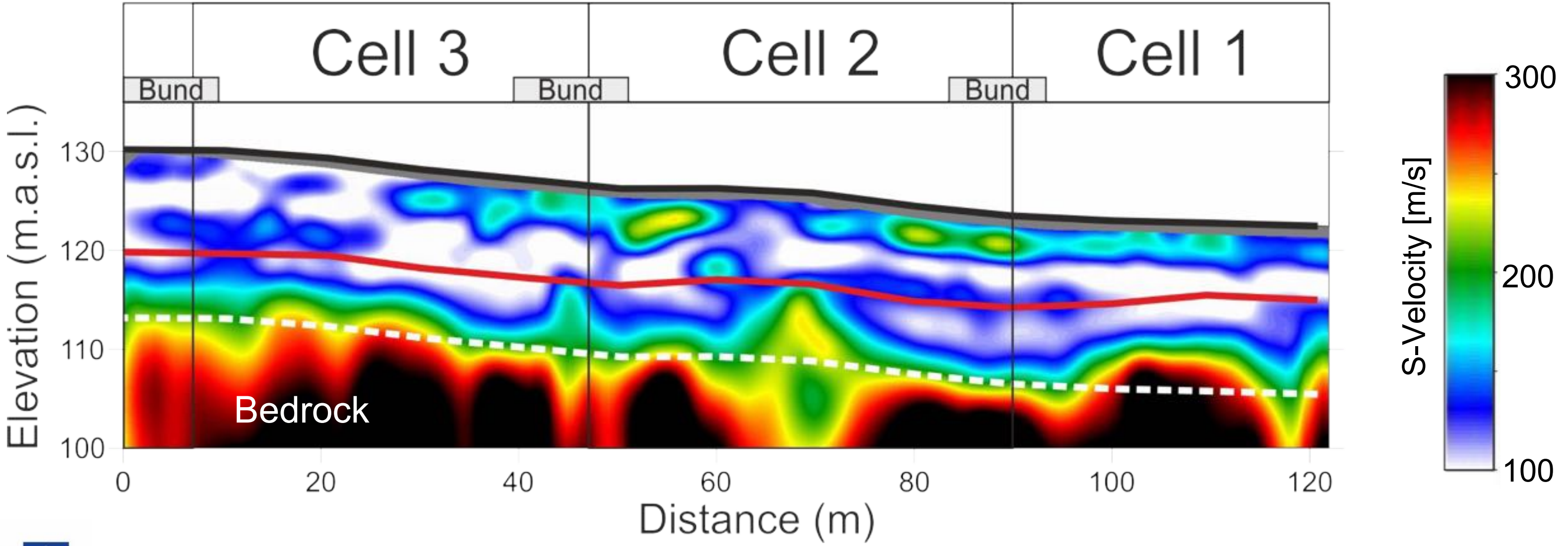
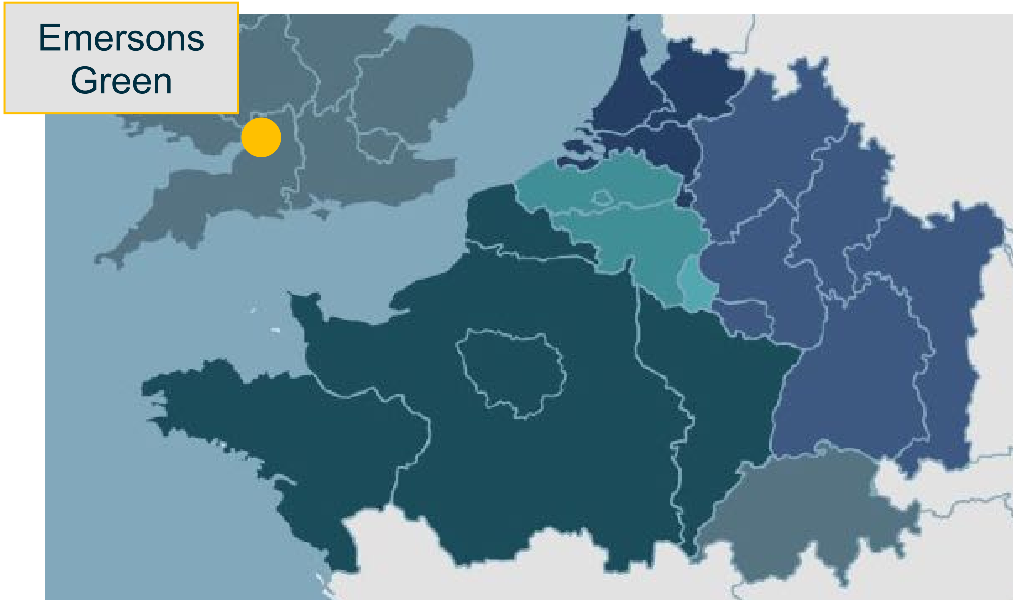
Active Seismics: Delineate landfill base



Applying geophysical methods to a case study: **Emersons Green**



CASE STUDY

Emersons Green

- Location: UK, near Bristol
- Excavated for new housing in 2019

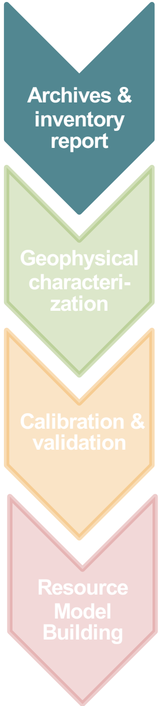
CASE STUDY

Emersons Green

- Location: UK, near Bristol
- Excavated for new housing in 2019

➢ Ground truth data to calibrate geophysics

Site Information



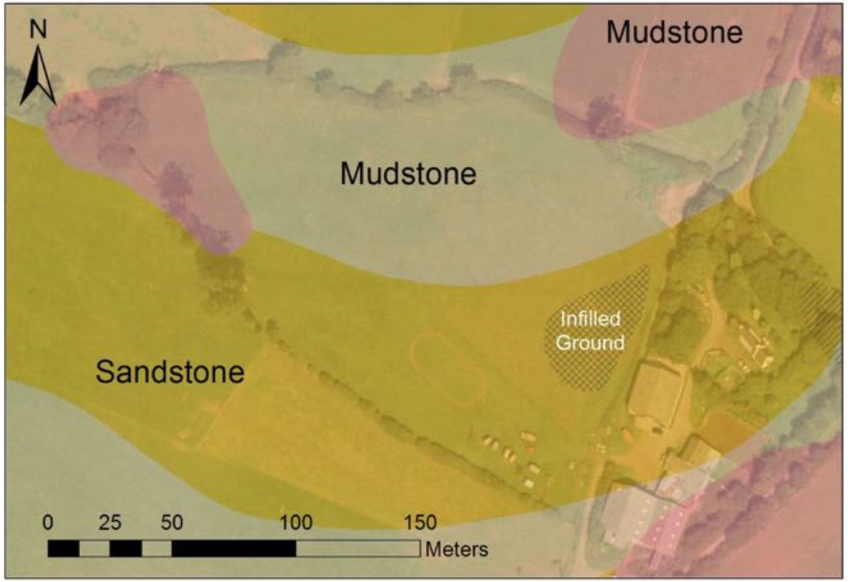
- Landfill size: 23,000m2

Landfill operation (1984 – 1991)

- Inert & industrial/commercial waste
- Dilute & disperse basis

Geology:

- North: Mudstone
- South: Sandstone
- East: historic quarry

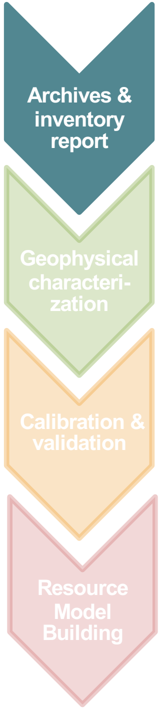


Interreg North-West Europe RAWFILL

European Regional Development Fund

Co-funded by the Walloon region

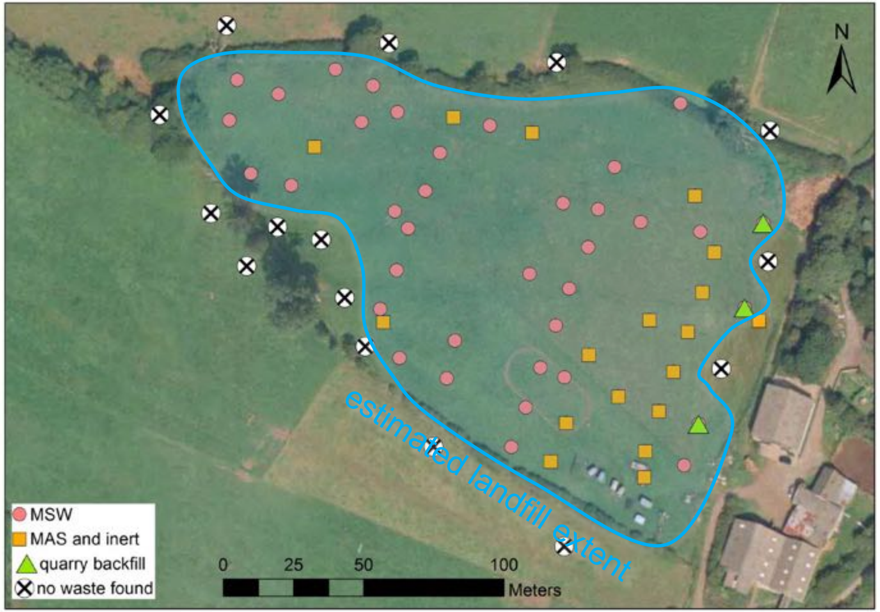
Site Information: Ground truth data



Ground truth data available across site:

- 59 Trial pits
- 12 Boreholes

	Name	Thickness
Cap	Clay cap	up to 2.6m average: 1.1m
Waste material	Municipal solid waste (MSW)	min: 0.3m max: > 4.1m
	Municipal solid waste (MSW) + inert content	min: 0.6m max: > 3.4m
	Quarry backfill	0.7m to 2m
Host	Clay	-
	Mudstone	-
	Sandstone	-



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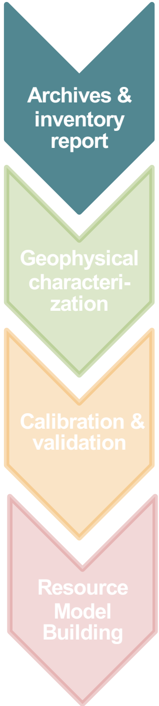
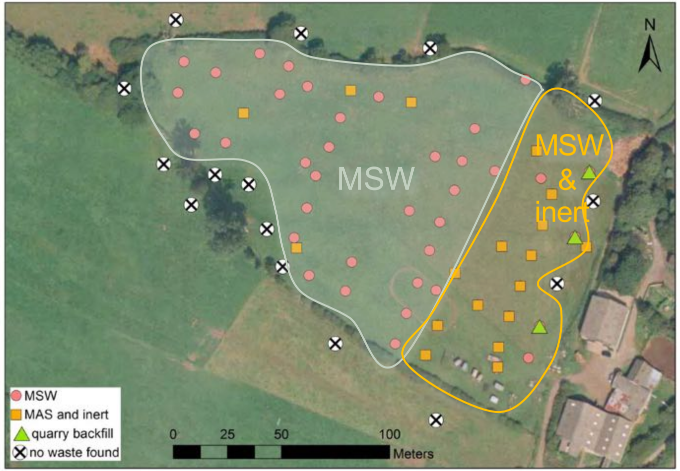
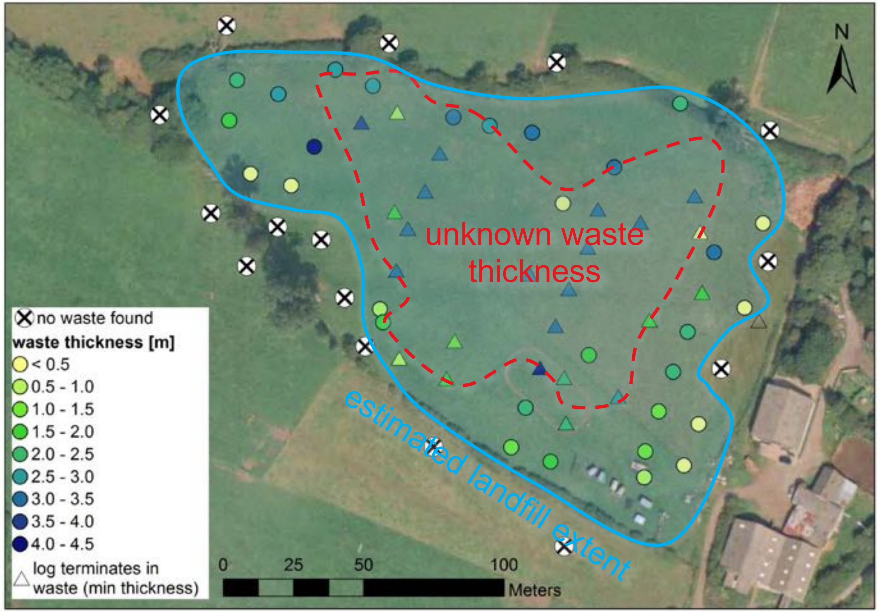
Site Information: Knowledge Gaps



- Waste thickness unknown towards centre of landfill → difficult to estimate waste volume
- Structure of landfill unclear. Is there a change in waste composition towards East?





→ Use geophysics to fill these knowledge gaps

Geophysical methods

- Archives & inventory report
- Geophysical characteri-zation
- Calibration & validation
- Resource Model Building

MAPPING METHODS

Lateral extent

Metallic items

Metal content

Goal:

- Improve knowledge of lateral landfill geometry
- Delineate zones of different waste composition

Lateral extent

Leachate content

Metal content

PROFILING METHODS

Goal:

- Delineate landfill thickness
- Delineate layers of different waste composition and leachate content

ERT/IP:

Waste types

Leachate content

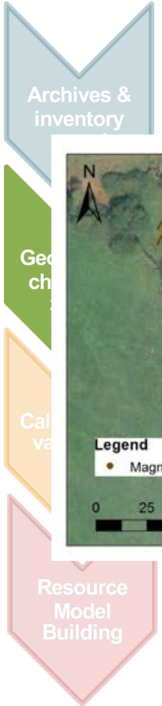
Thickness of landfill

MASW:

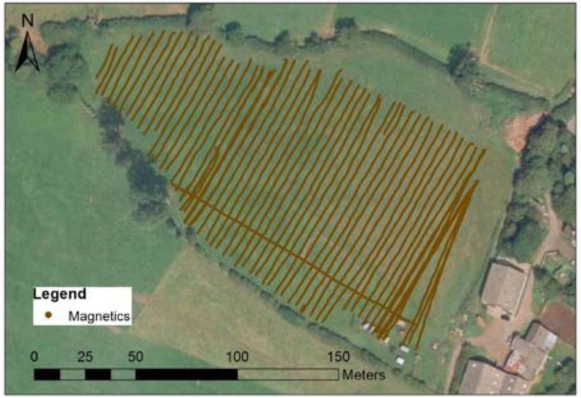
Layers of different stiffness

Thickness of landfill

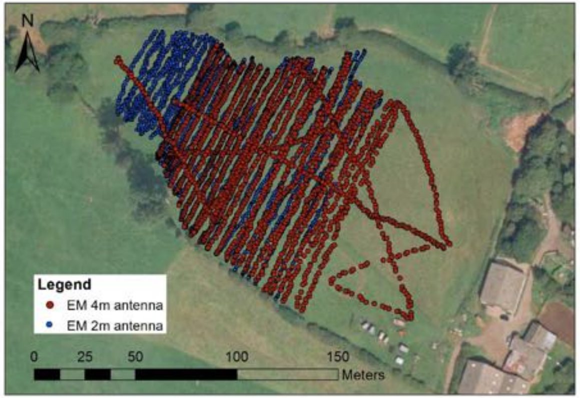
Geophysical characterisation: Measurement extent



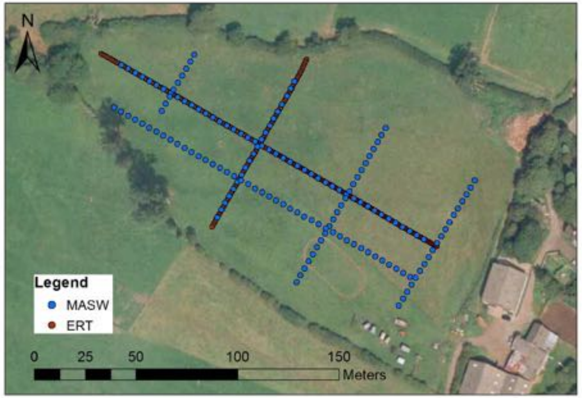
Magnetics



EM: depths: 1.5m, 2.5m, 3m, 6m

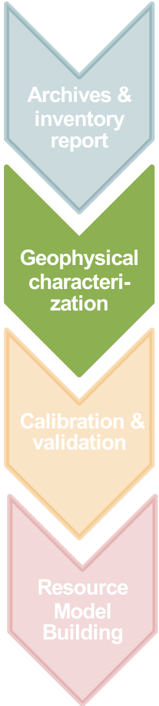


ERT/IP and MASW



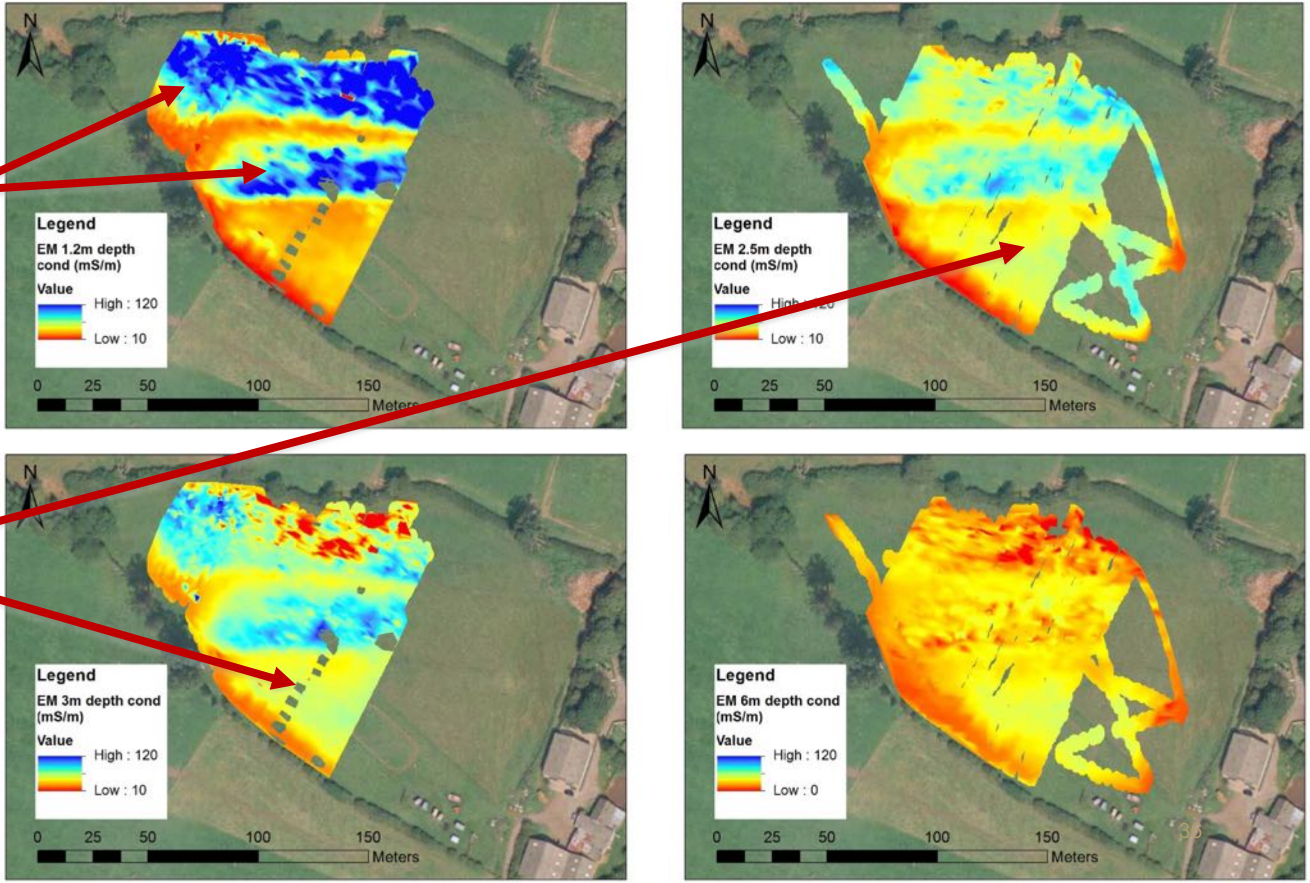
~3 day campaign with 4 personal

Geophysical characterisation: Results EM



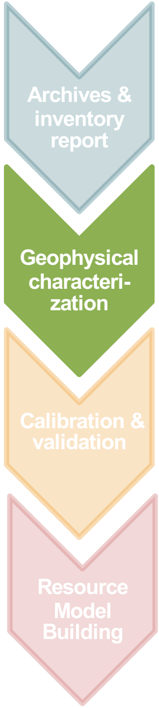
Cell type structure?

Additional cell with less metal content or thicker cover layer?

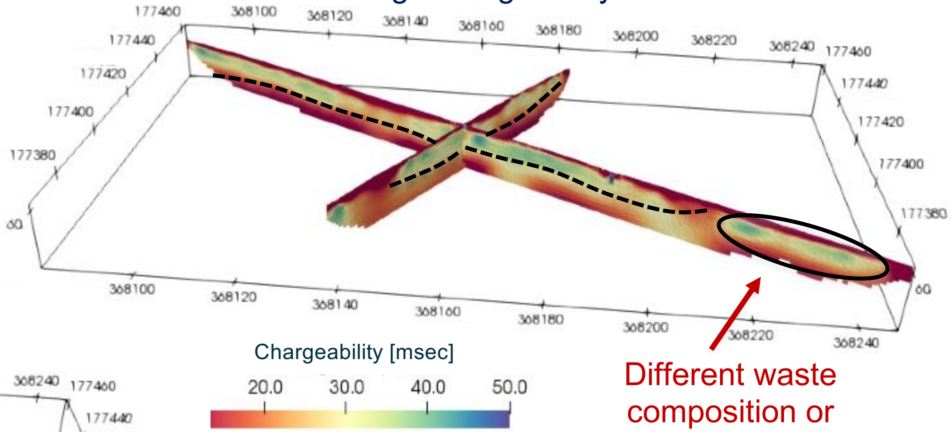


CASE STUDY EMERSONS GREEN

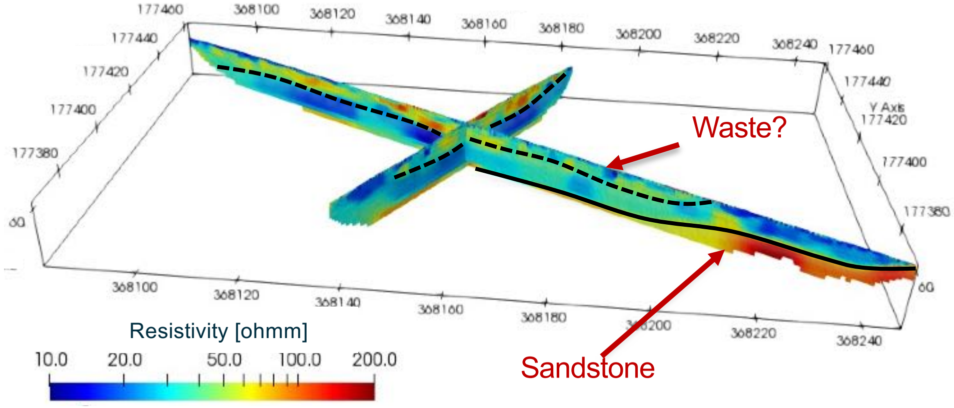
Geophysical characterisation: Results ERT and IP

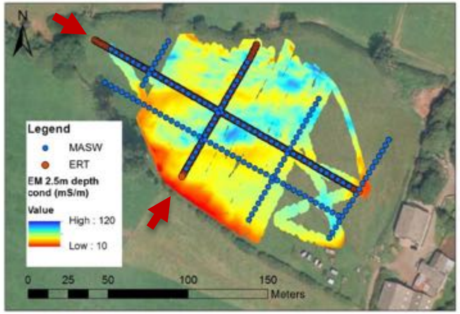


IP: high chargeability indicates waste



ERT: Layered structure

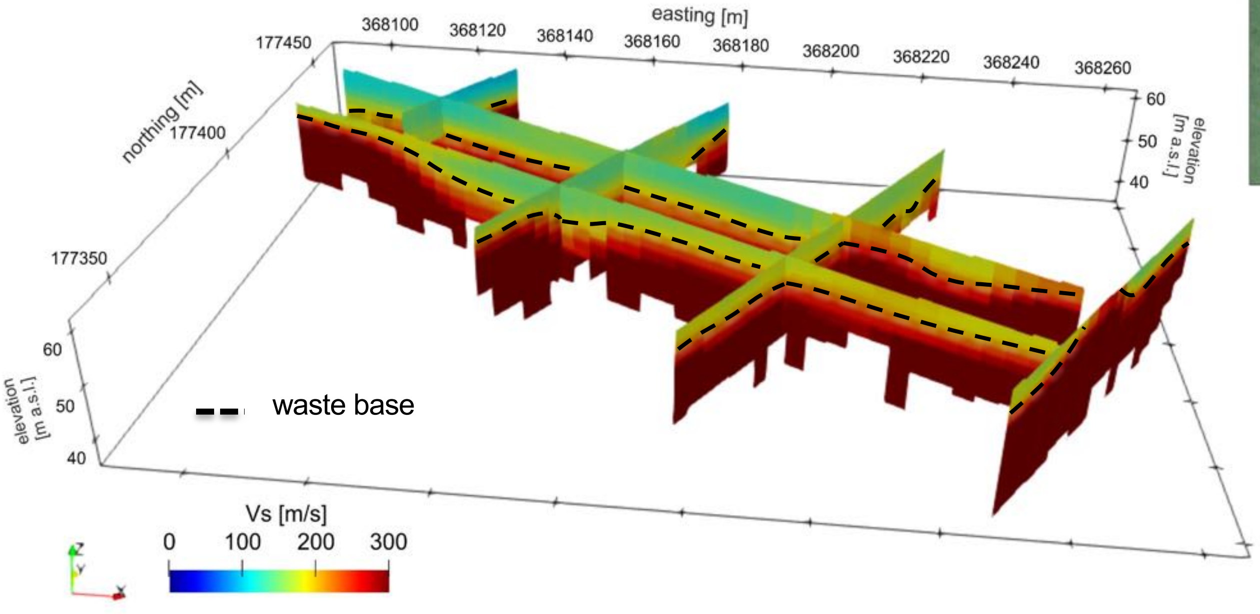


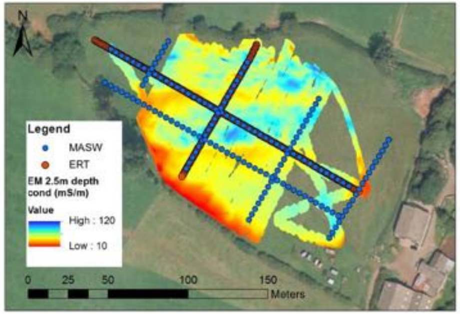


Geophysical characterisation: Results MASW

- Archives & inventory report
- **Geophysical characteri-zation**
- Calibration & validation
- Resource Model Building

Low velocities correspond to waste layer





Calibration and Validation

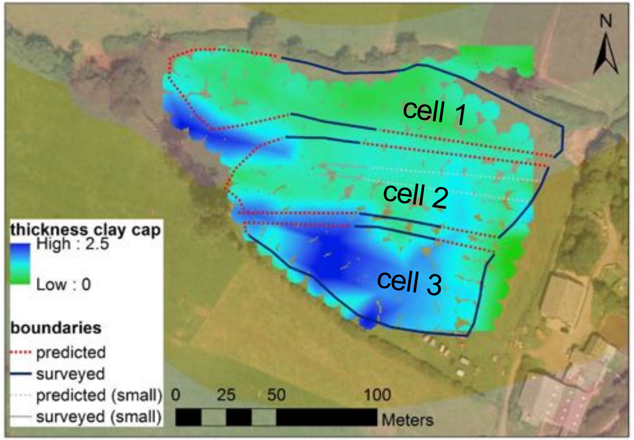
Additional ground truth data through excavations

- The landfill was separated into three cells. These cells were excavated into the natural clayey ground and filled with waste.
- A thicker clay cap and a thinner waste layer was found in cell 3.
- A step in the landfill base between cells 2 and 3 might be associated with the underlying sandstone.

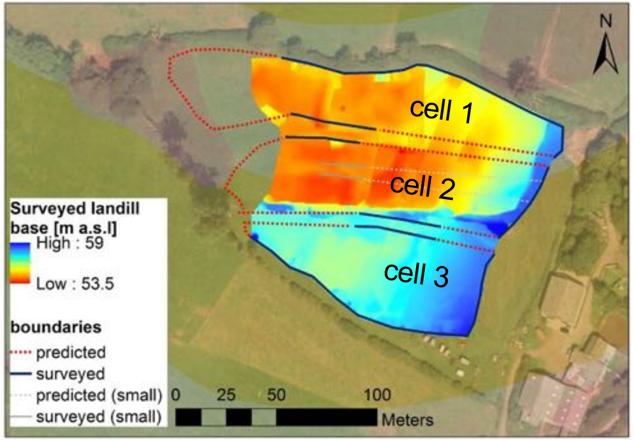
clay stank dividing the waste cells

- The waste composition was a mix of plastic, metal, wood, paper, fabric, inert with no strong compositional changes across the site.

clay cap thickness

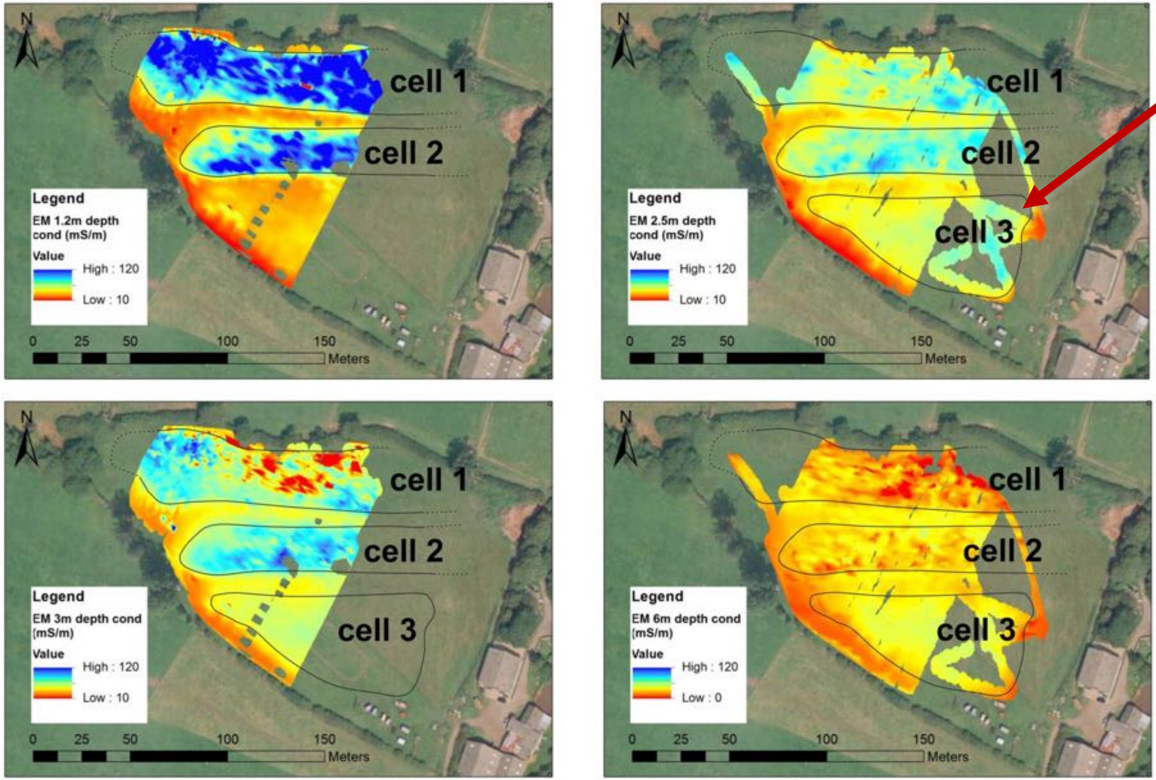


base of waste layer



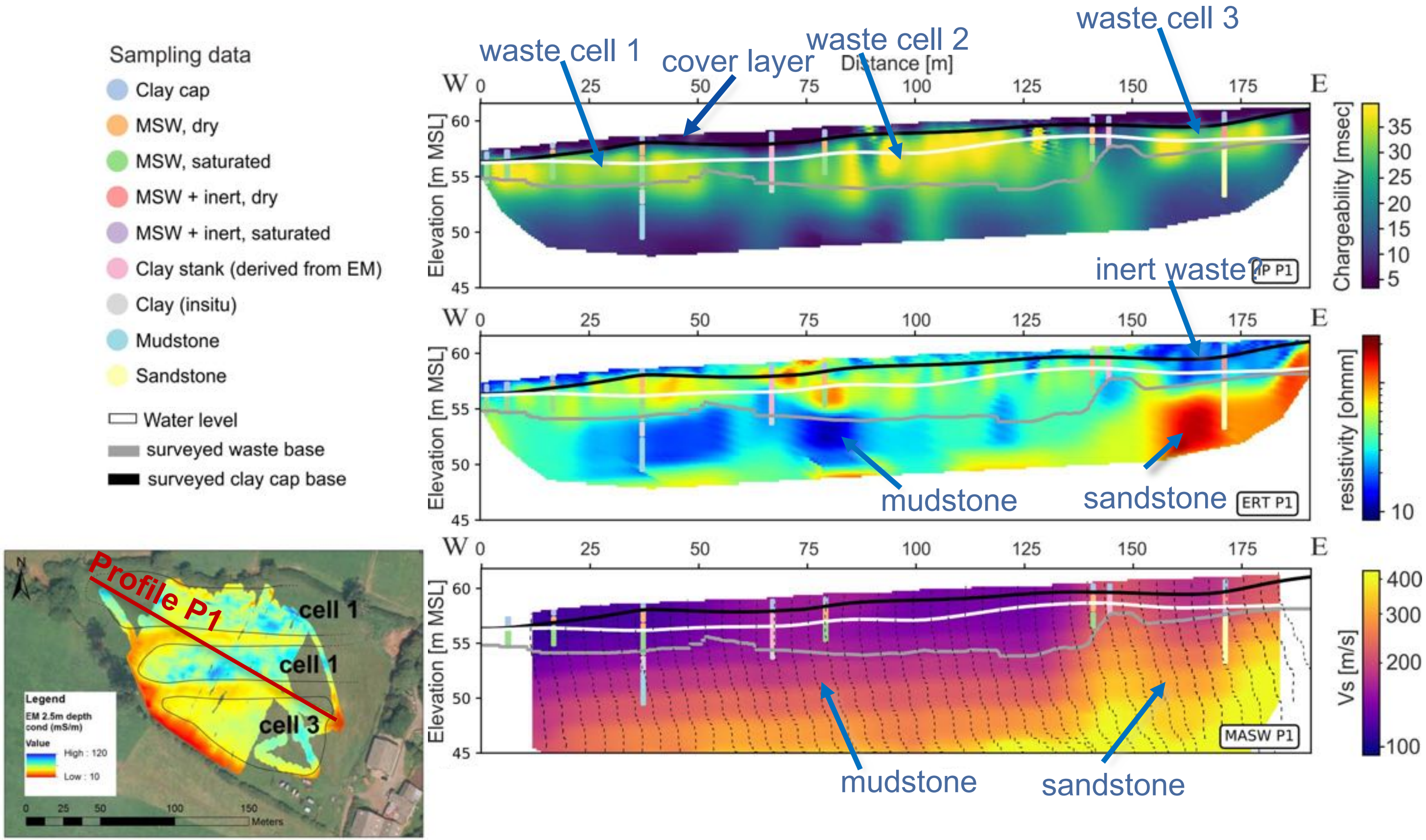
Calibration and Validation

EM: good delineation of waste cell extent and cover layer



Lower conductivities of cell 3 are probably associated with a thicker cover layer and a thinner waste layer

Calibration and Validation



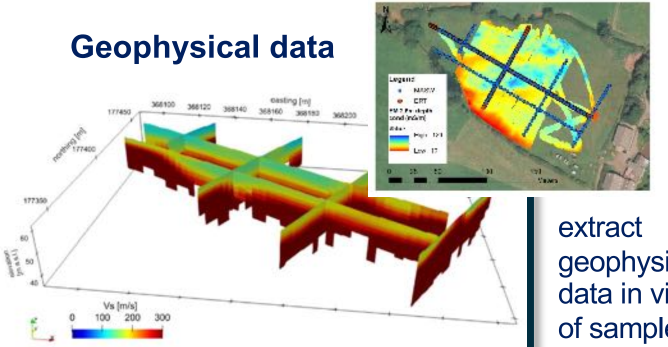
IP
resolves clay cap and waste cells

ERT
resolves sandstone interface

MASW
resolves sand-stone interface, mudstone interface less clear

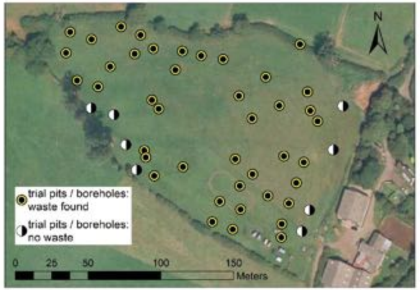
Building Resource Distribution Model

Geophysical data



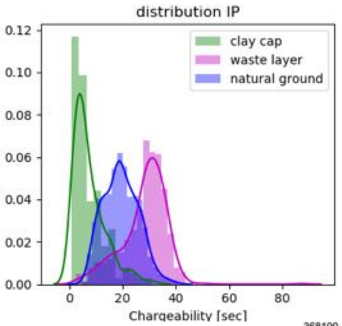
extract geophysical data in vicinit of samples

Trial pits & boreholes



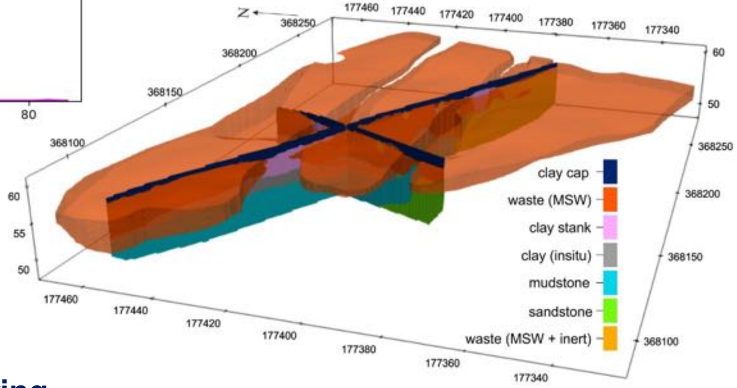
discretize sampling logs into relevant categories (e.g. clay cap, saturated waste…)

Correlation analysis



choice of relevant geophysical parameters

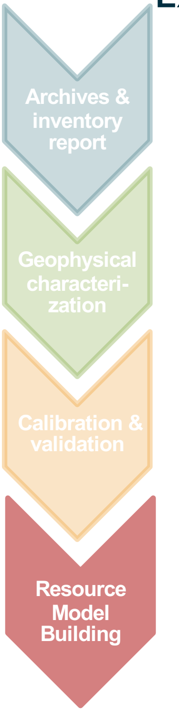
Model building through supervised machine learning (classification)



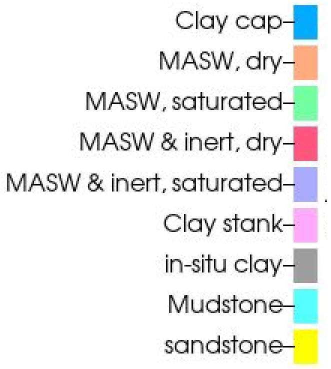
Volume rendering

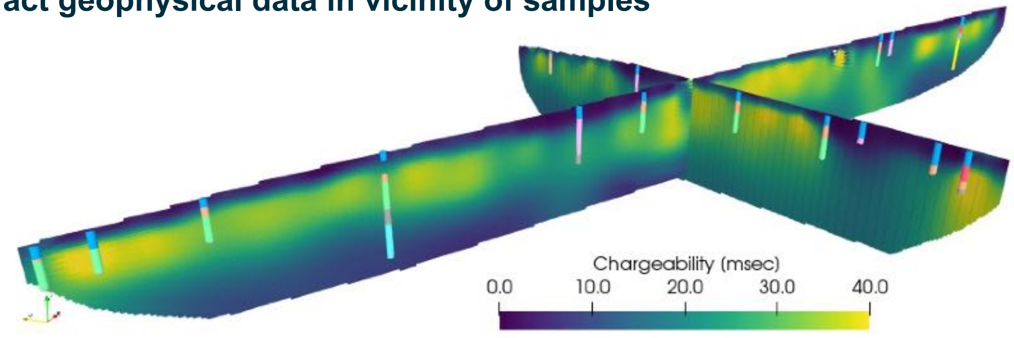
	Cell 01 (North)	Cell 02 (centre)	Cell 03 (South)	Total
Volume of waste material (m3)	15’258	10’654	9’547	35’450

Building RDM: Correlation Analysis

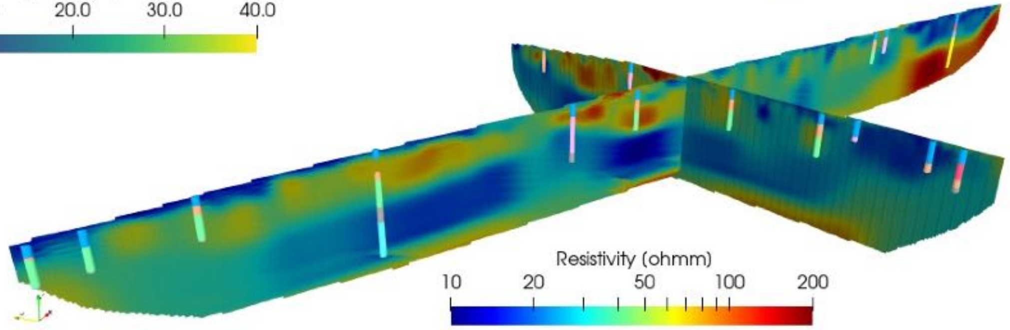


Extract geophysical data in vicinity of samples

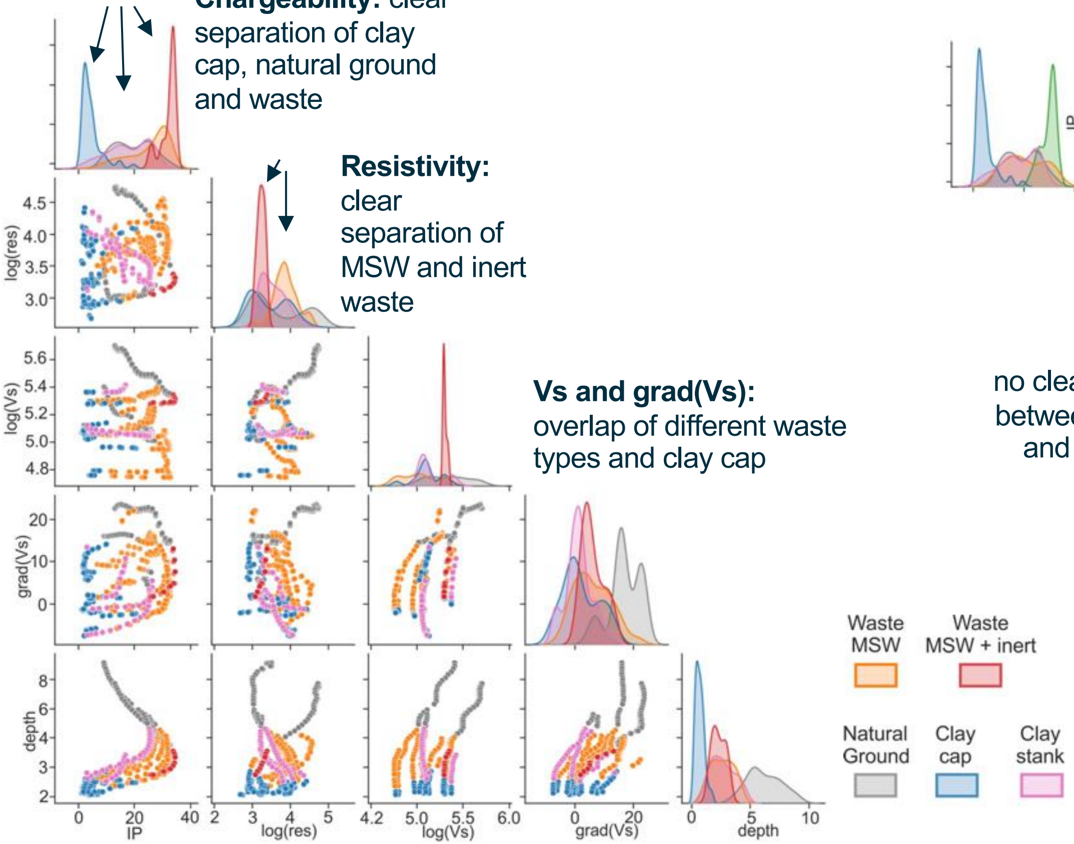




- Position of clay stank was defined according to EM data
- Same was done for MASW data



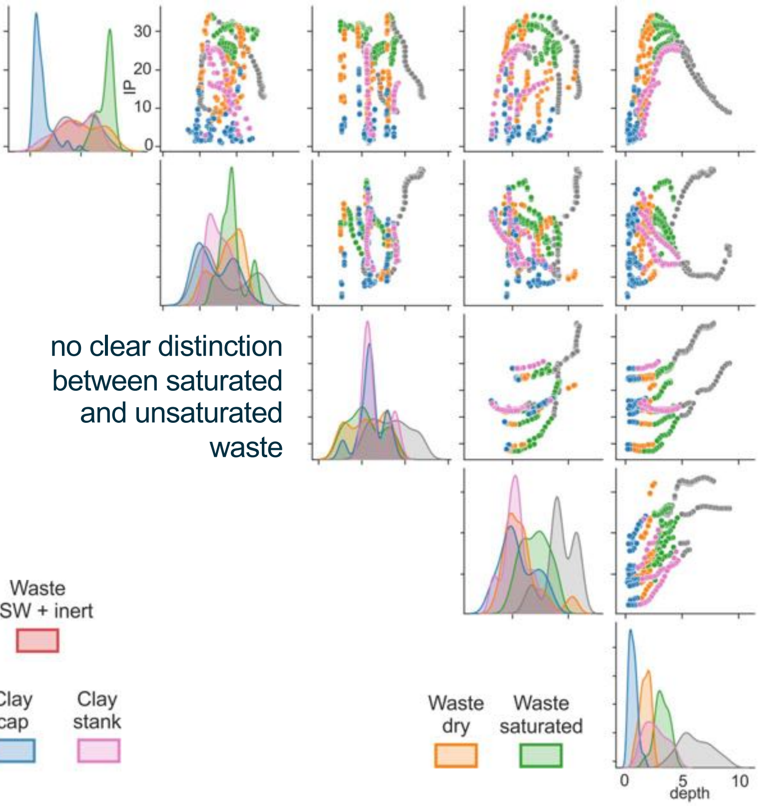
Building RDM: Correlation Analysis



Chargeability: clear separation of clay cap, natural ground and waste

Resistivity: clear separation of MSW and inert waste

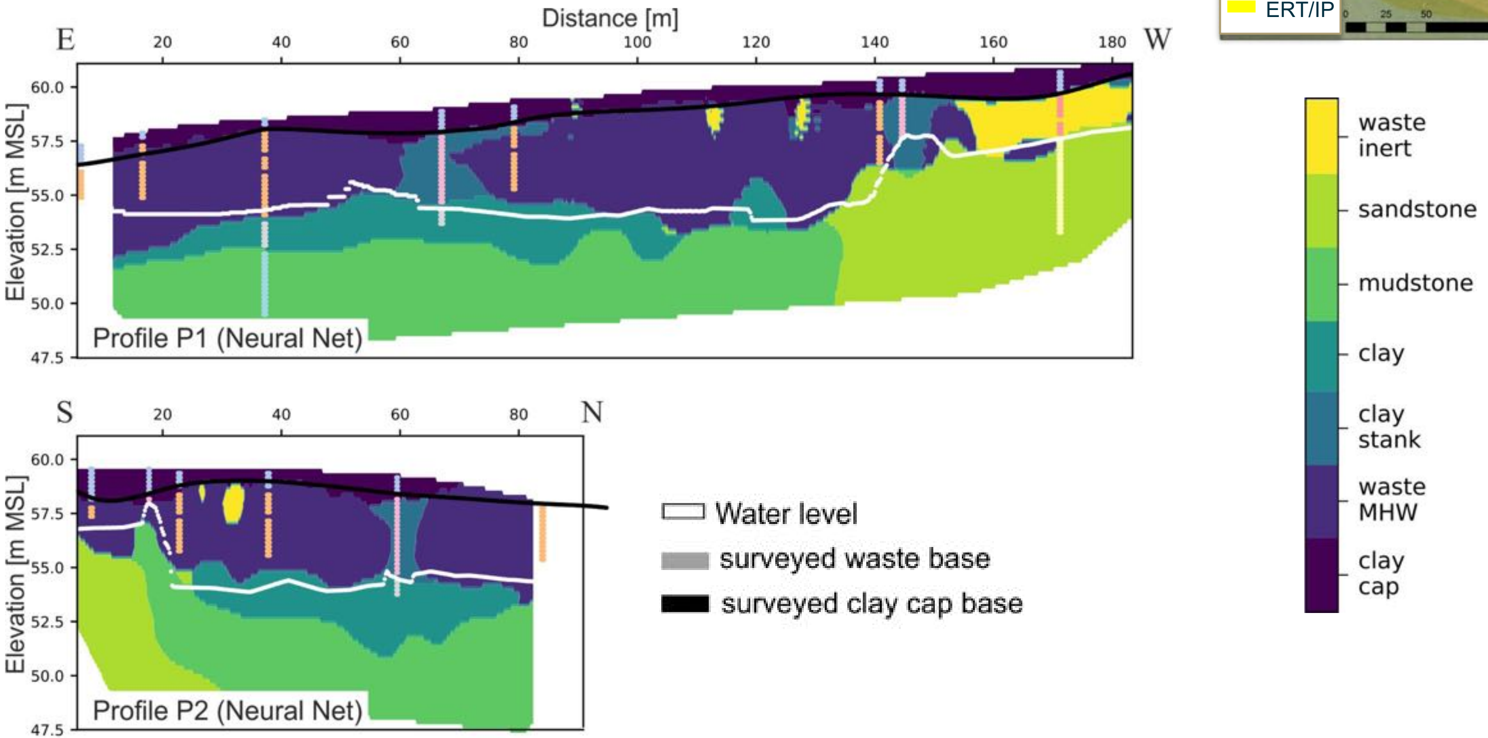
Vs and grad(Vs): overlap of different waste types and clay cap

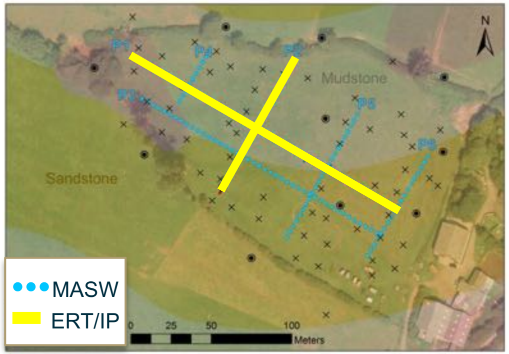


no clear distinction between saturated and unsaturated waste

Building RDM: machine learning Classification

- Tested and compared different classification algorithms.
- Best results achieved with Neural Network.

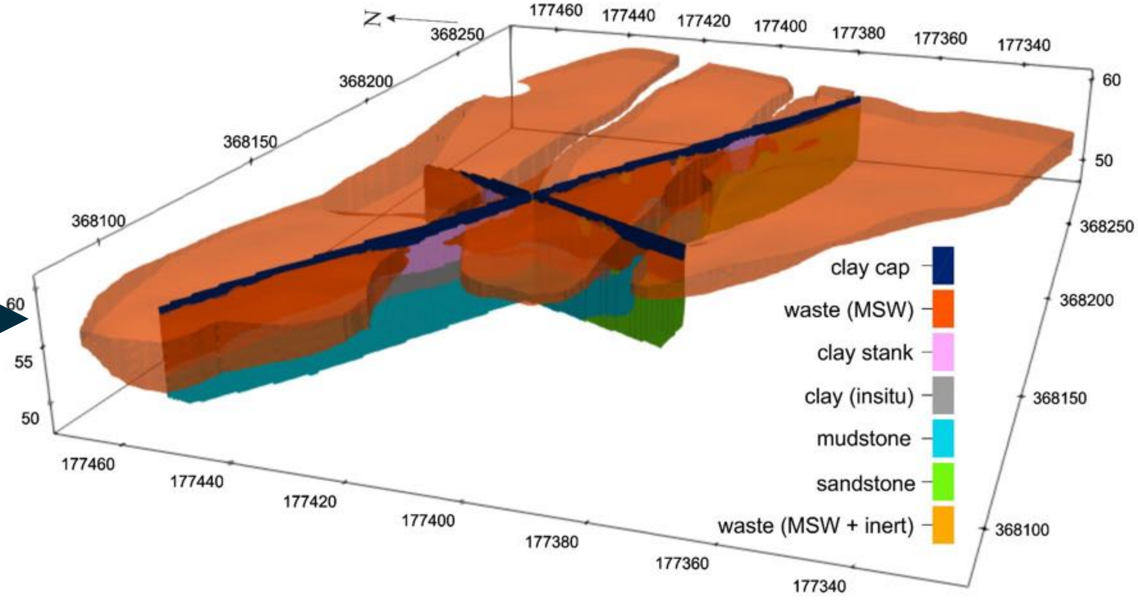




Building RDM: Volume rendering

Inputs

- Boundaries from classification
- Depth information from samples
- Lateral extent from EM data



	Cell 01 (North)	Cell 02 (centre)	Cell 03 (South)	Total
Volume of waste material (m3)	15’258	10’654	9’547	35’450

Conclusion

Using geophysics for LF characterisation:

- Is cost effective.
- Delivers relatively high resolution data (when mapping and profiling techniques are combined).
- Allows targeted sampling.
- Allows reliable interpretation when combining different methods and targeted sampling.

Outlook

- Uncertainties not yet considered.
- Machine learning classification maybe a good approach to combine geophysical methods and ground truth data.
- Using geophysics to monitor leachate and gas migration.

Thank you

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