Geophysical instruments and data processing: Stepped Frequency Kontur GPR

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Codevintec Italiana srl

IR0000032 – ITINERIS, Italian Integrated Environmental Research Infrastructures System
(D.D. n. 130/2022 - CUP B53C22002150006) Funded by EU - Next Generation EU PNRR-Mission 4 “Education and Research” - Component 2: “From research to business” - Investment 3.1: “Fund for the realisation of an integrated system of research and innovation infrastructures”

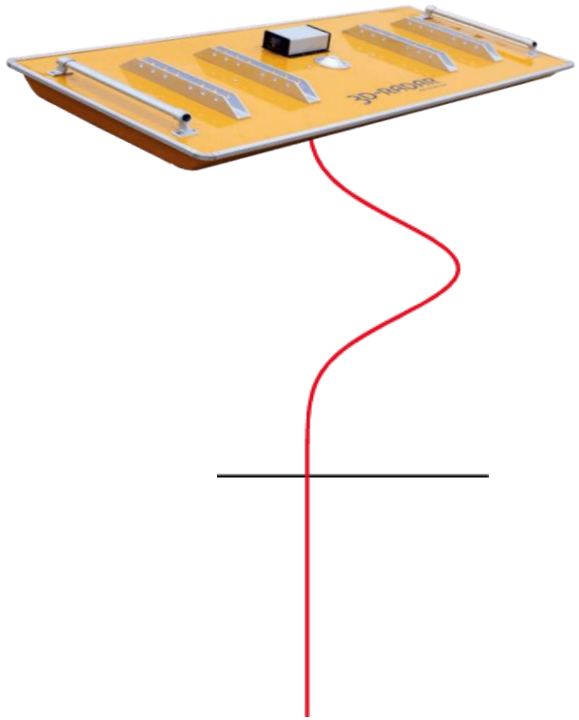
Finanziato dall'Unione europea NextGenerationEU
Ministero dell'Università e della Ricerca
Italiadomani

Agenda – 9 June 2025

11:30 – 13:00	**1h30m**	**Stepped Frequency Multichannel Kontur GPR: theoretical aspects**
13:00 – 14:00		Lunch Break
14:00 – 16:00	2h00m	Stepped Frequency Multichannel Kontur GPR: practice
16:00 – 16:15		Coffee Break
16:15 – 17:45	1h30m	Stepped Frequency Multichannel Kontur GPR: data analysis

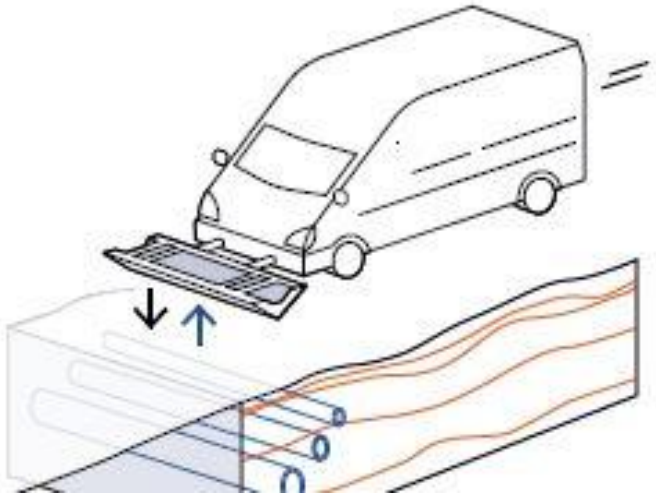
Ground penetrating radar technology

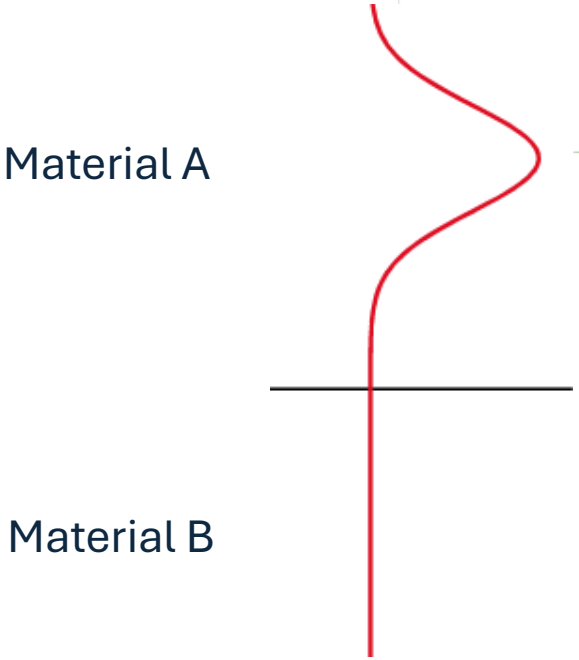
- Ground-penetrating radar is a geophysical method that uses radar pulses to image the subsurface, looking for the changes in material properties.



Ground penetrating radar technology

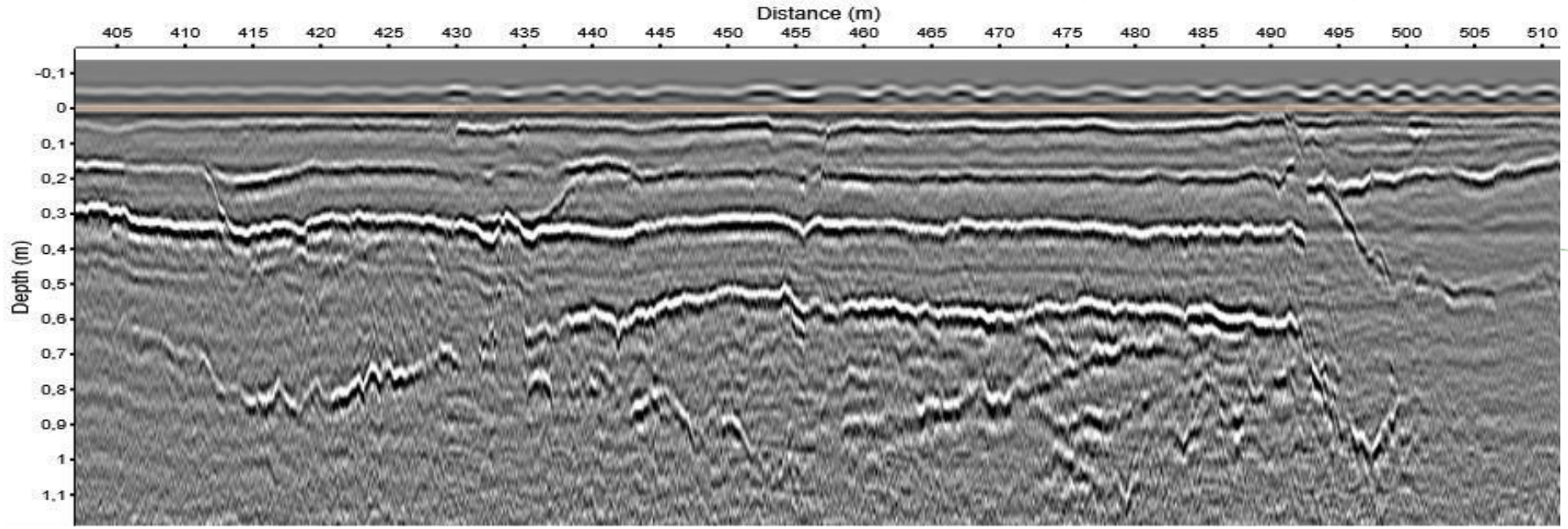
- If the electromagnetic impulse hits an object with different properties than the material surrounding it, it reflects, refracts, and scatters the signal.
- Different properties of material means **dielectric constant**.
- The lower the dielectric constant, the higher the wave velocity.





Ground penetrating radar technology

- The lower the dielectric constant, the higher the wave velocity.
- The higher difference of dielectric constant between materials, the stronger the reflections



Ground penetrating radar at the beginning

What about the first use of GPR?

Tunnel detection in Vietnam war

Snow/ice thickness detection

First GPR in Italy: 1983

1983, Italian highway - tunnel walls survey

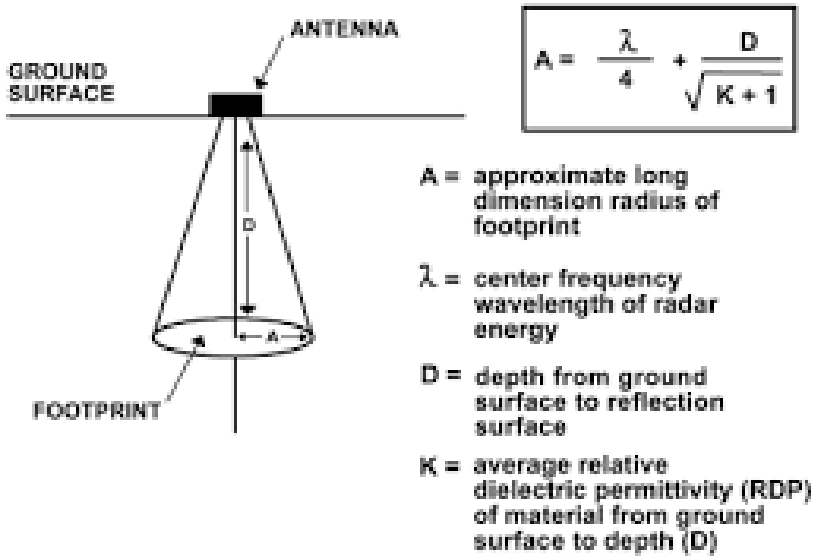
About antenna coupling

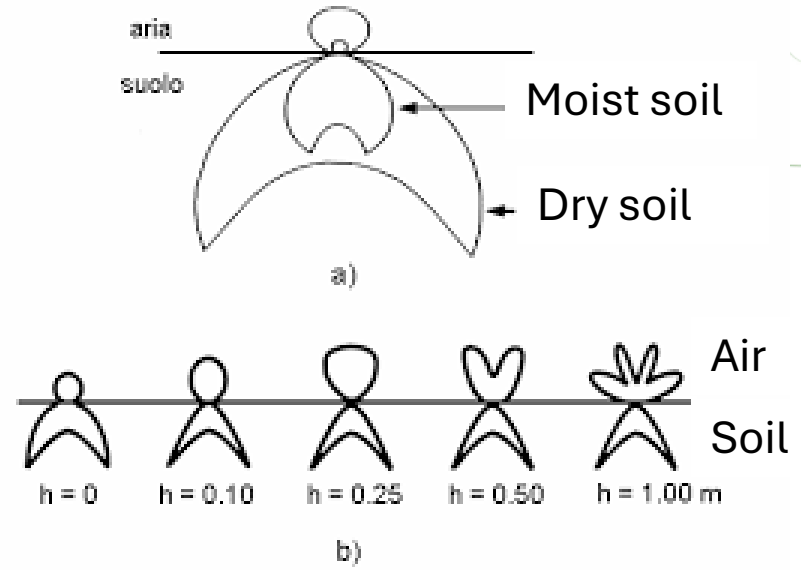
Air coupled

Ground coupled

About antenna coupling

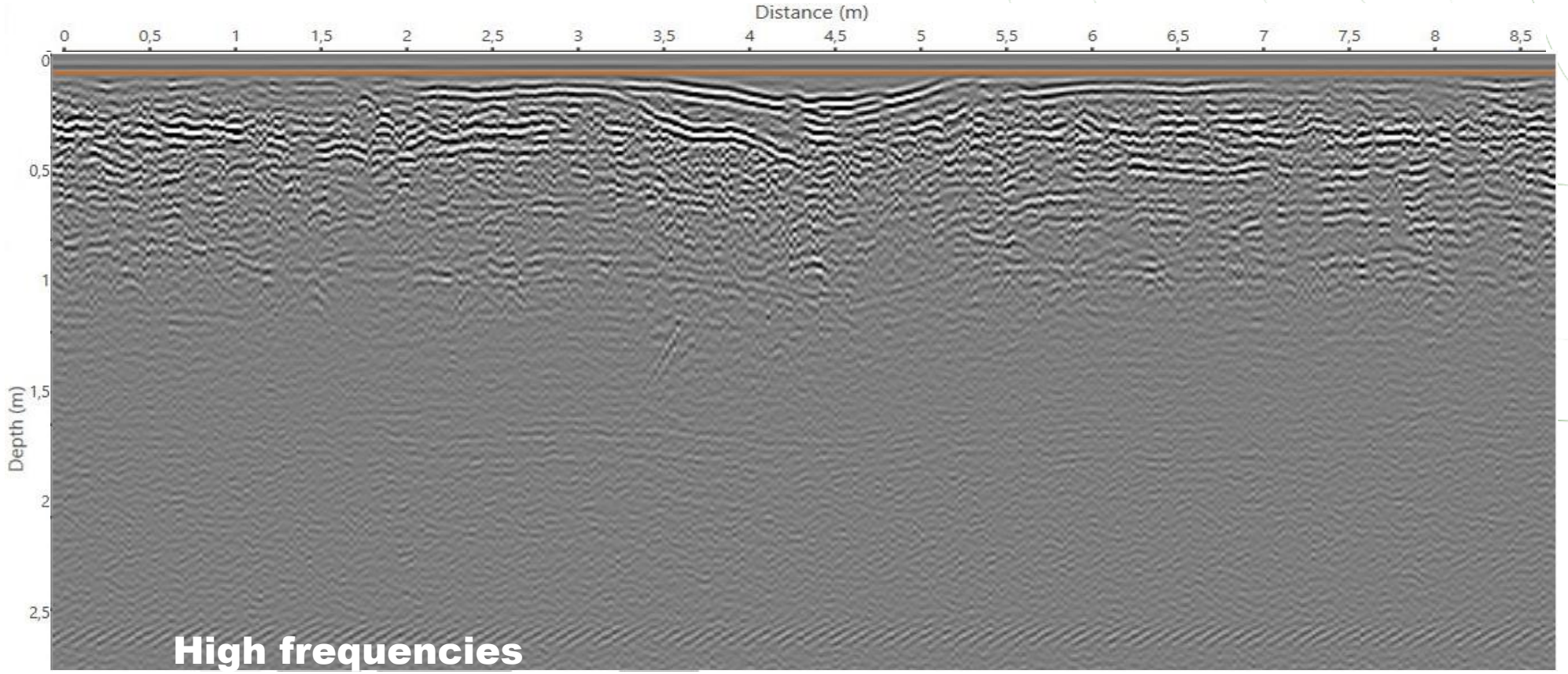
Ground coupled antenna





About frequency

- The lower the frequency, the lower the resolution, the higher the penetration.
- The higher the frequency, the higher the resolution, the lower penetration.



What is Step-Frequency?

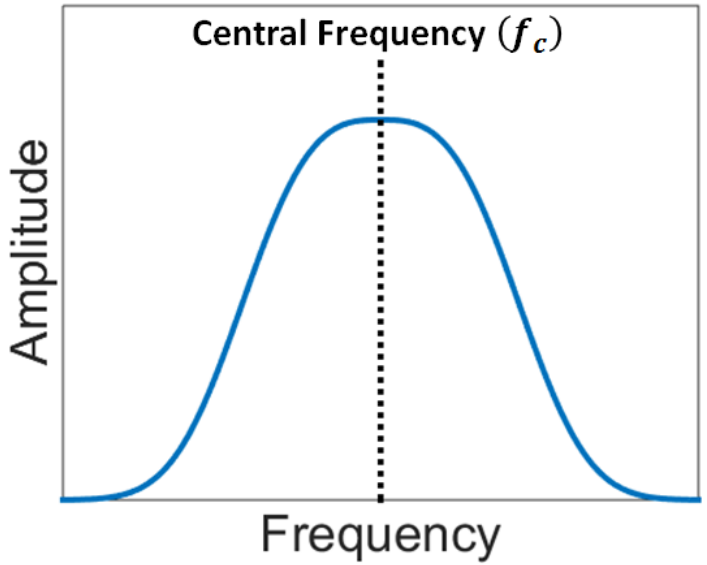
- **Step-frequency** is a **radar waveform** consisting of a **series of sine waves** with **linearly increasing frequency**.
- The **radar** measures the **phase** and **amplitude on each frequency** and uses an inverse **Fourier transform** of this data to build a **time-domain profile** (A-scan).
- Thus, the step-frequency radar collects data in the **frequency domain** and **converts** the data to **time-domain** data through computer processing.
- The **step-frequency waveform** gives the **optimum source signature** with a uniform frequency spectrum. The computer control allows the user to set the dwell time on each frequency as well as the start and stop frequencies.

Step-Frequency Vs Impulse-based Radar

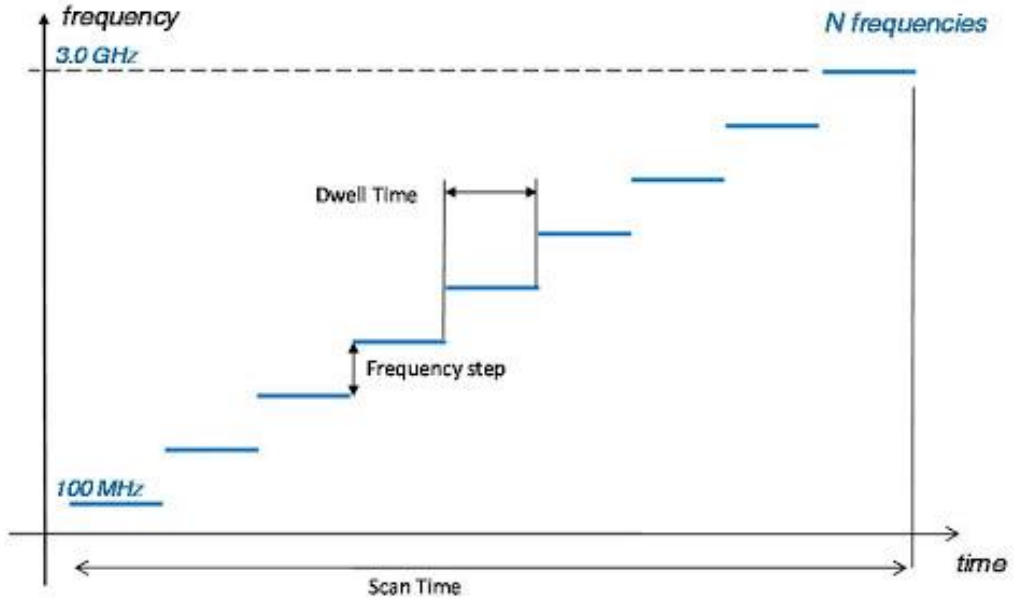
- **Impulse-based** radars transmit **very short pulses** (impulses) with a fixed pulse repetition rate (PRF) and use stroboscopic sampling to build the time domain trace from several subsequent pulses. Hence**, the impulse-based** radar data is **the direct reading of the time-domain reflection** from the underground.
- The **step-frequency** radar data can either be stored **as frequency domain data or as time-domain** data after inverse Fourier transform.
- The **time-domain data from a step-frequency** radar are **equivalent** to **time-domain data from an impulse-based radar**.
- However, the **frequency data** allows a much **wider range of frequency-domain processing** possibilities.

GPR: impulse or step frequency

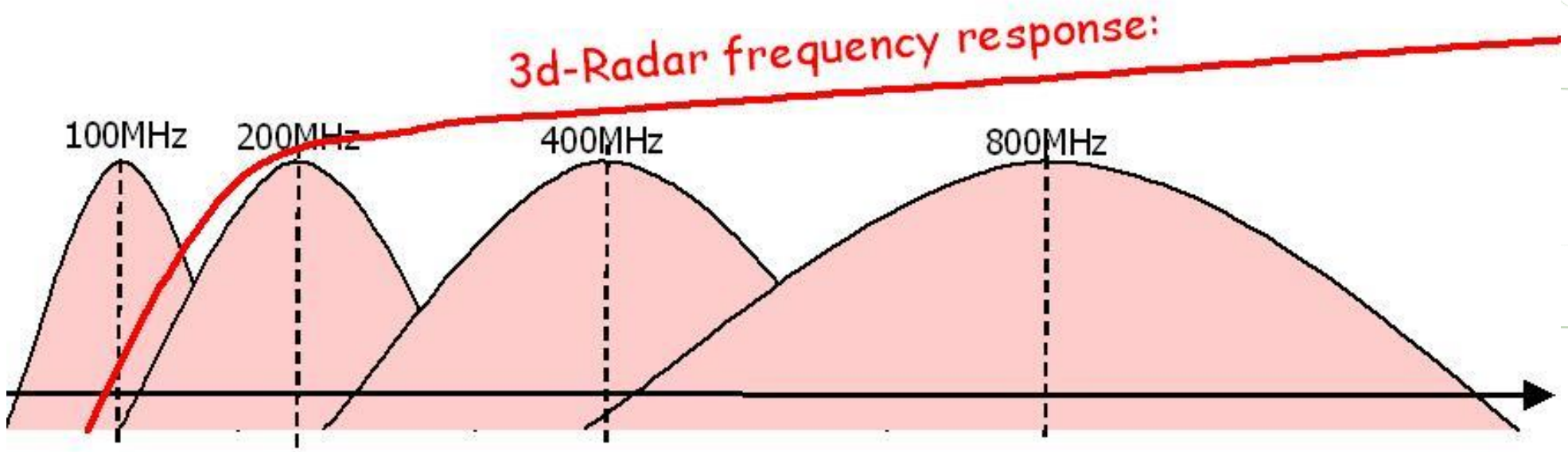
Impulse



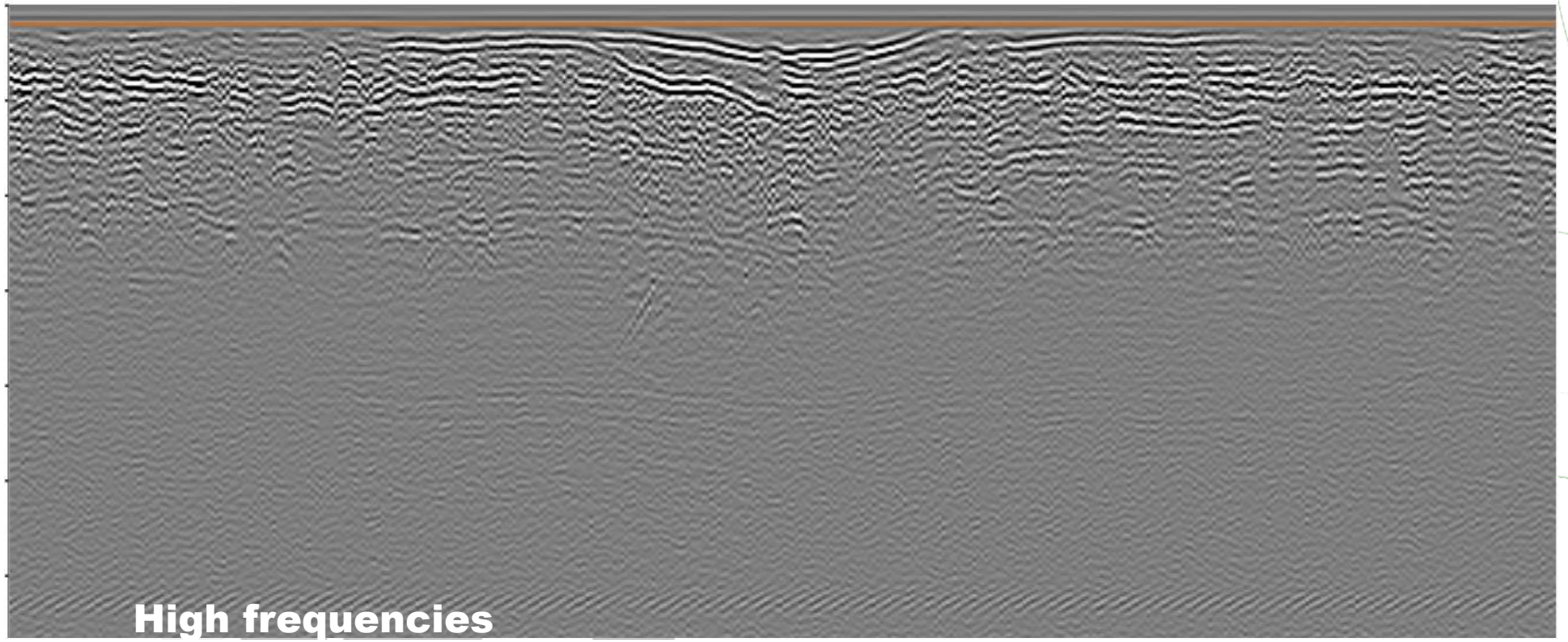
Step Frequency



GPR: impulse or step frequency

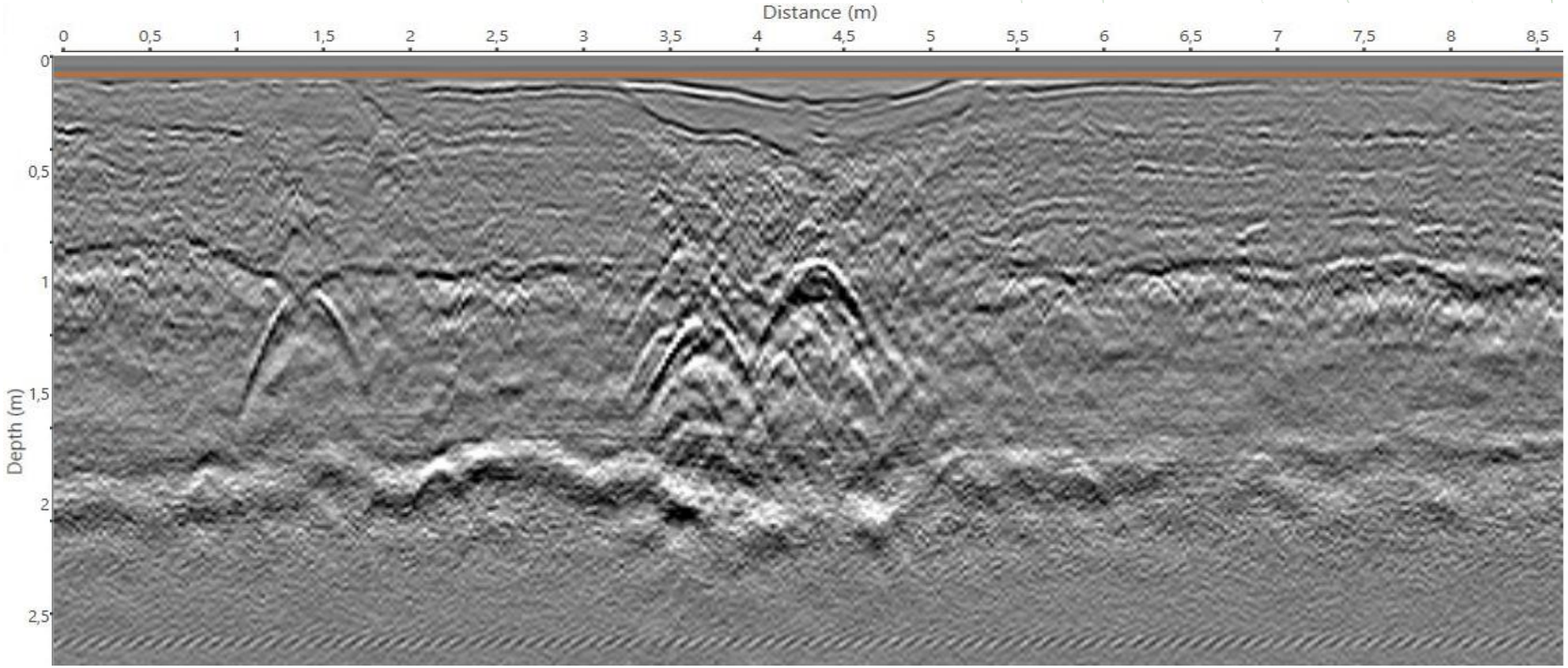


Step frequency: Resolution and Penetration



Step frequency: Resolution and Penetration

Step frequency



KONTUR GPR: which array?

DEEP

The deepest

AIR

The fastest

GROUND

Best combination

KONTUR GPR: which array?

- Continuous frequency generated:

from 30 MHz up to 4.5 GHz

GPR array sensor types

AIR

Superior resolution at shallow depths, capturing 3D data safely, and at high speeds.

GROUND

High-resolution near-surface 3D imaging with deep penetrating capabilities.

DEEP

Exceptional depth capabilities and 3D imaging in challenging environments.

PAVEMENT INVESTIGATION
High-speed data collection and intuitive analysis options provide an invaluable insight into the quality of pavement networks.

AIRPORTS
Ideally suited for aviation environments, Kontur Air provides a multi-application, large scale evaluation method that is repeatable.

RAILWAYS
Integrate Kontur Air to provide subsurface insights into ballast thickness, contamination and more, collected at high speeds.

UNEXPLODED ORDNANCE (UXO)
By conducting airborne subsurface mapping in the search for UXO's, the future looks safer and more autonomous.

UTILITY MAPPING
depths without sacrificing resolution. Quickly track pipes, utilities, rebar and other structures.

AIRPORTS
Ideally suited for aviation environments, Kontur Air provides a multi-application, large scale evaluation method that is repeatable.

BRIDGE DECK INVESTIGATION
Comprehensive, accurately positioned coverage in high resolution for detailed bridge deck evaluations.

RAILROAD INSPECTION
Programmable to utilise unique scan patterns enabling a "look under rails" capability.

UTILITY MAPPING
Wider antenna arrays ideally suited for large-scale utility mapping and fieldwork.

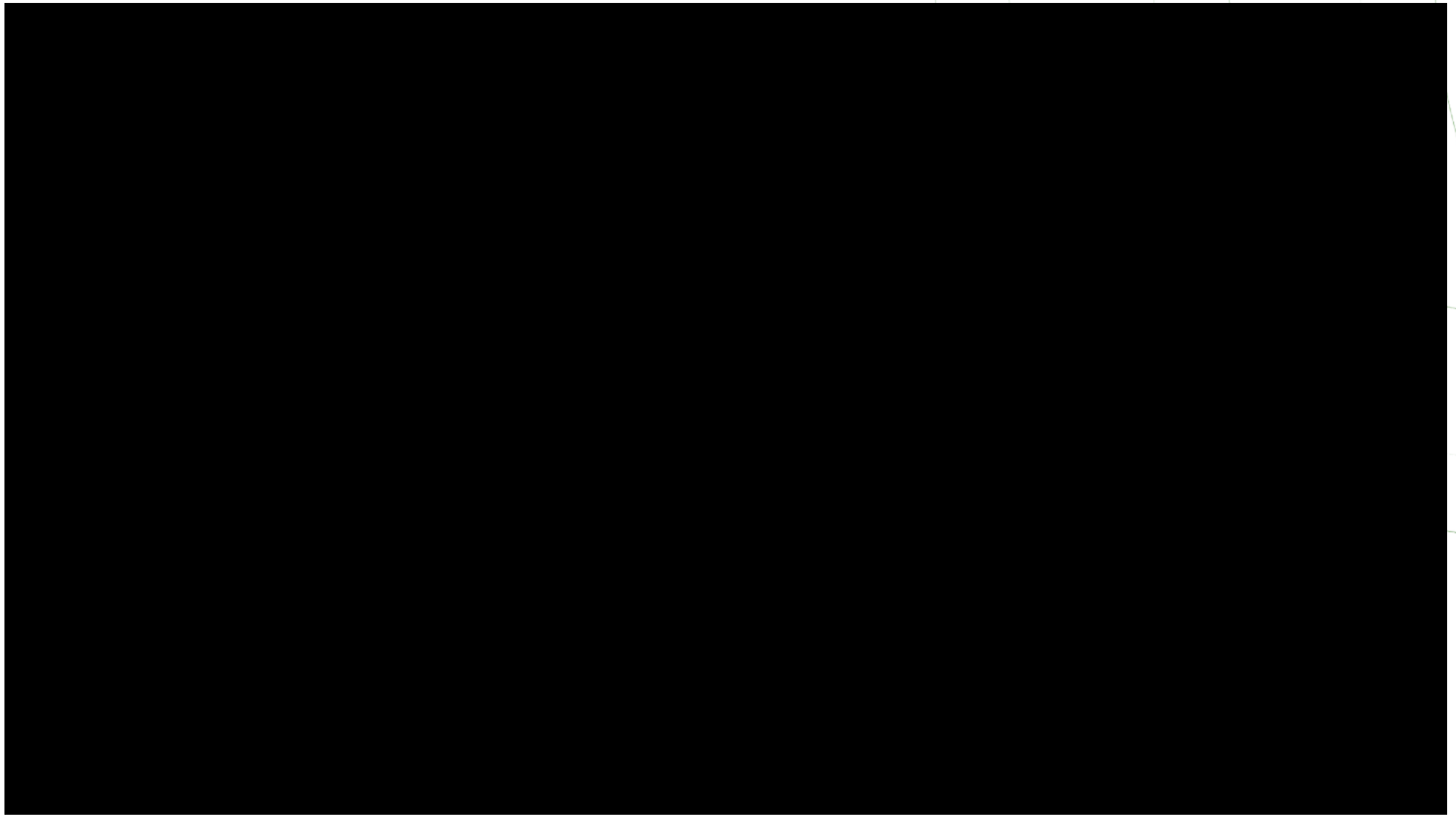
ROAD INSPECTION
Deploy Kontur Deep to detect deeper road construction and identify failures such as voiding.

PIPELINES
Efficient mapping of deeper and large pipeline infrastructure.

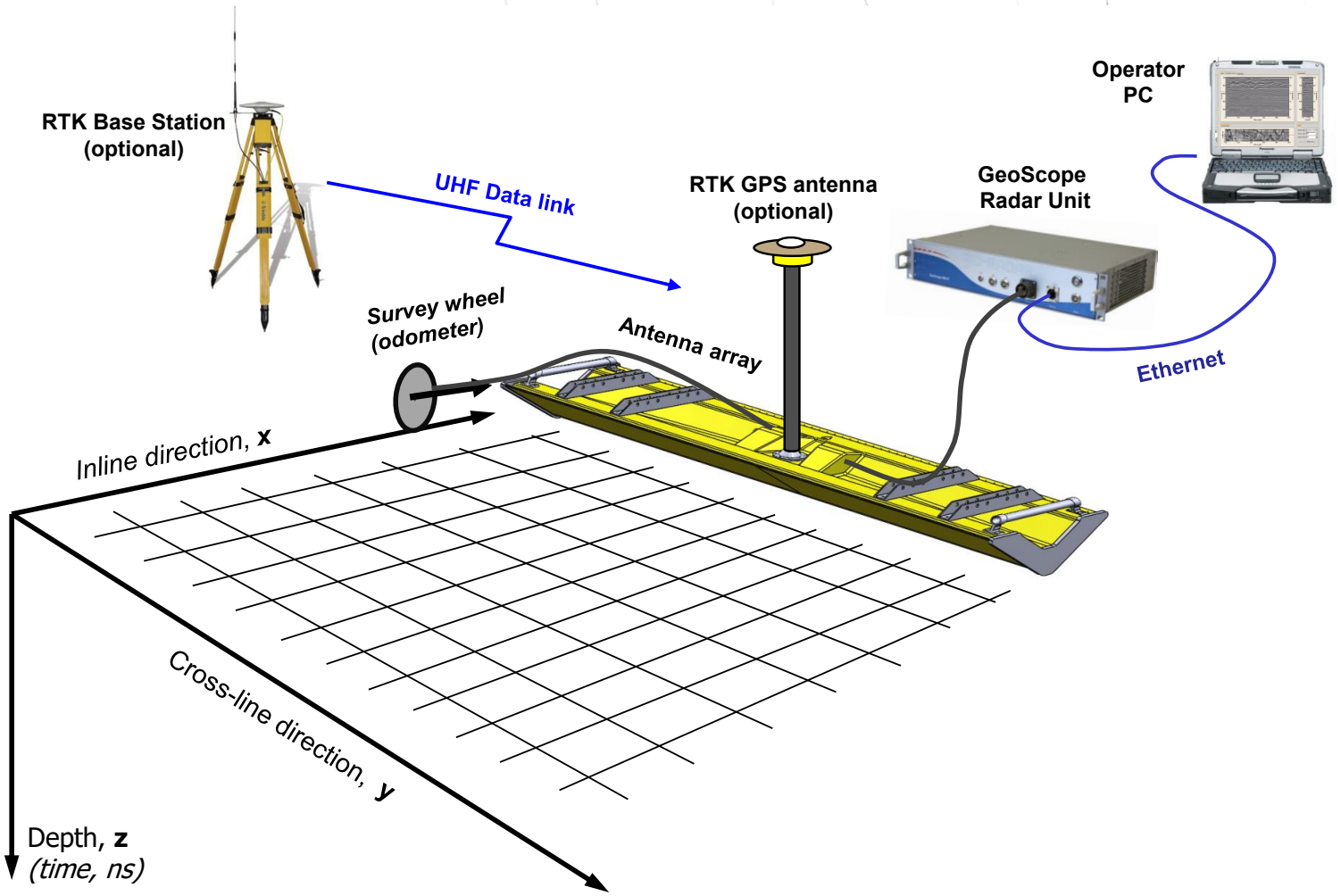
ARCHAEOLOGY
Increased depths, multichannel antenna array support and high-resolution reduce data collection time while providing the best possible imagery.

Applications

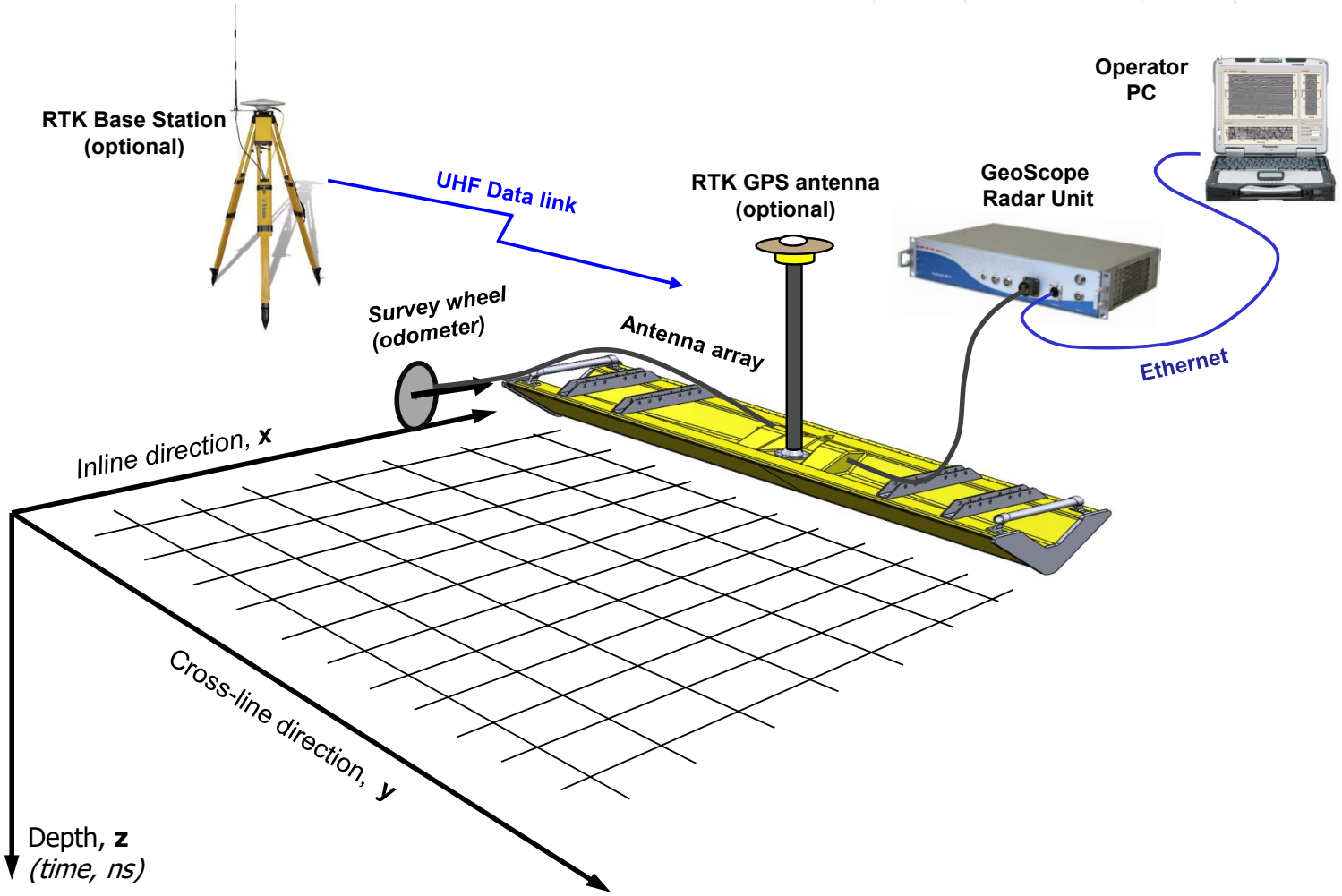
Applications



KONTUR ARCHITECTURE



KONTUR ARCHITECTURE

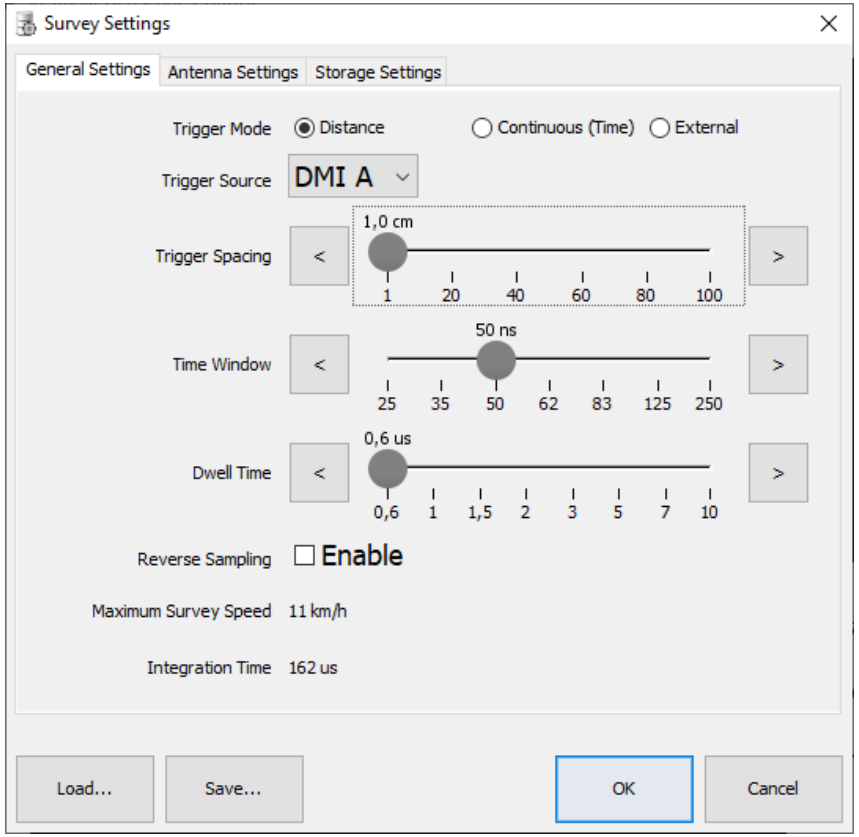


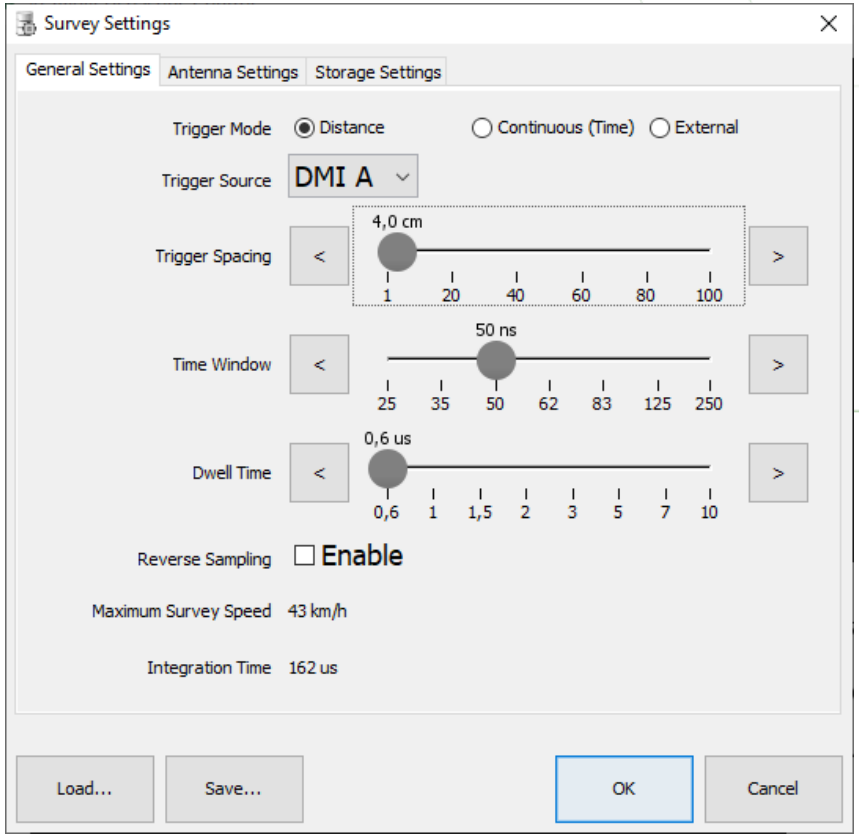
KONTUR GROUND1212

- Ground coupled array
- 1.2m wide, 0.9m scan size
- Stepped frequency
- 12 CHANNELS, 200 MHz – 3 GHz
- 7.5 cm channels spacing
- Internal GPS
- Possibility to customize the scan pattern

KONTUR ACQUISISTION SOFTWARE

Parameters setup

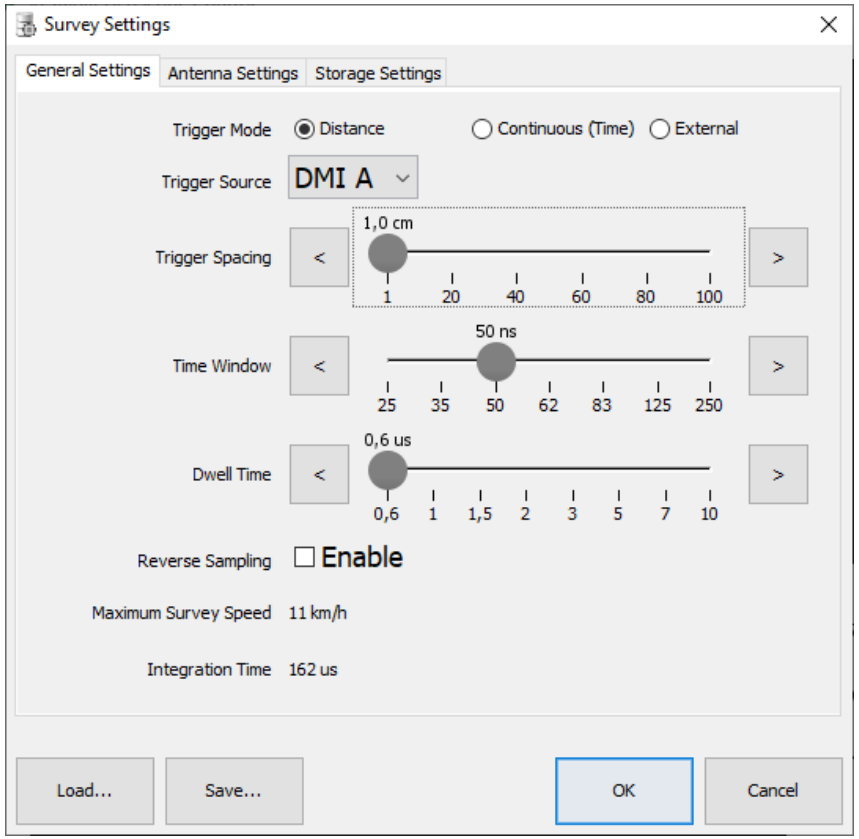




Example:
Ground coupled array G0908
Max survey speed: 76 km/h
Inline sampling = 4 cm

KONTUR ACQUISISTION SOFTWARE

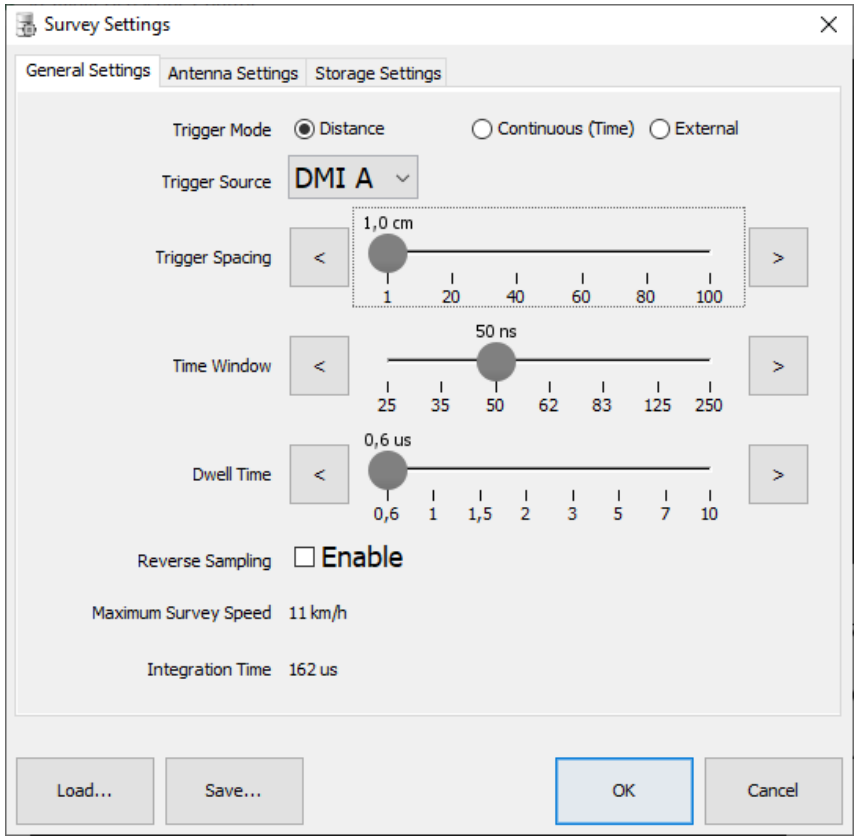
Parameters setup



- Trigger spacing: inline spacing
- Time window: how long (deep) it records
- Dwell Time: how long is the single step interval

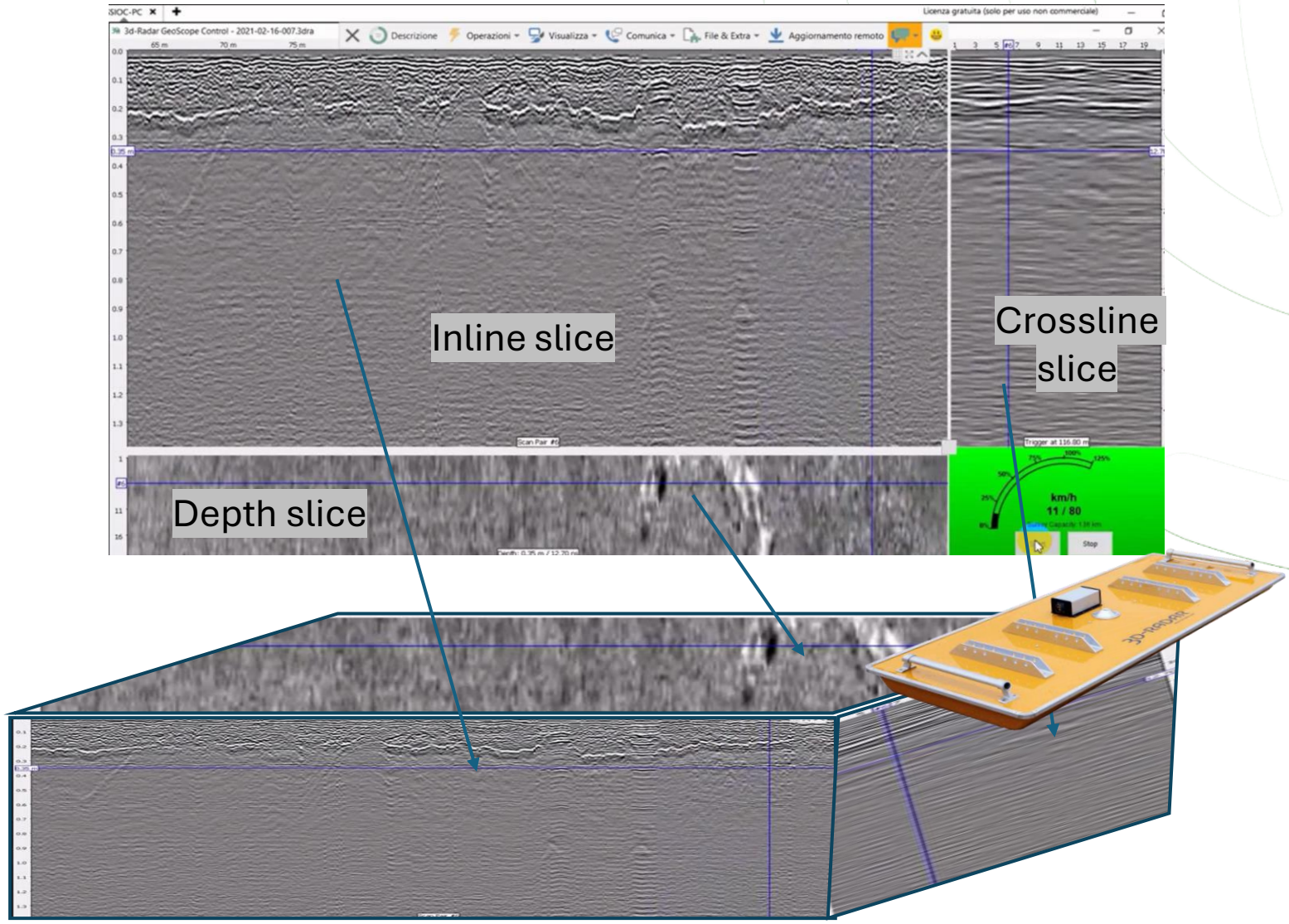
KONTUR ACQUISISTION SOFTWARE

Parameters setup



- Trigger spacing: inline spacing
- Time window: time(deep) range
- Dwell Time: single step frequency range

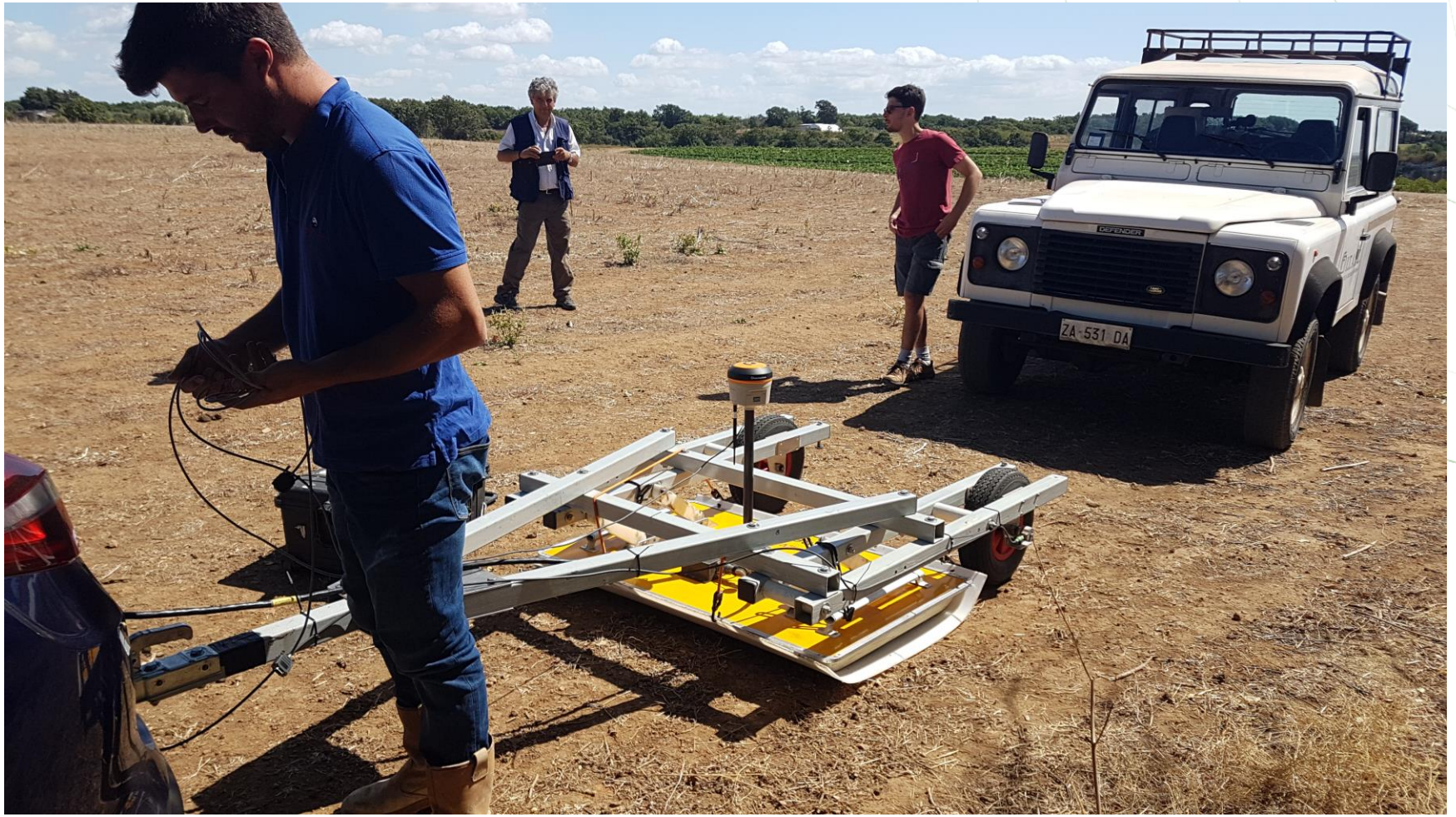
What you will see in real time?



Case studies

Archeology

- Monte Abatone, Cerveteri – Kontur GPR Ground coupled 1212



Archeology

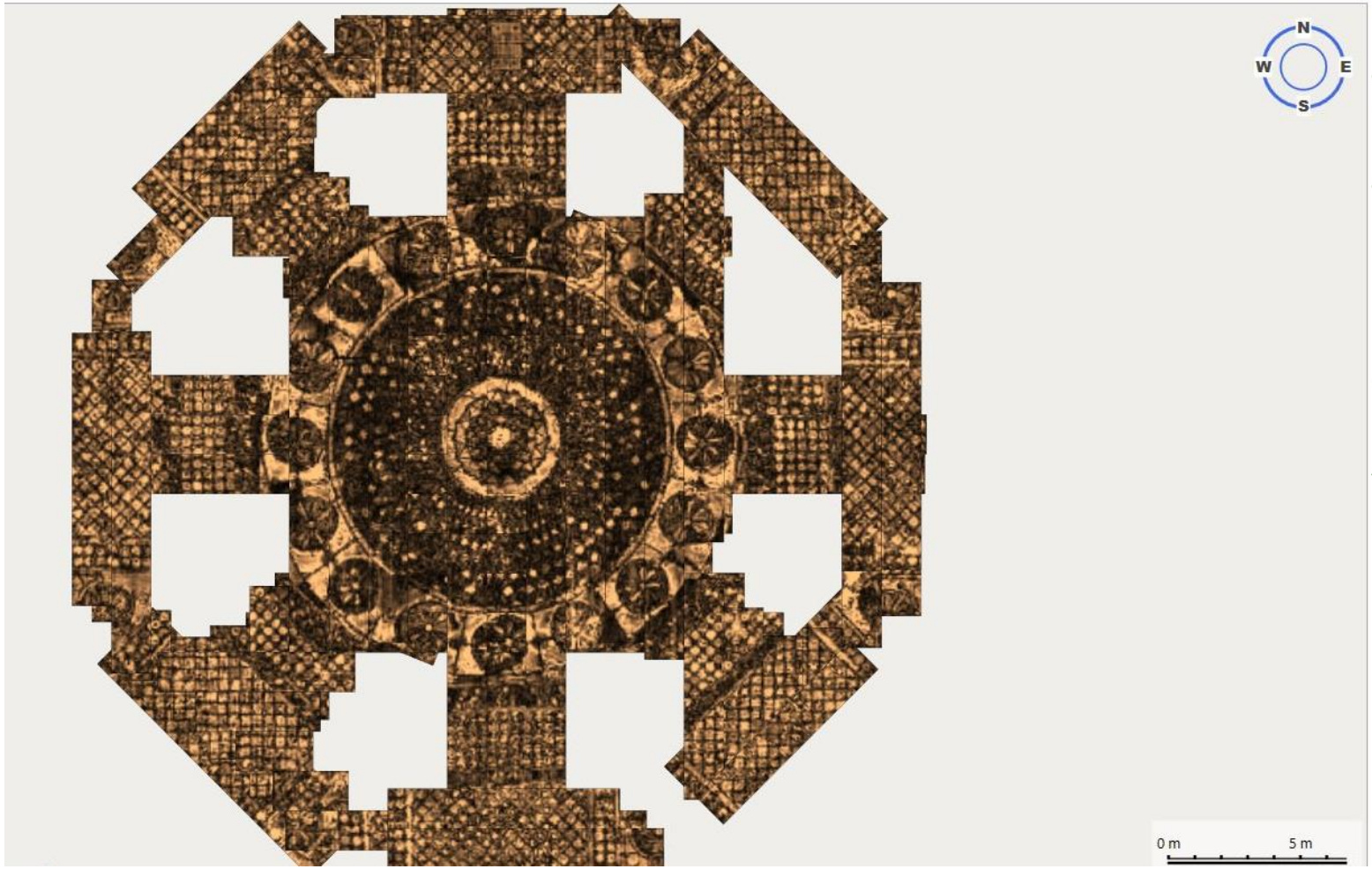
Catacombs, Monte abatone, Cerveteri – Kontur GPR

Archeology application

- Basilica della Salute, Venice - Kontur GPR Ground coupled 1820

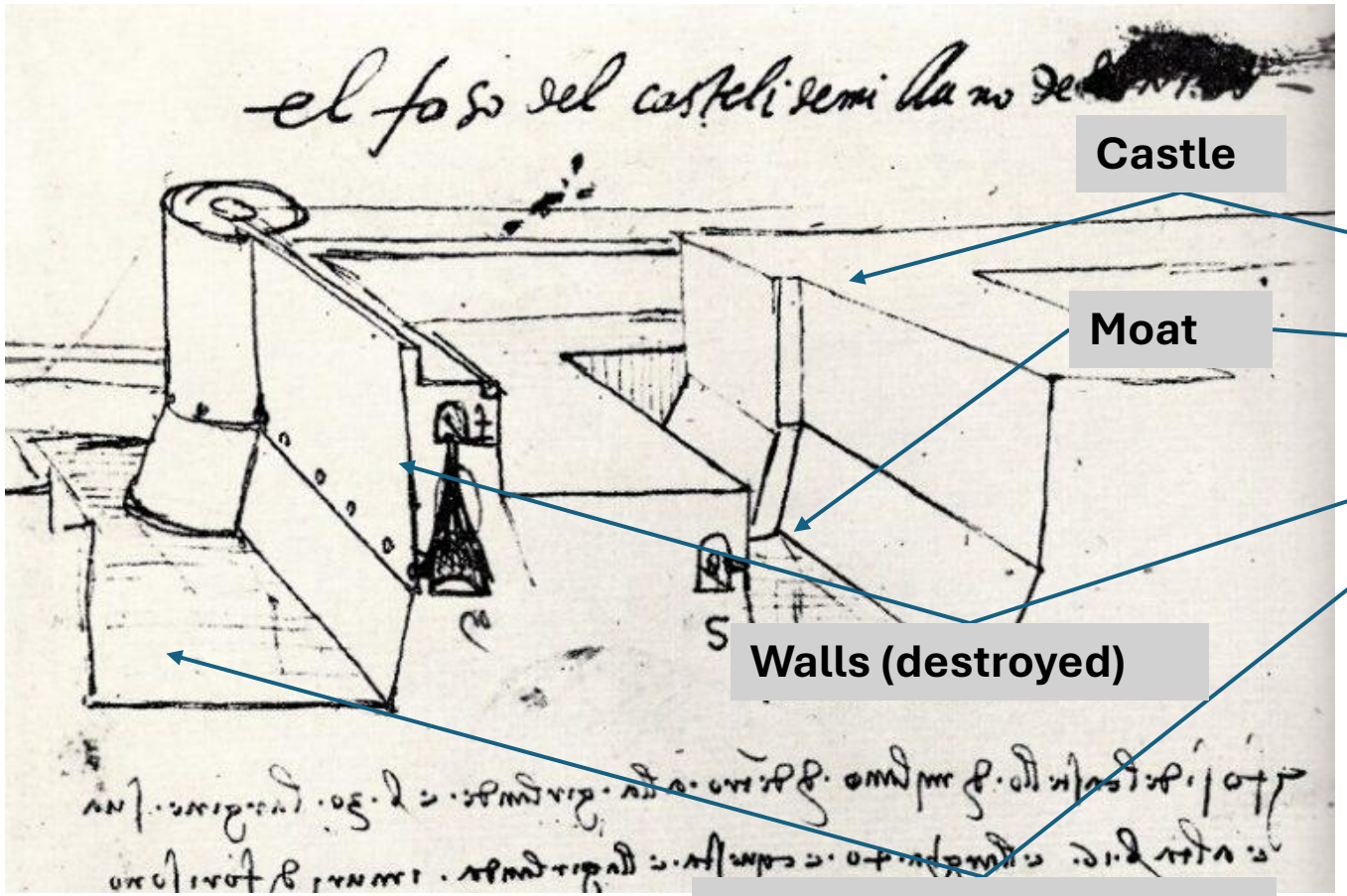
Archeology application

- Pavement of Basilica della Salute, Venice - Kontur GPR Ground coupled 1820



Archeology application

Castello Sforzesco tunnels - Kontur GPR Ground coupled 1820



Archeology application

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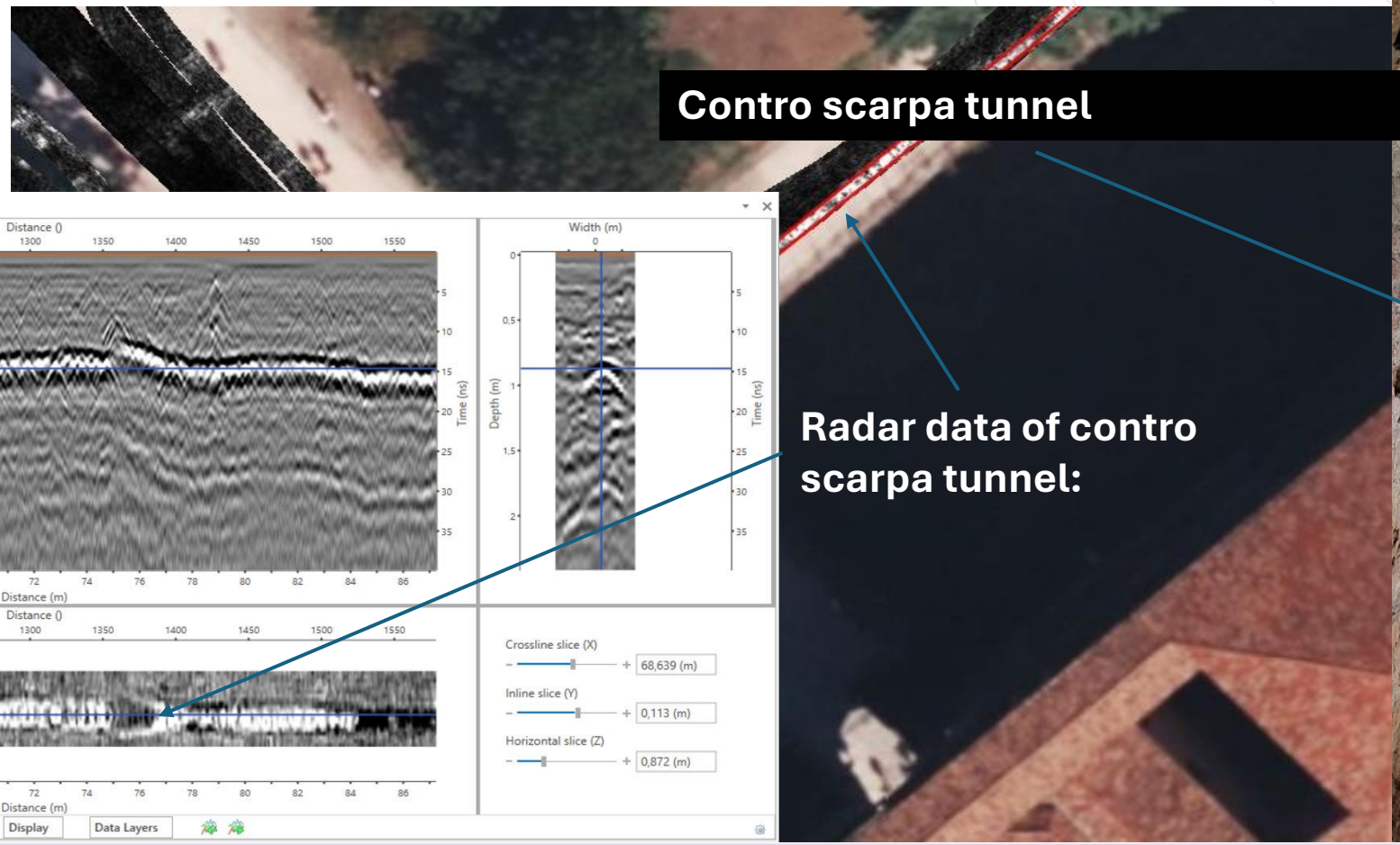
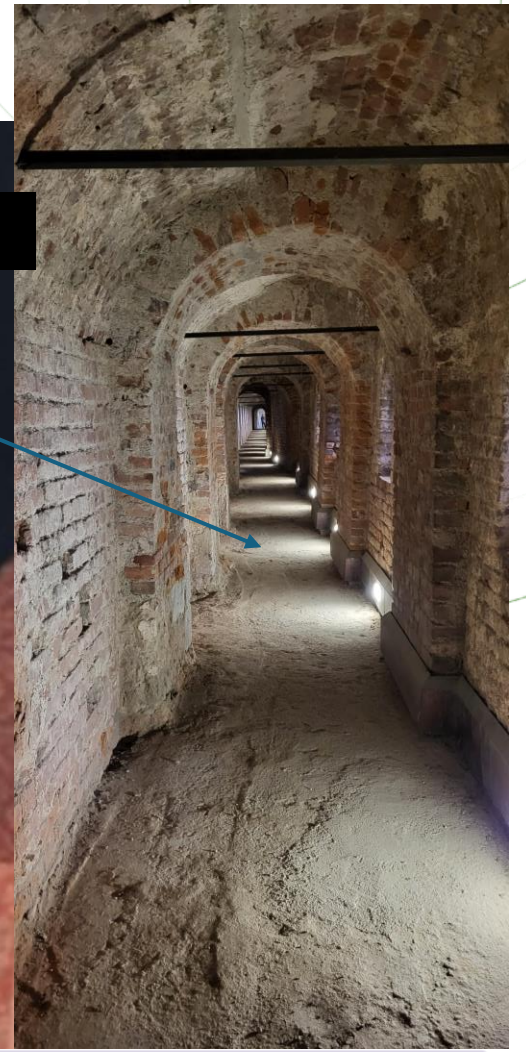




Archeology application

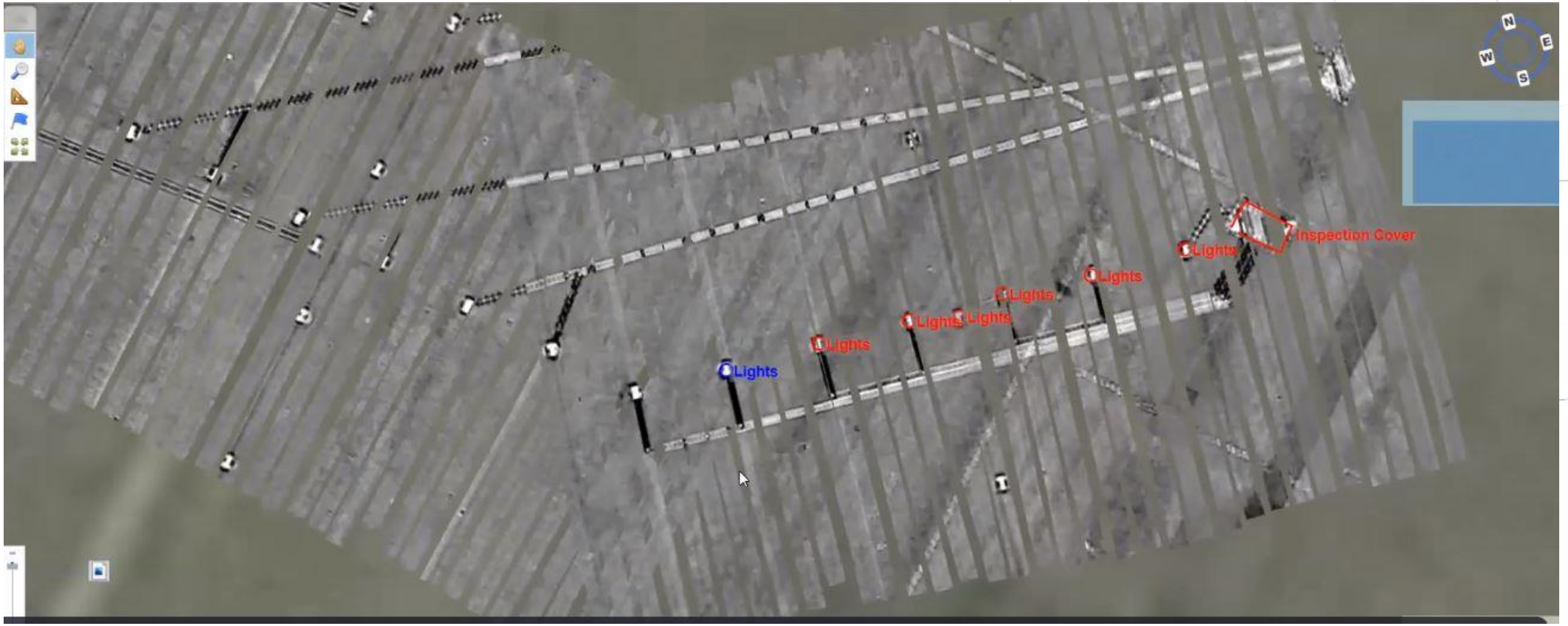
Castello Sforzesco tunnels - Kontur GPR Ground coupled 1820

Archeology application

Castello Sforzesco tunnels - Kontur GPR Ground coupled 1820

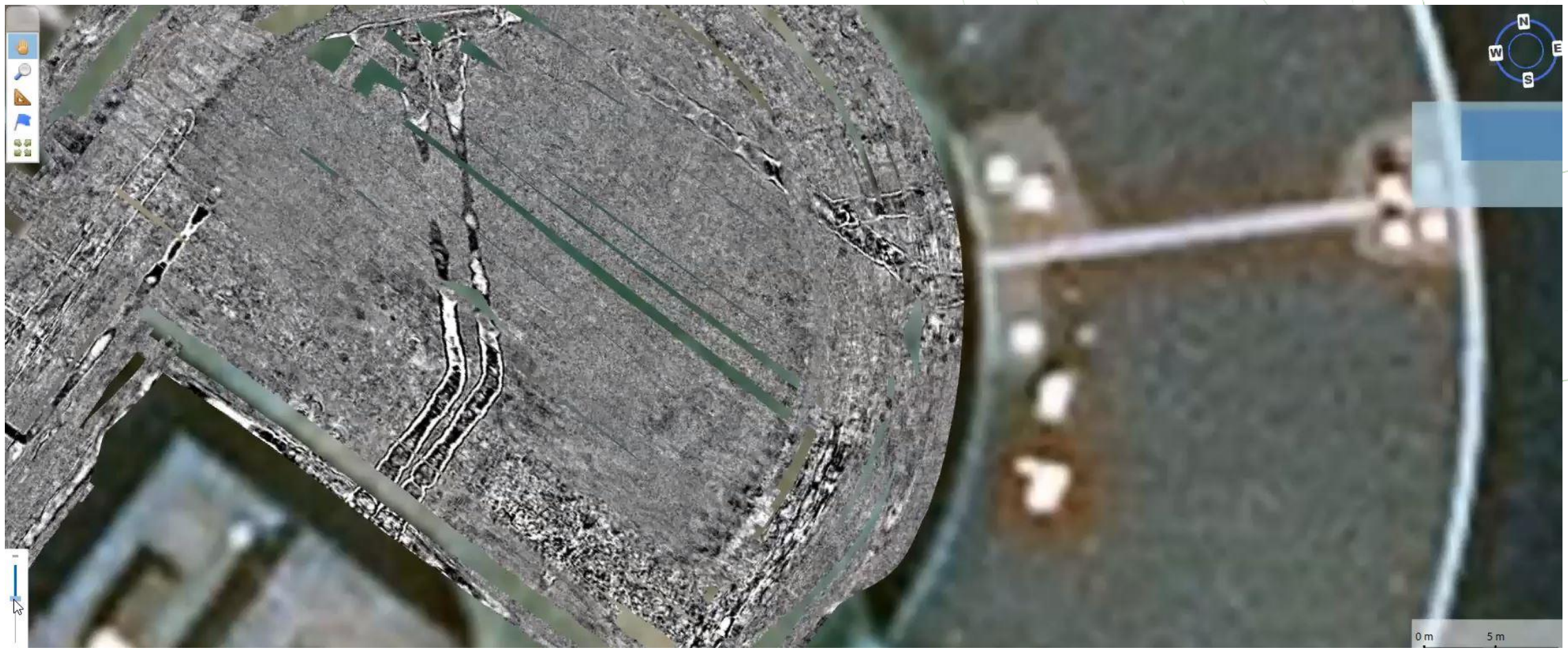
Utility mapping application

Airport - Kontur GPR Ground coupled 1820



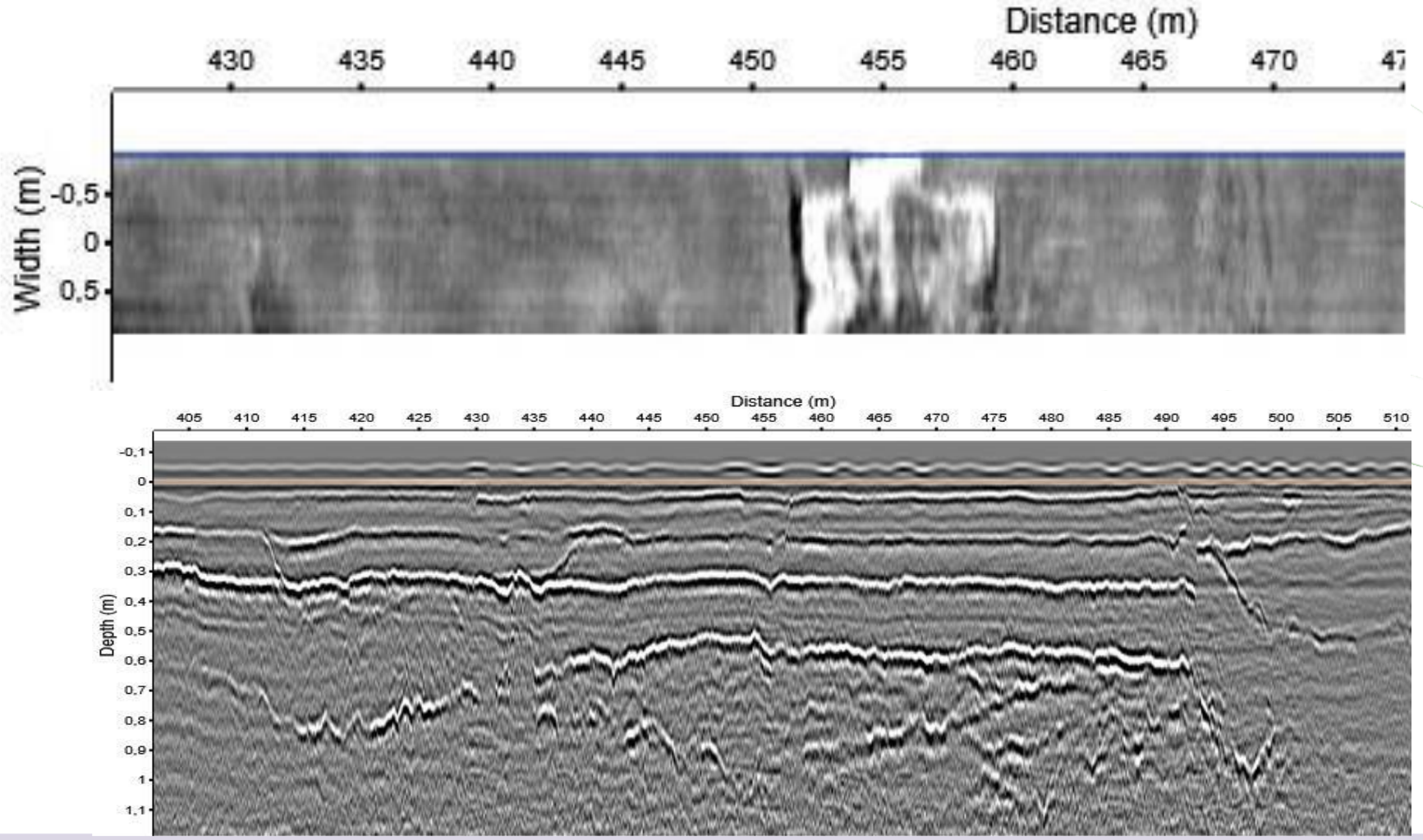
Utility mapping application

France - Kontur GPR Ground coupled 1820



Pavement application

Italian highways A1 - Kontur GPR Air coupled 2125

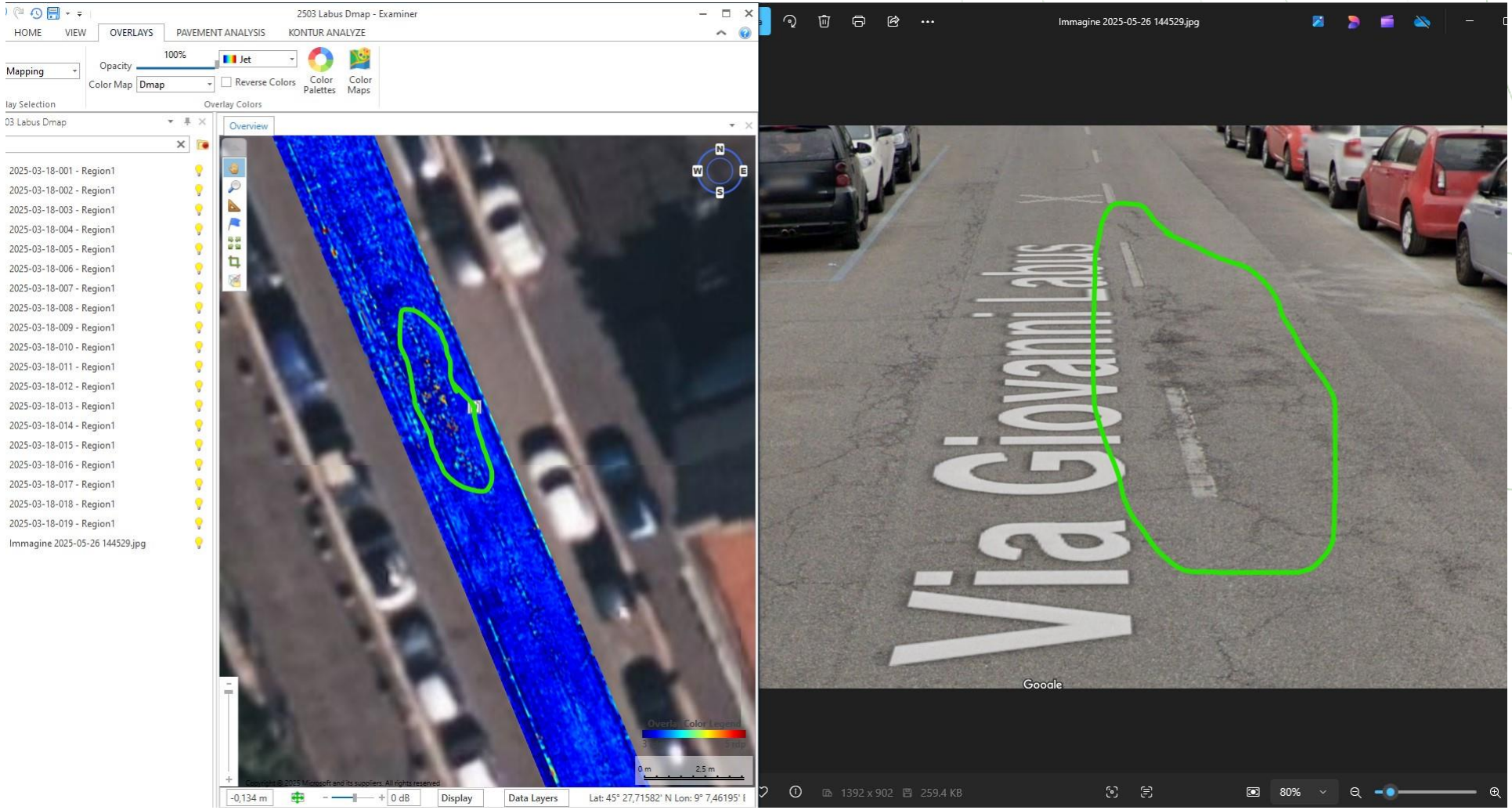


Pavement application – dielectric mapping

Urban road, Milano - Kontur GPR Air coupled 1820

Pavement application – dielectric mapping

Urban road, Milano - Kontur GPR Air coupled 1820

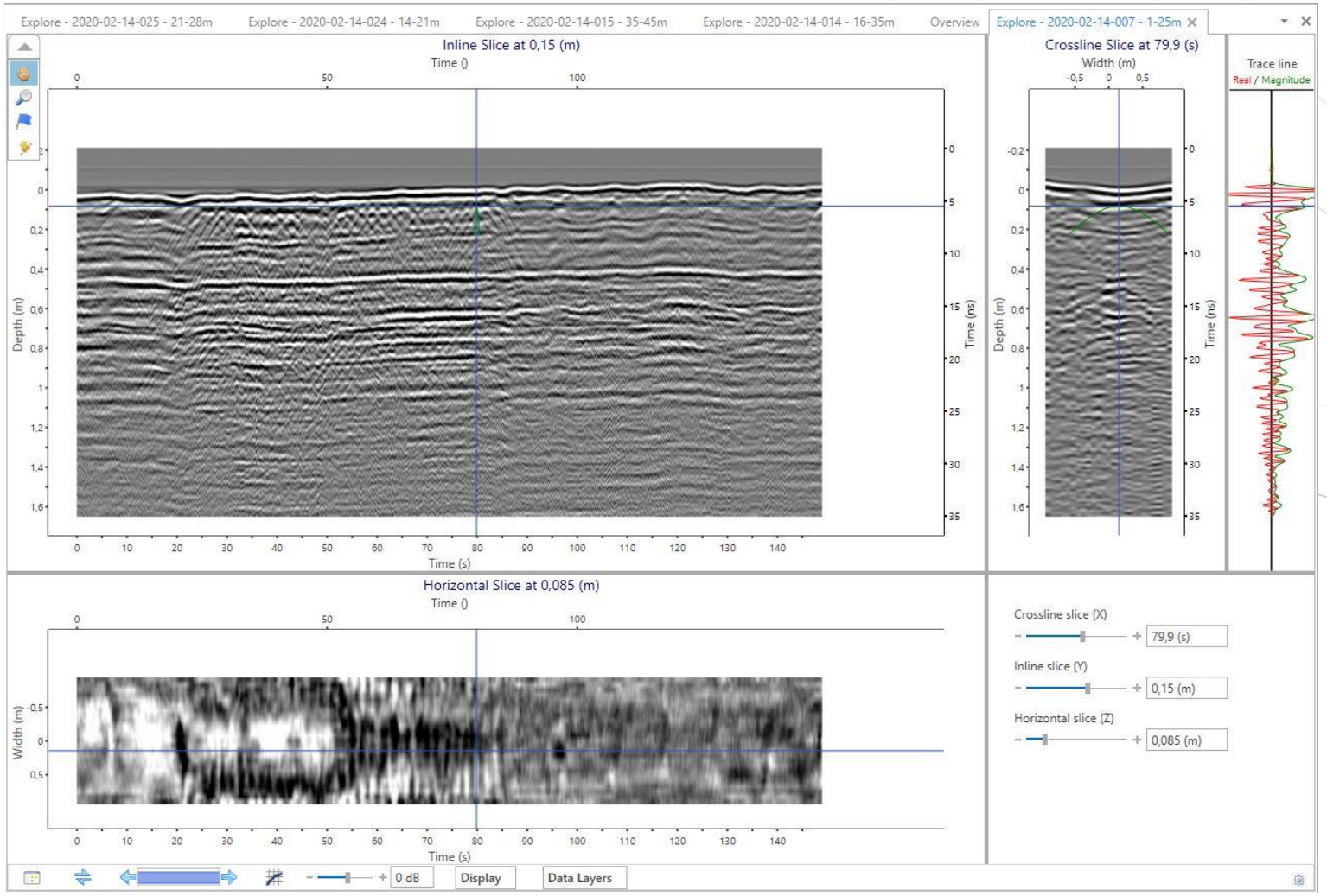


Tunnel application – dielectric mapping

- Galleria Coronata, Genova – Kontur GPR air coupled 2125

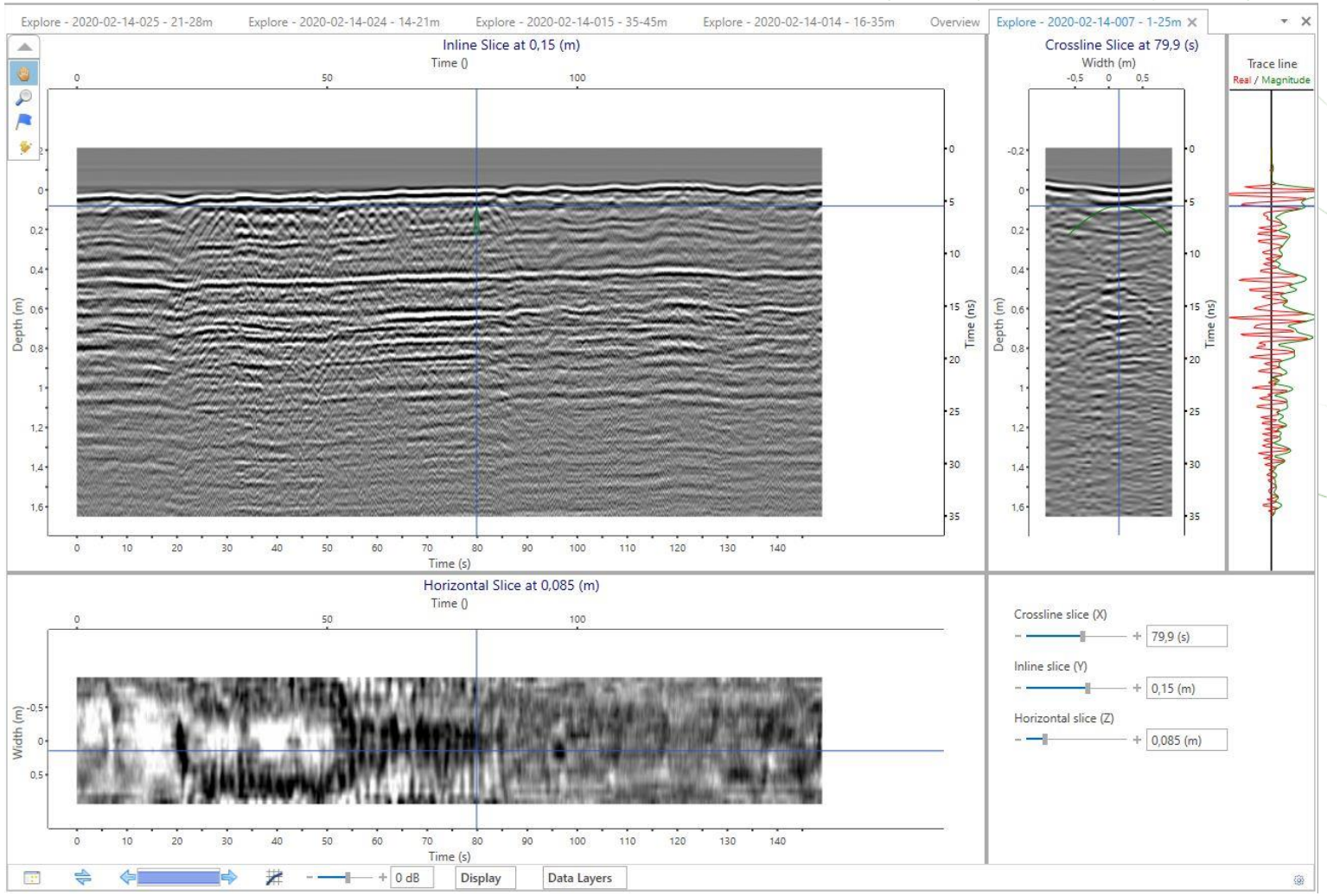
Tunnel application – dielectric mapping

Galleria Coronata, Genova – Kontur GPR air coupled 2125



Tunnel application – dielectric mapping

Galleria Coronata, Genova – Kontur GPR air coupled 2125

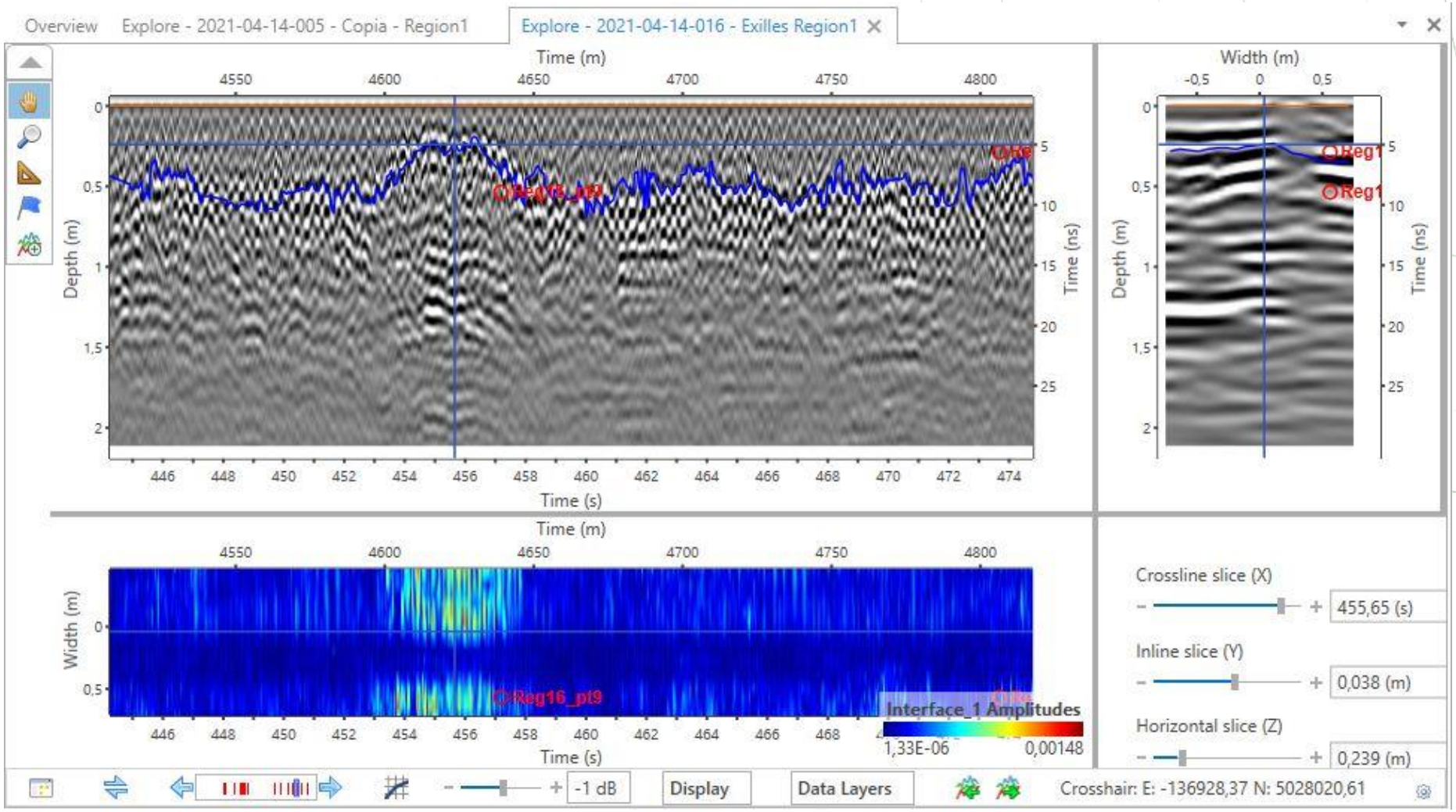


Railway application

Piemonte – Kontur GPR ground coupled 1820 + MX9 Trimble Lidar

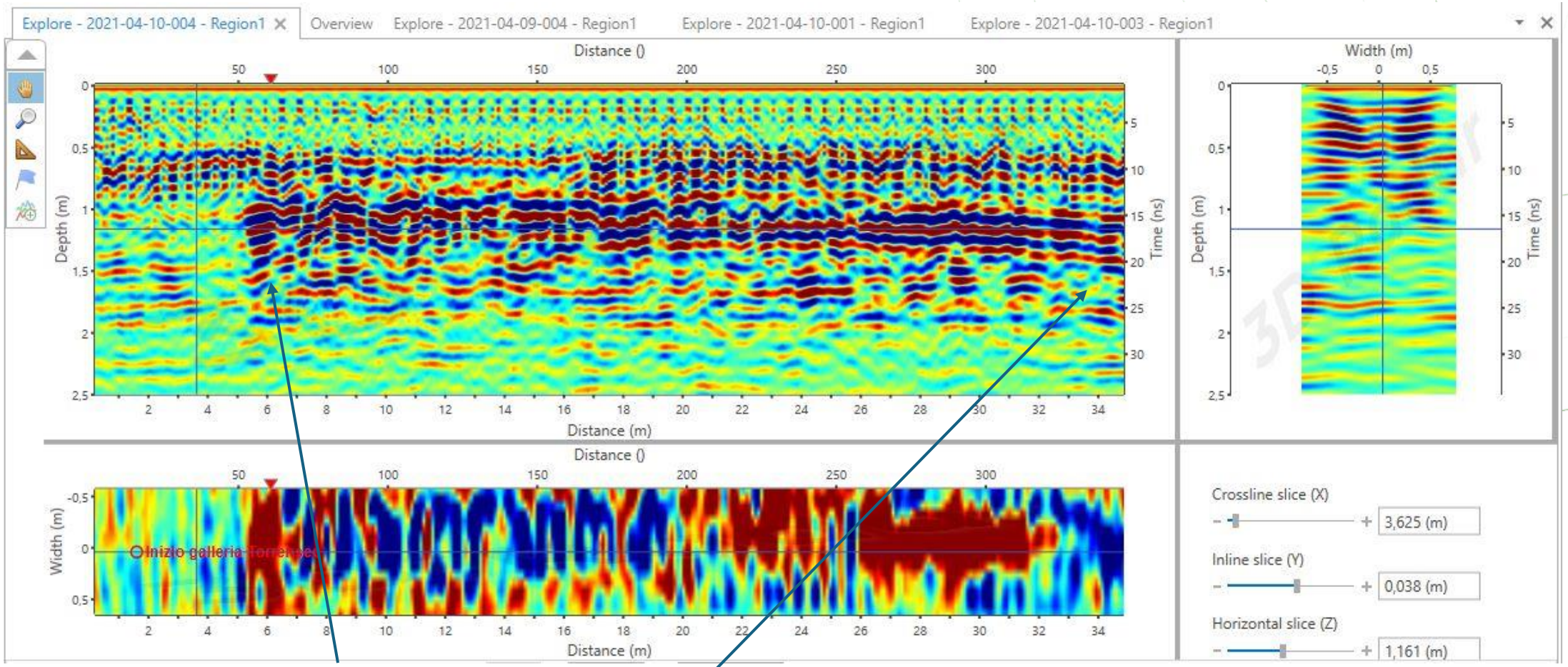
Railway application

Piemonte – Kontur GPR ground coupled 1820 + MX9 Trimble Lidar



Railway application

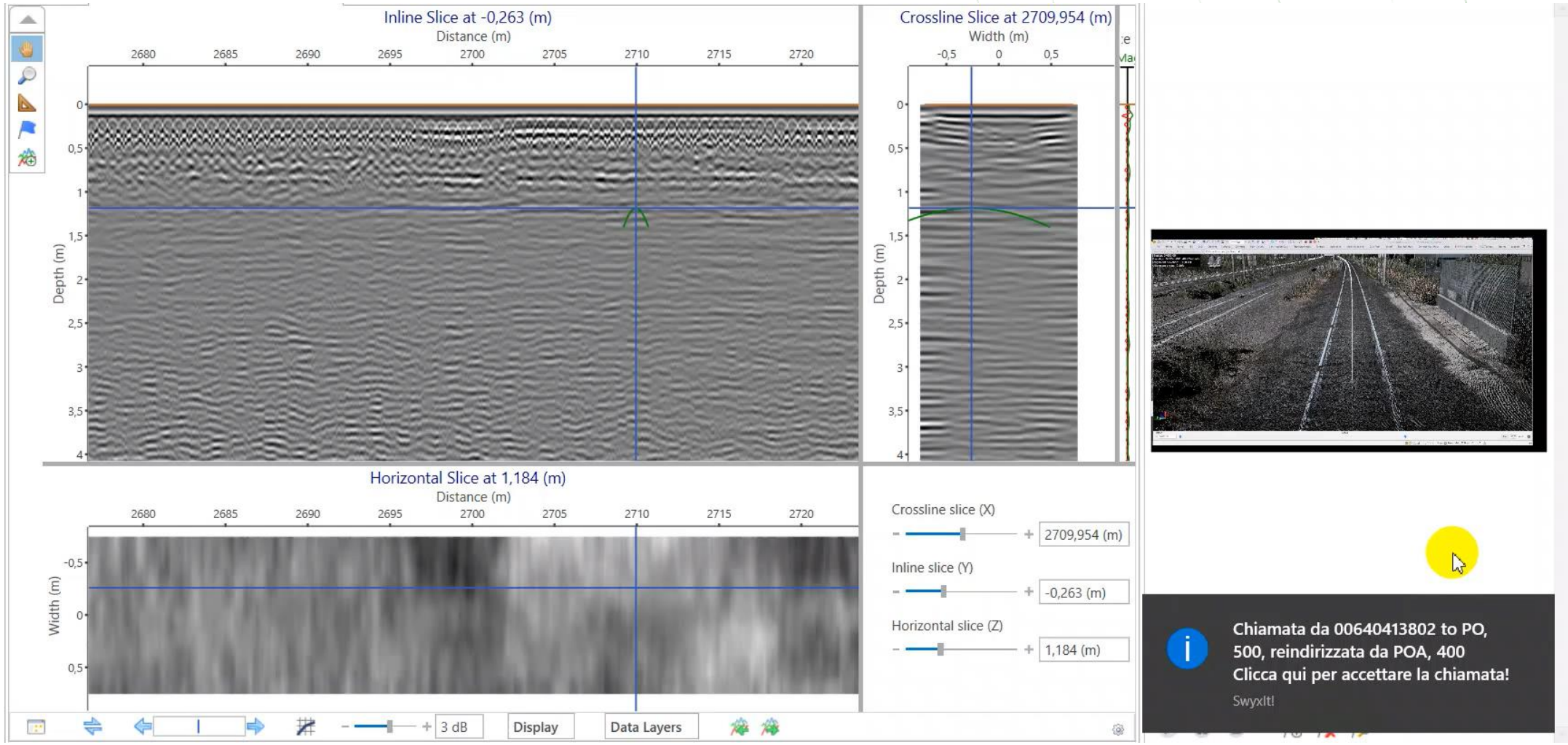
Piemonte – Kontur GPR ground coupled 1820 + MX9 Trimble Lidar



Reverse arch of tunnel

Railway application

Piemonte – Kontur GPR ground coupled 1820 + MX9 Trimble Lidar



Railway application

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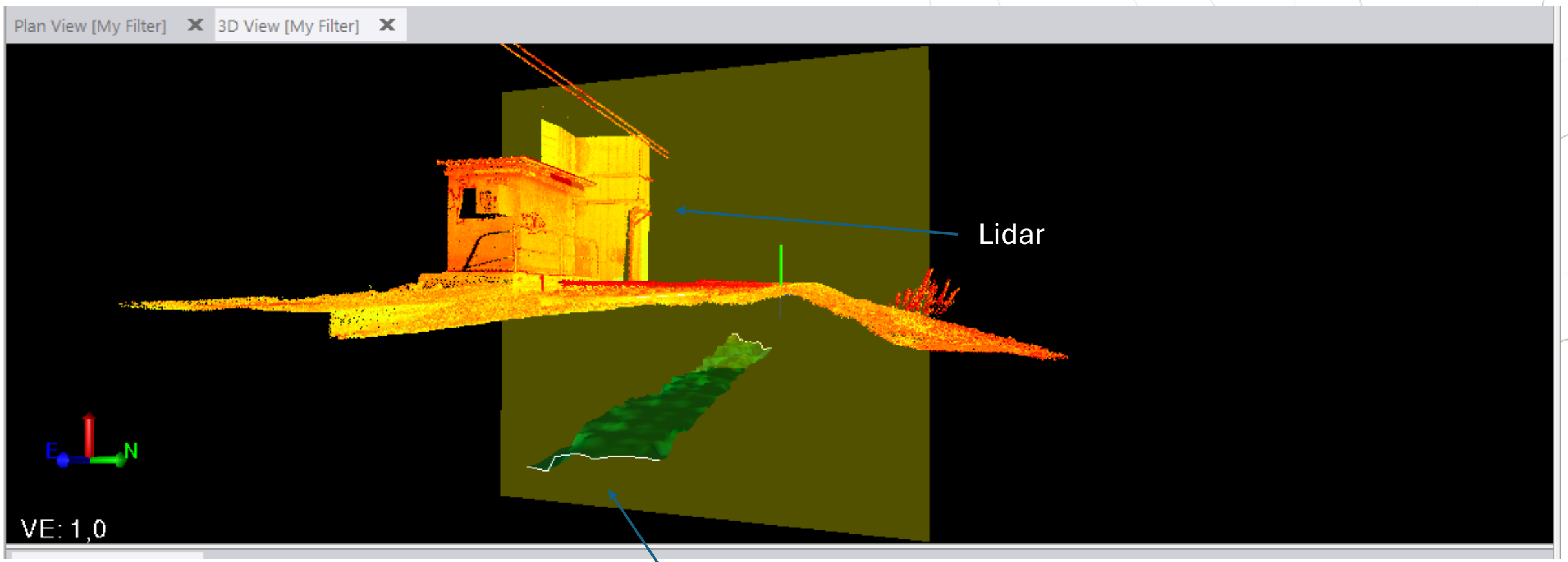
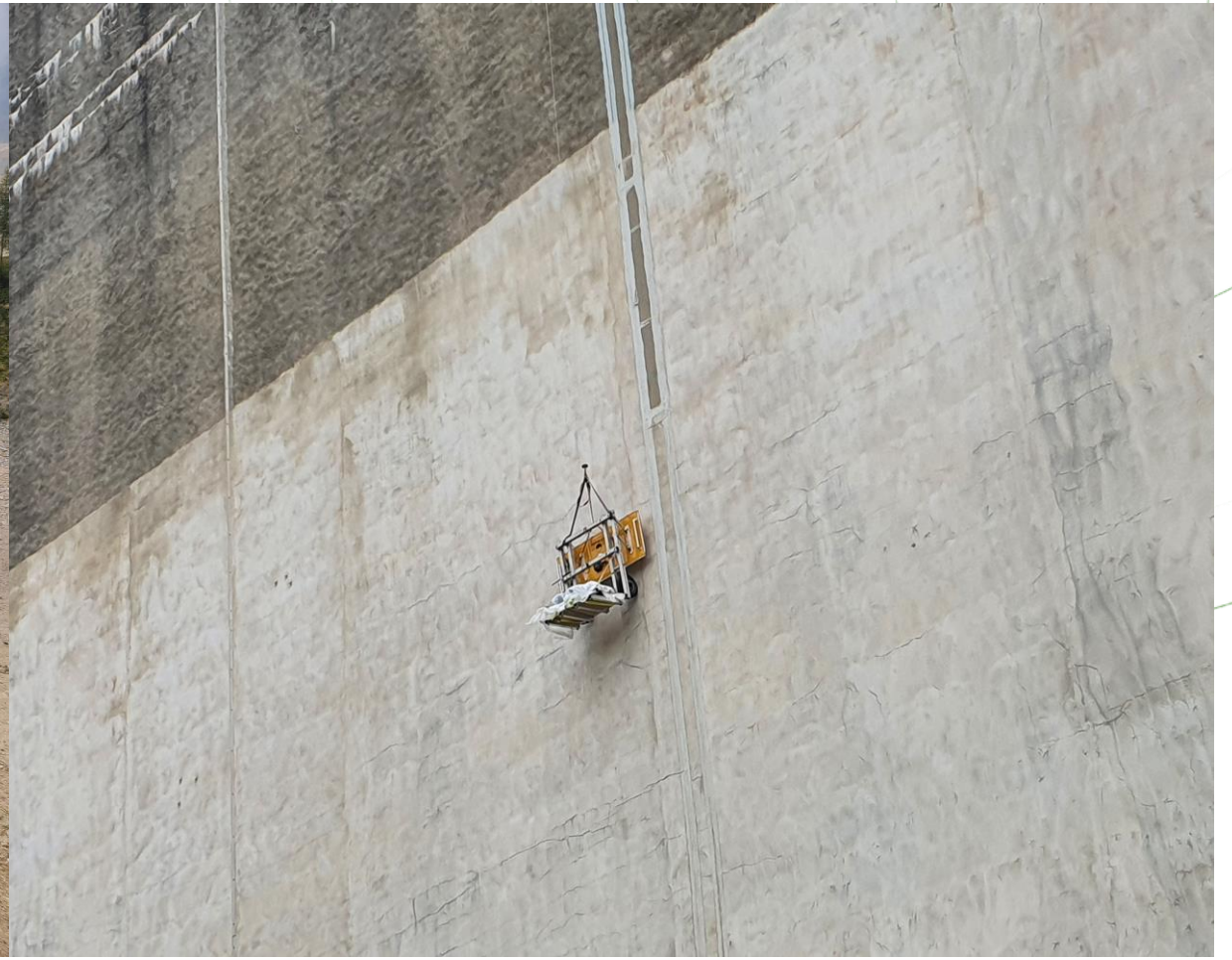


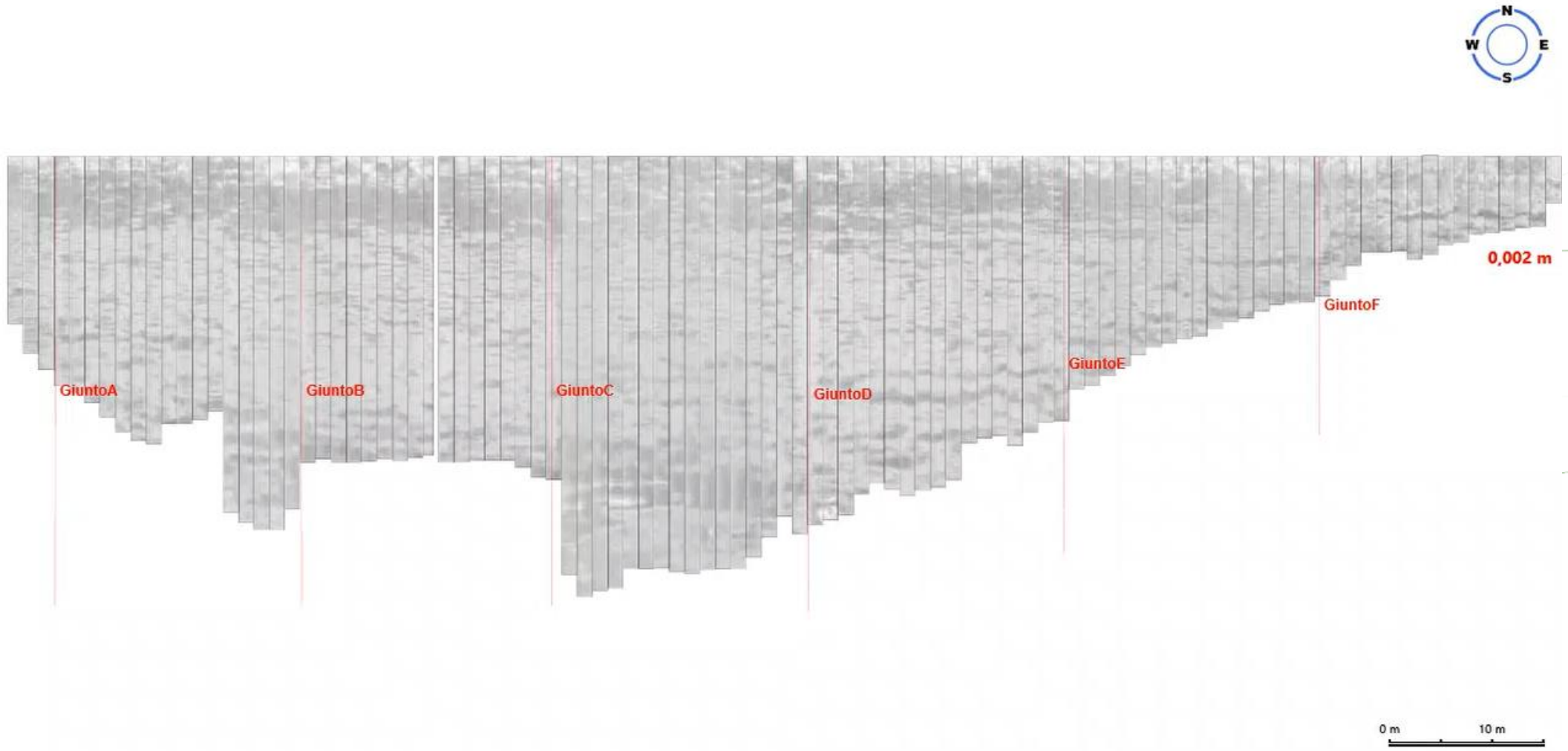
Dam wall application

Italy – Kontur GPR ground coupled 1820



Dam wall application

Italy – Kontur GPR ground coupled 1820

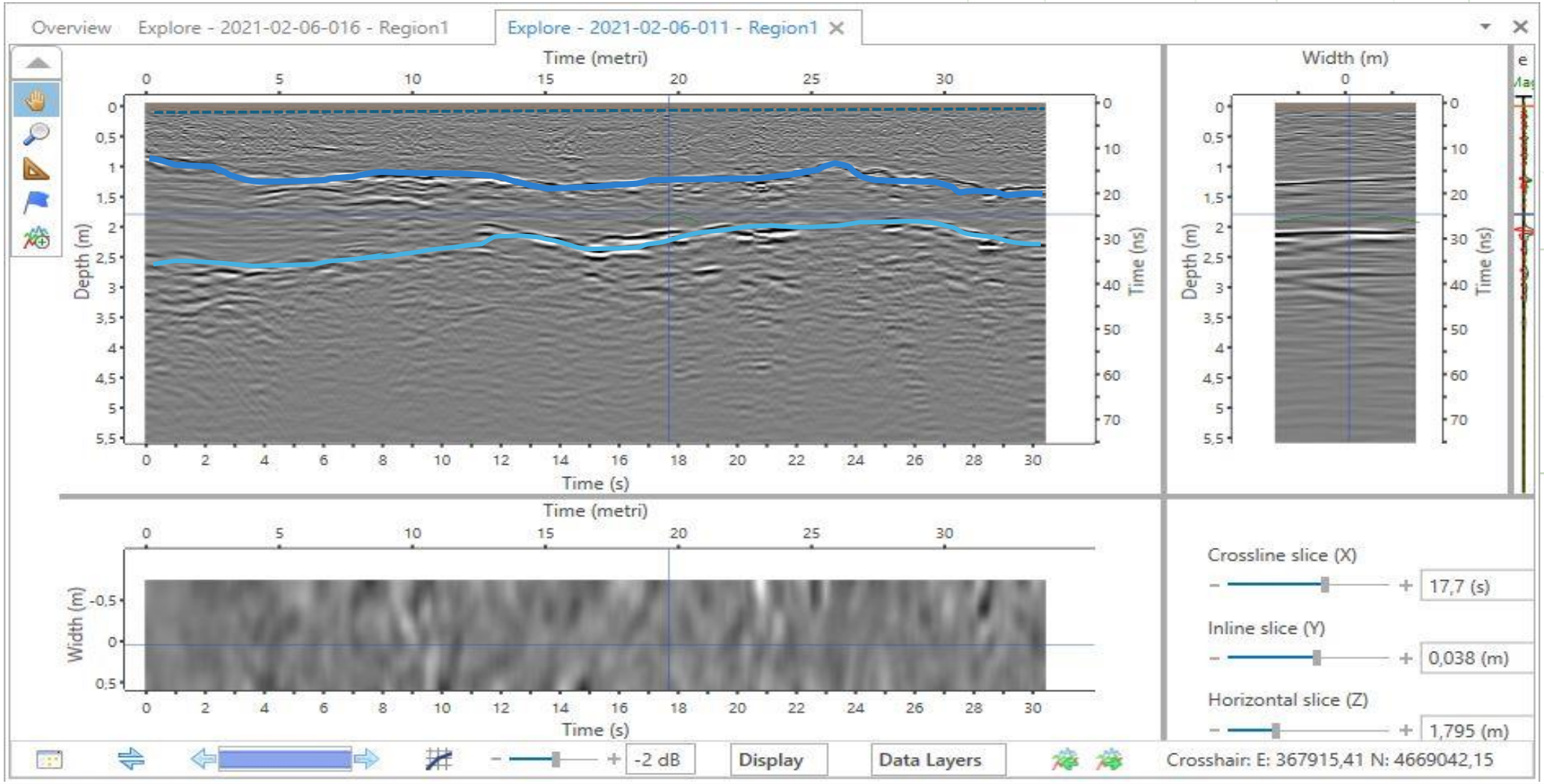


Search&Rescue application

Monte Velino – Kontur GPR ground coupled 1820

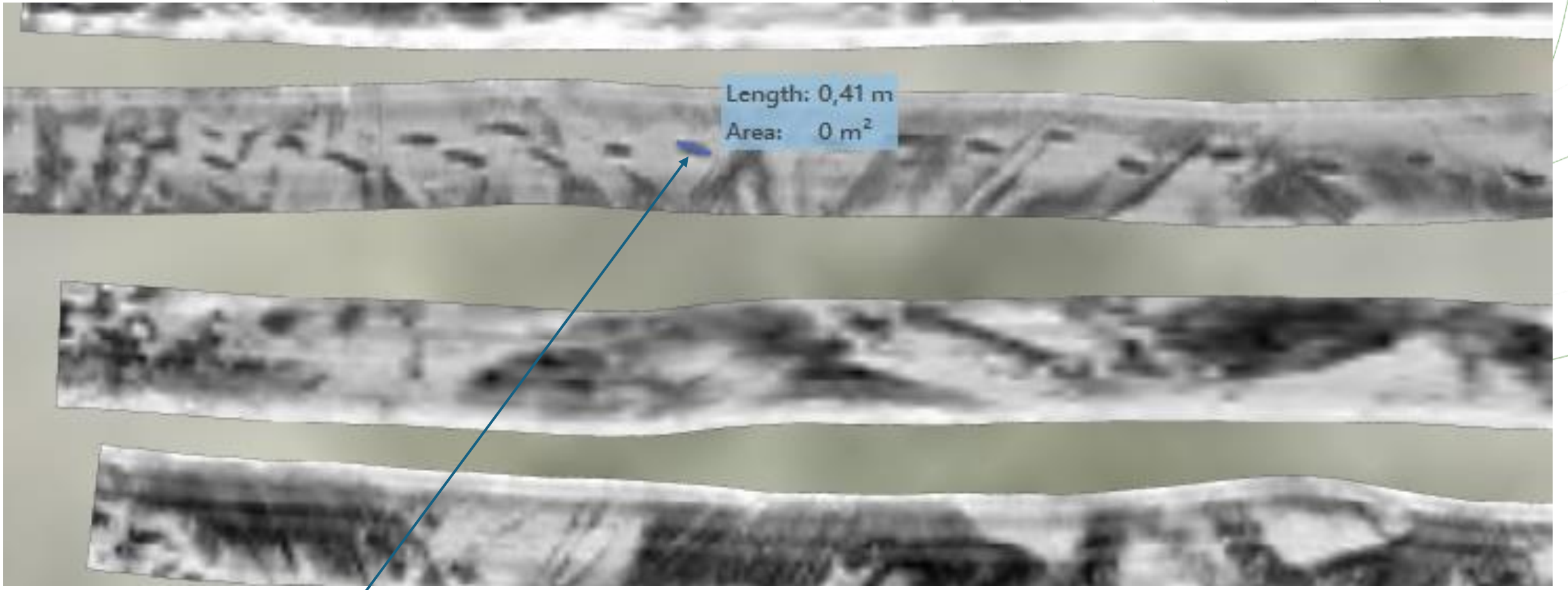
Search&Rescue application

Monte Velino – Kontur GPR ground coupled 1820



Search&Rescue application

Monte Velino – Kontur GPR ground coupled 1820



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THANKS!

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