

Time-lapse ERT monitoring of hydrogeological risks

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TECH-LEVEE WATCH

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grant N. 2016-0785*

Fondazione
CARIPLO



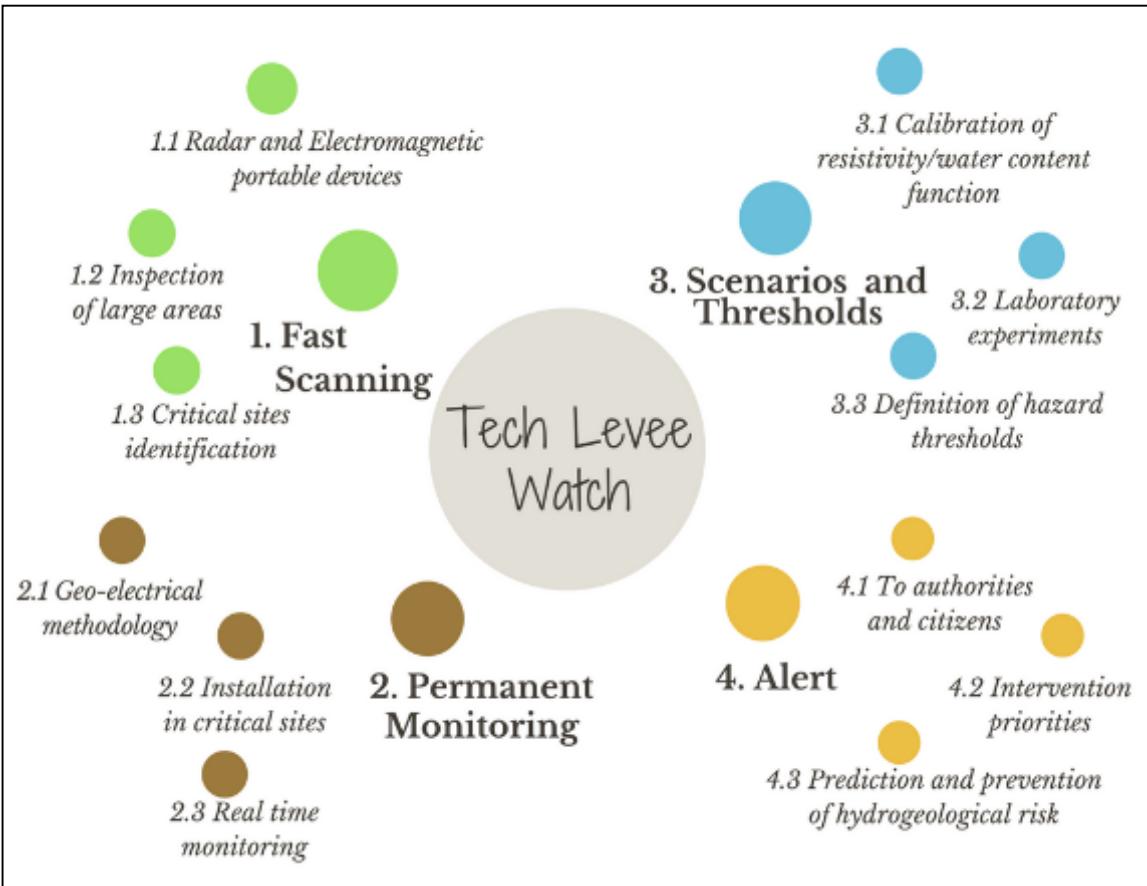
DILEMMA

*Funded by Ministero dell'Ambiente e
della Tutela del Territorio e del Mare*



MINISTERO DELL'AMBIENTE
E DELLA TUTELA DEL TERRITORIO E DEL MARE

Hydrogeological risks



1st MONITORING SITE

San Giacomo delle Segnate (MN)

**CONSORZIO di BONIFICA
TERRE DEI GONZAGA
IN DESTRA PO**



Via Marconi



Via Dugale

Installation of the system



San Giacomo – 15/9/2015

Control measurements

CONSORZIO di BONIFICA
TERRE DEI GONZAGA
IN DESTRA PO

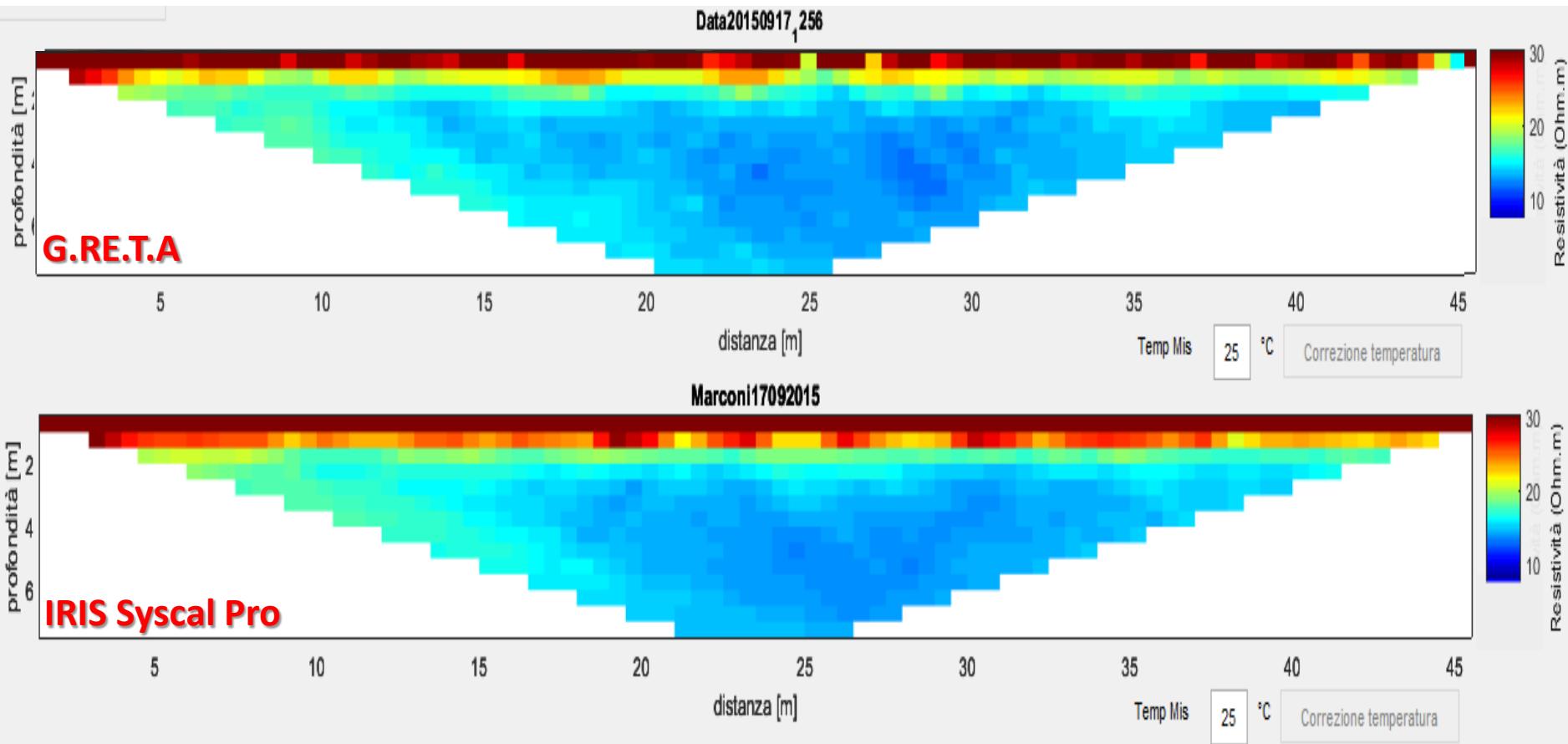


San Giacomo – 8/8/2016



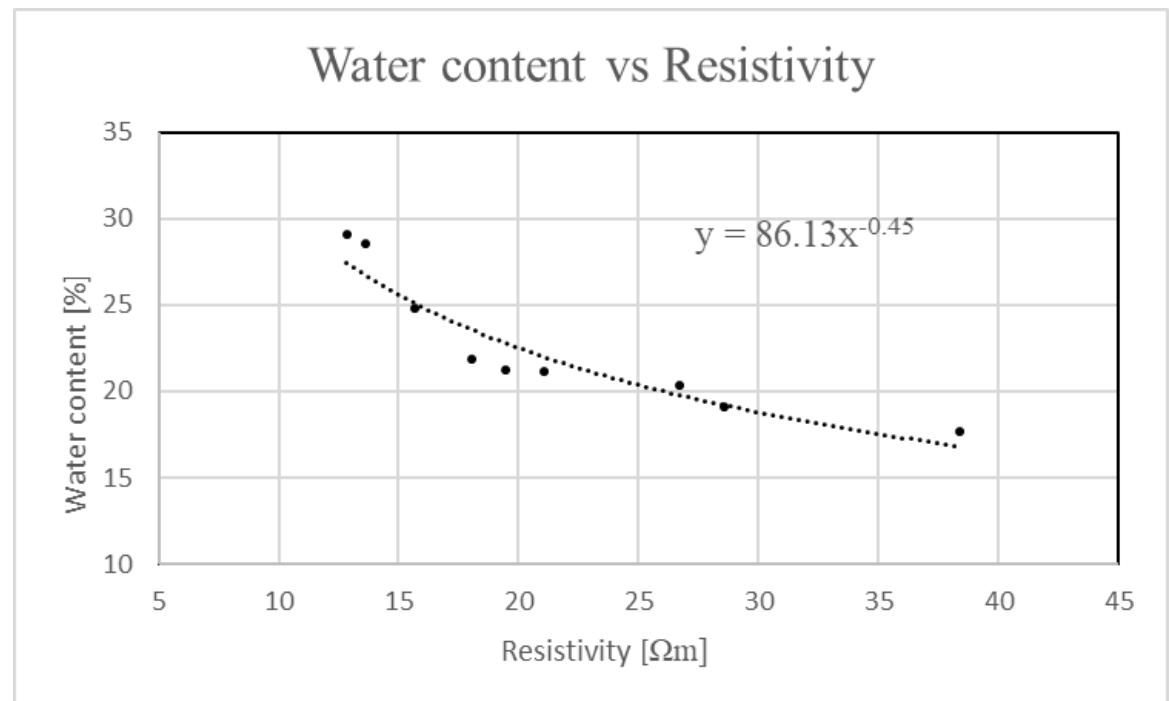
Control measurements

CONSORZIO di BONIFICA
TERRE DEI GONZAGA
IN DESTRA PO



Water content maps

CONSORZIO di BONIFICA
TERRE DEI GONZAGA
IN DESTRA PO



SELECTING THE 2nd SITE



Site visits

Abbiategrasso
18/5/2017



ERT measurements



Castelletto di Cuggiono – 5/7/2017

ERT measurements

Roll-along measurements
Wenner array, $a=1m$
Total length: 144m



ERT measurements

Roll-along measurements

Wenner array, $a=2m$

Total length: 286m

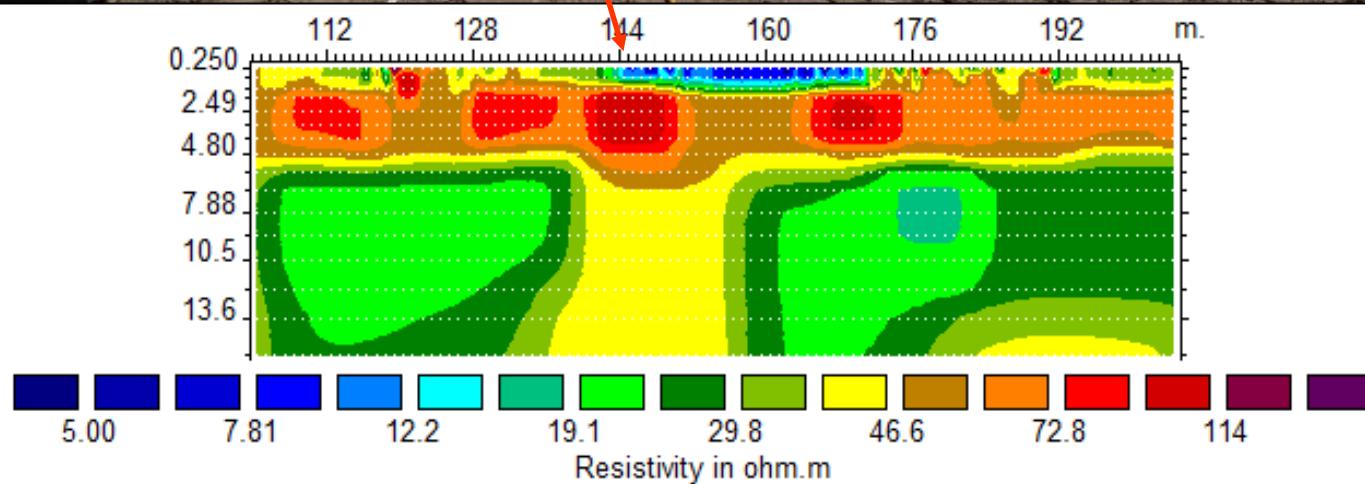
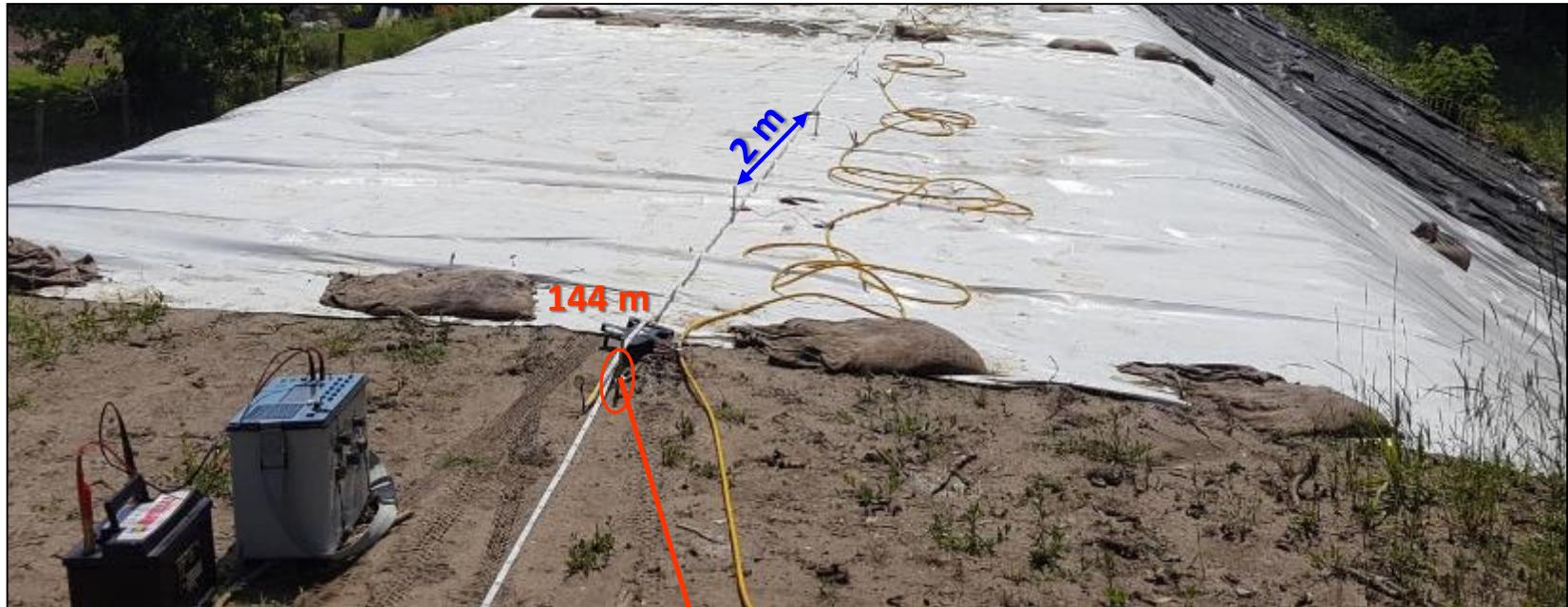


ERT measurements

Colorno – 25/7/2018



Discussing the results



INSTALLATION OF THE SYSTEM

Installation of the system



Colorno (PR)

Installation of the system

Wenner array, $a=2m$, 48 plate electrodes ($20\times20\text{cm}$) buried at 50cm



Installation of the system

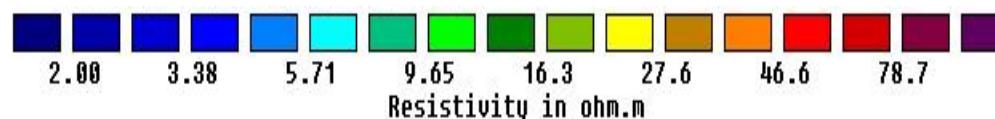
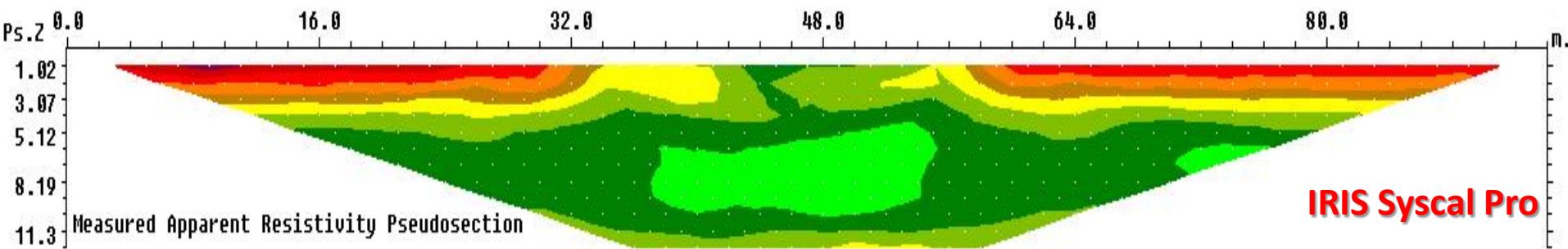
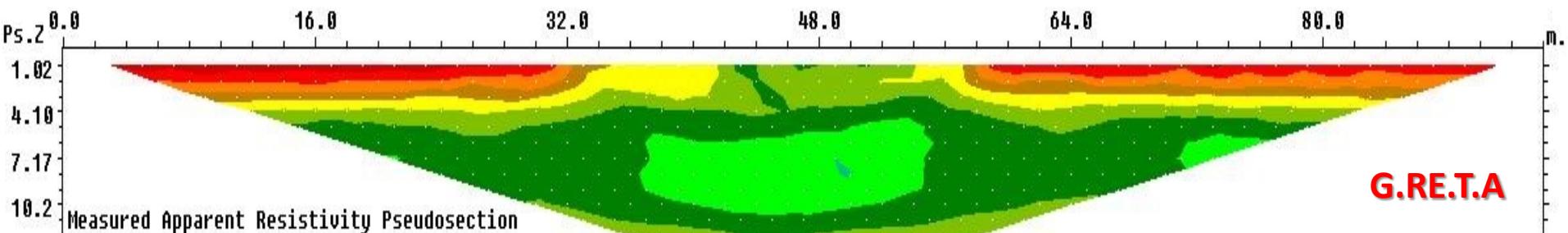


Colorno - 26/11/2018

Control measurements - Colorno



Colorno data_11Dec2018

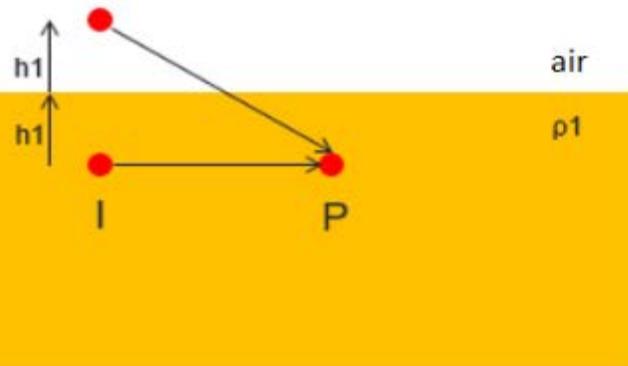


26/11/2018

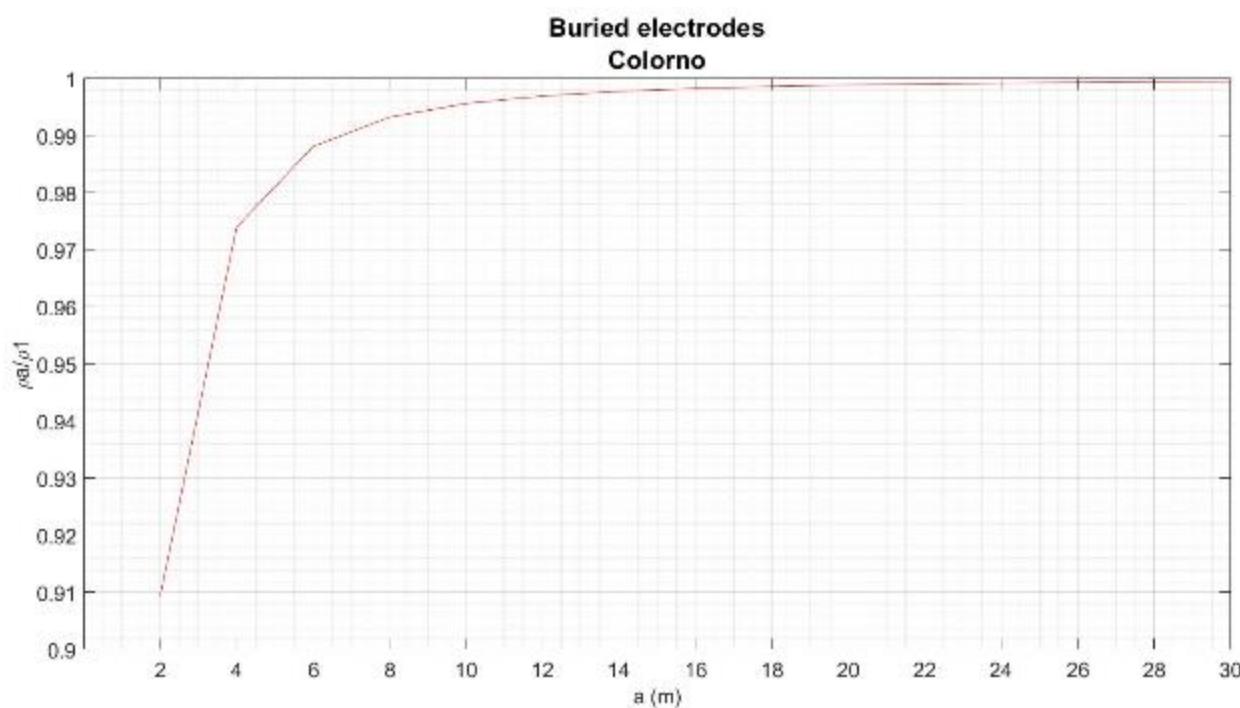
11/12/2018

DATA PROCESSING

Buried electrodes



$$\frac{\rho_{app}}{\rho_1} = \left[\frac{1}{2} + \frac{1}{\sqrt{1 + \left(\frac{2h_1}{a}\right)^2}} - \frac{1}{\sqrt{4 + \left(\frac{2h_1}{a}\right)^2}} \right]$$



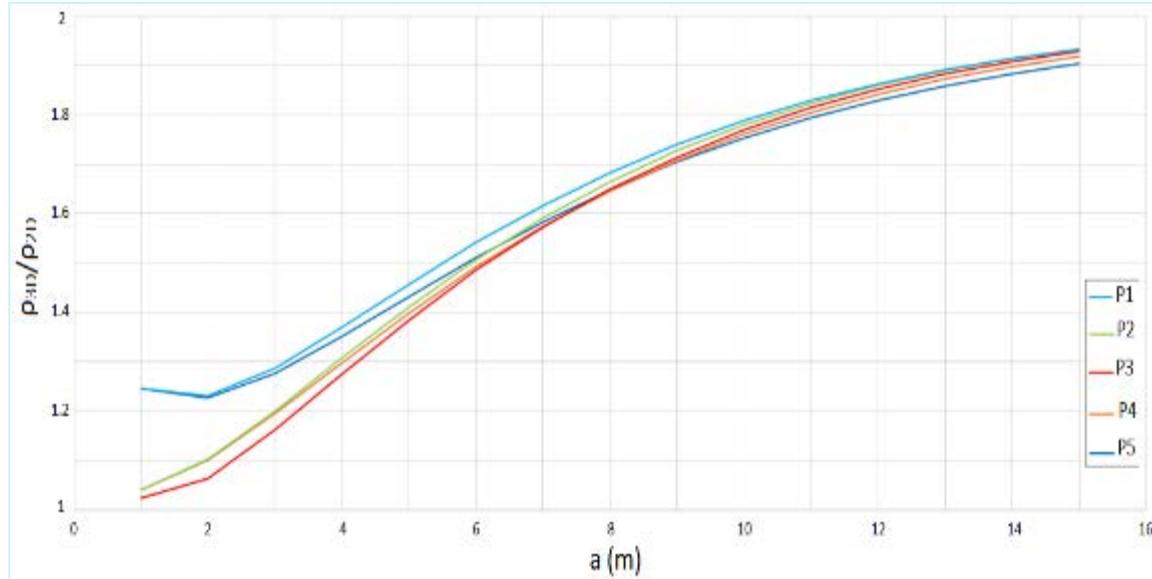
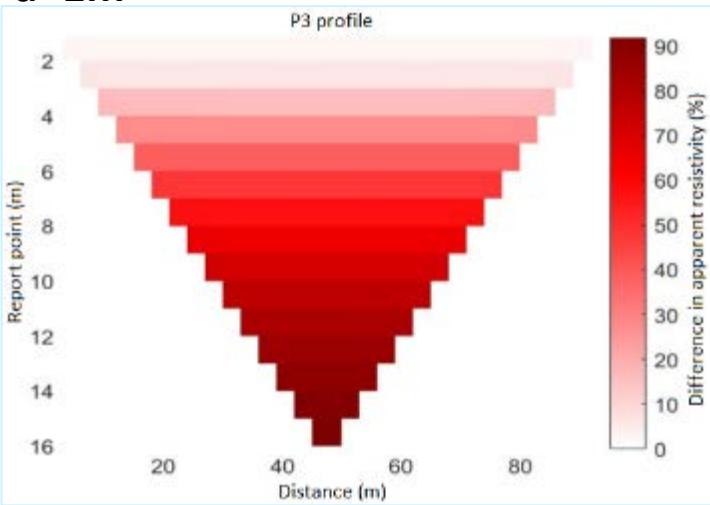
3D effects

For 2D ERT measurements along embankments, the apparent resistivity pseudosections are affected not only by vertical resistivity changes below the ERT profile, but also by lateral resistivity changes perpendicular to the ERT line.

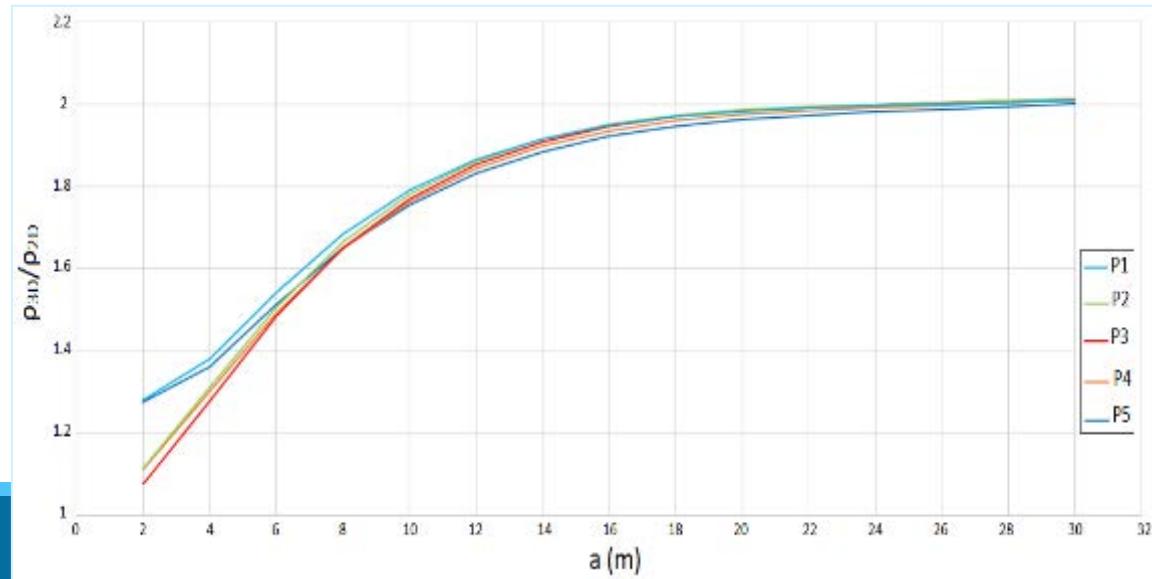
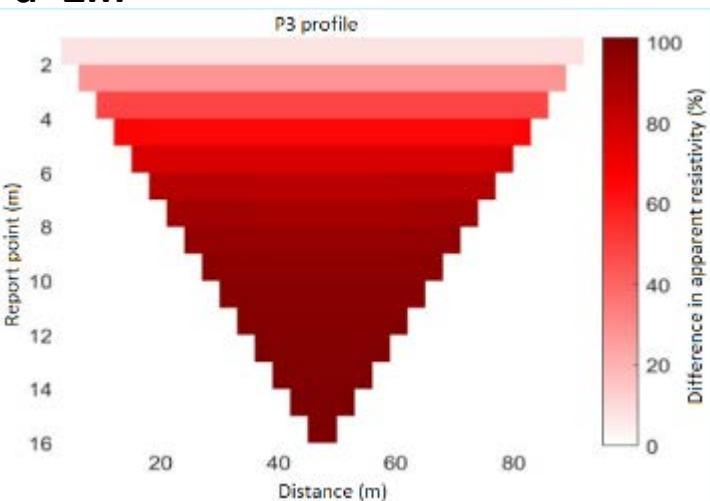


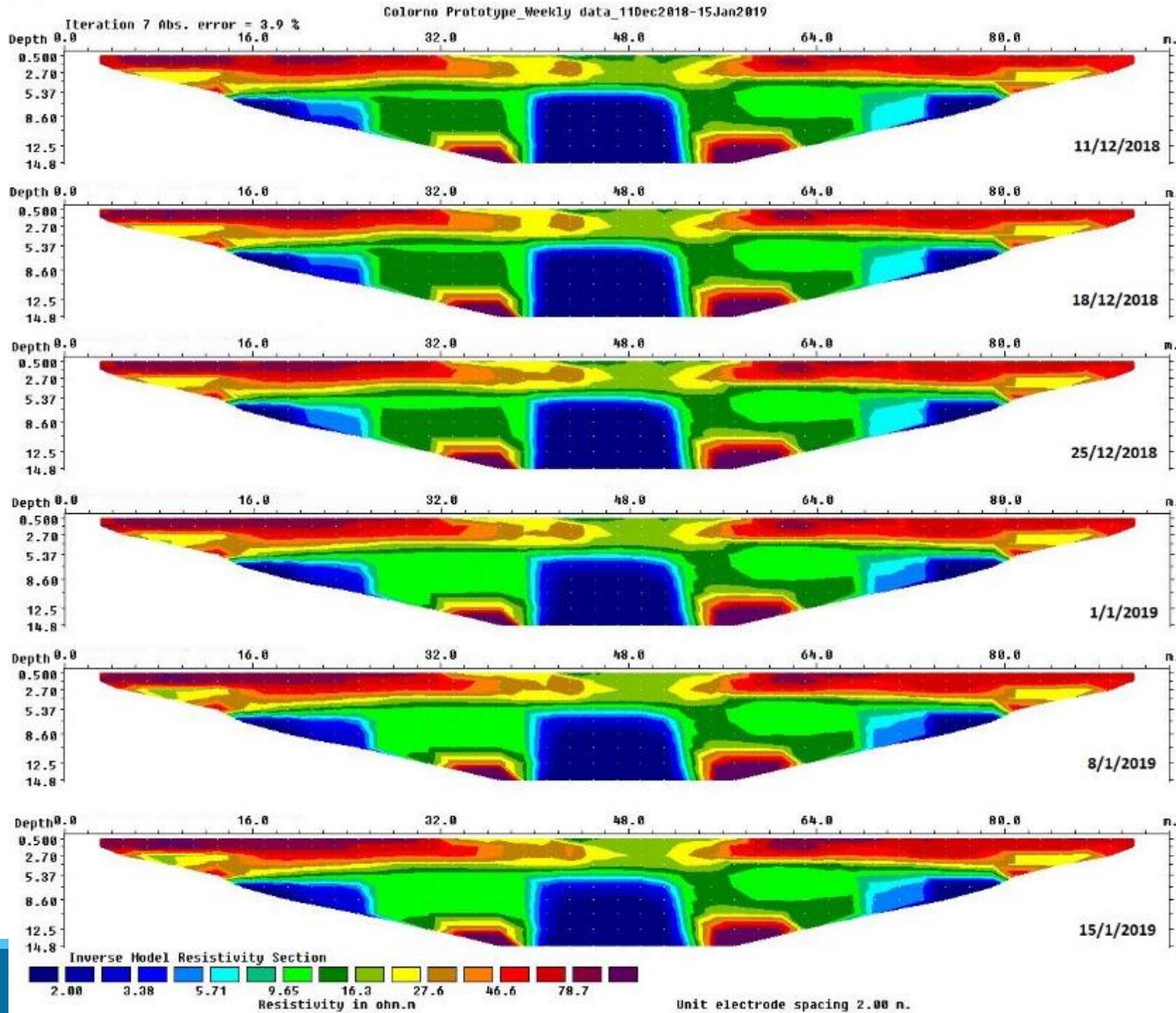
3D effects

$a=1\text{m}$



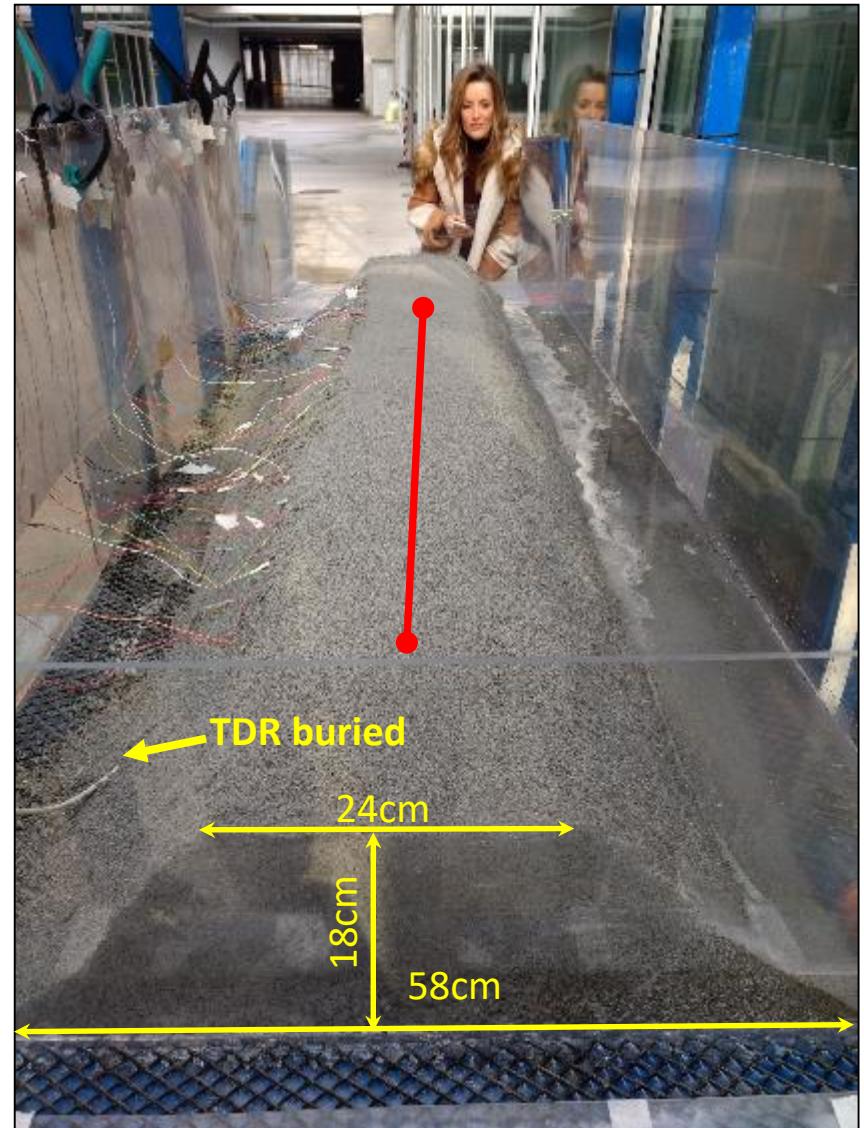
$a=2\text{m}$





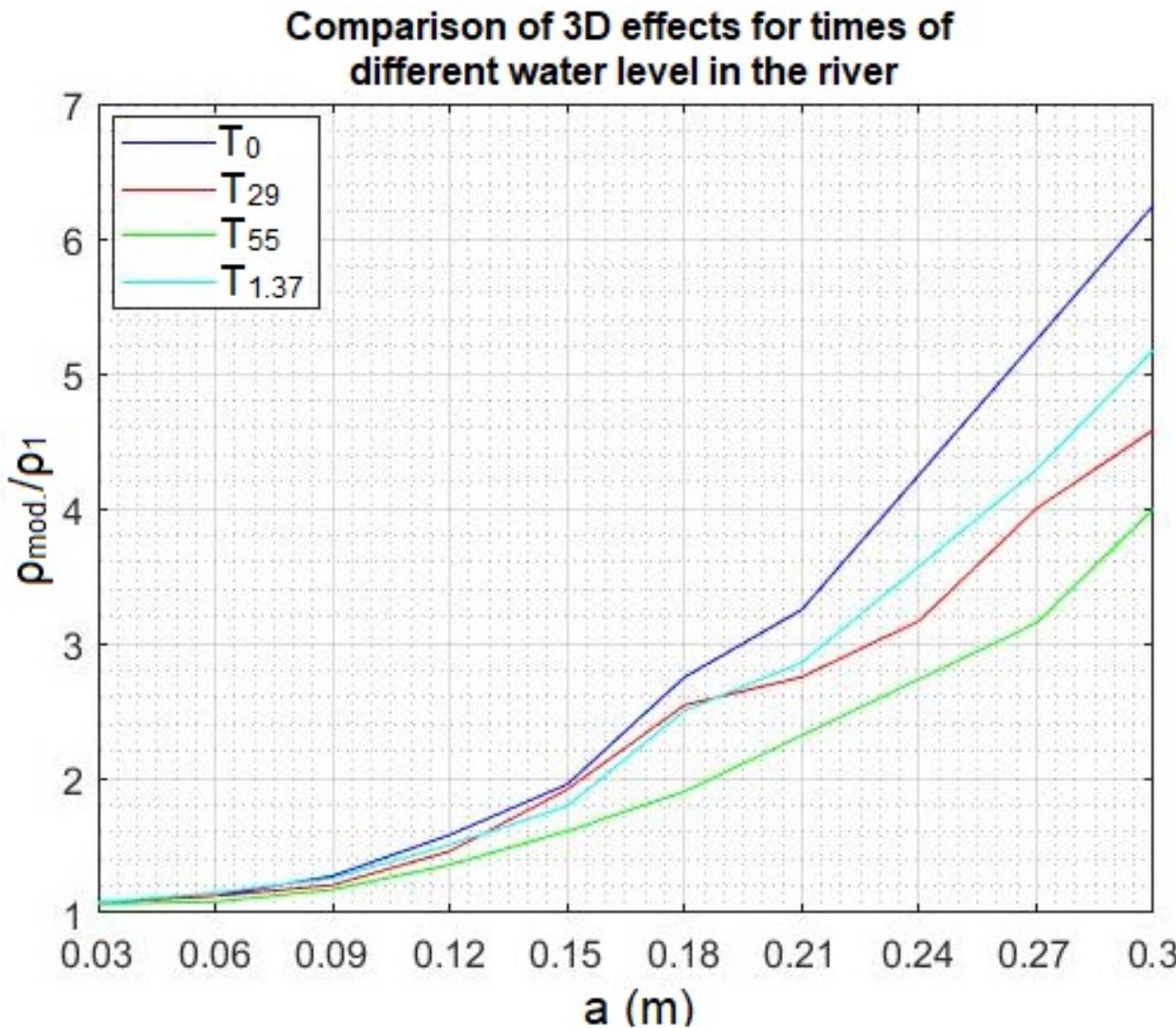
LABORATORY SIMULATIONS

Laboratory simulations (levees)

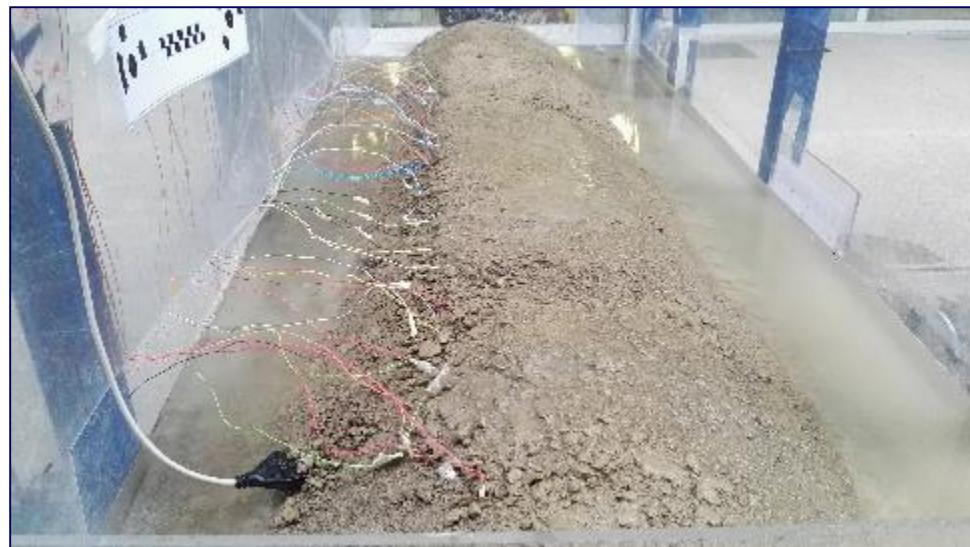


Sand material, simulating different water levels in the canal and various rainfalls

3D effects – Different periods

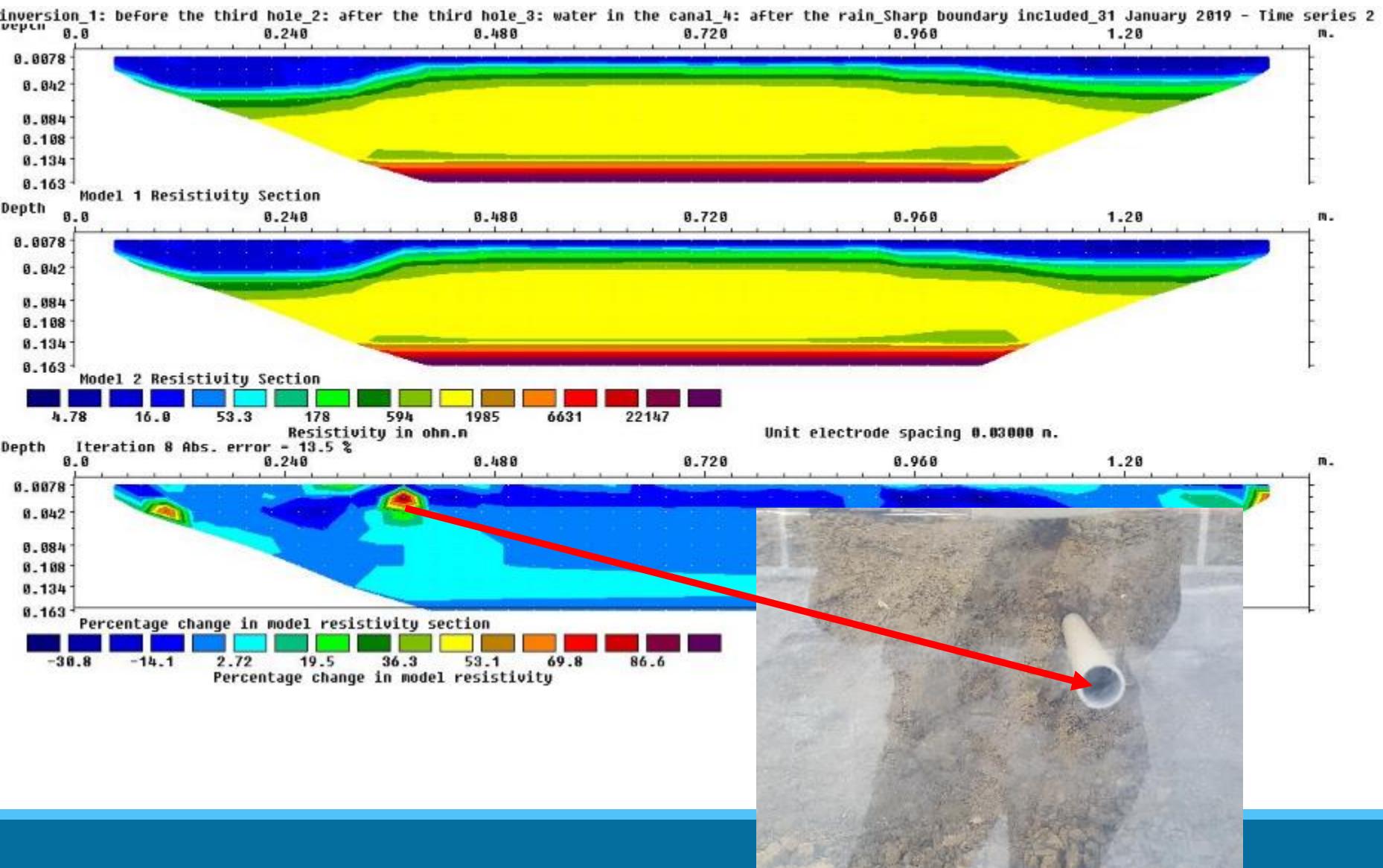


Laboratory simulations (levees)



Soil from the site, simulating different seasons, simulating voids

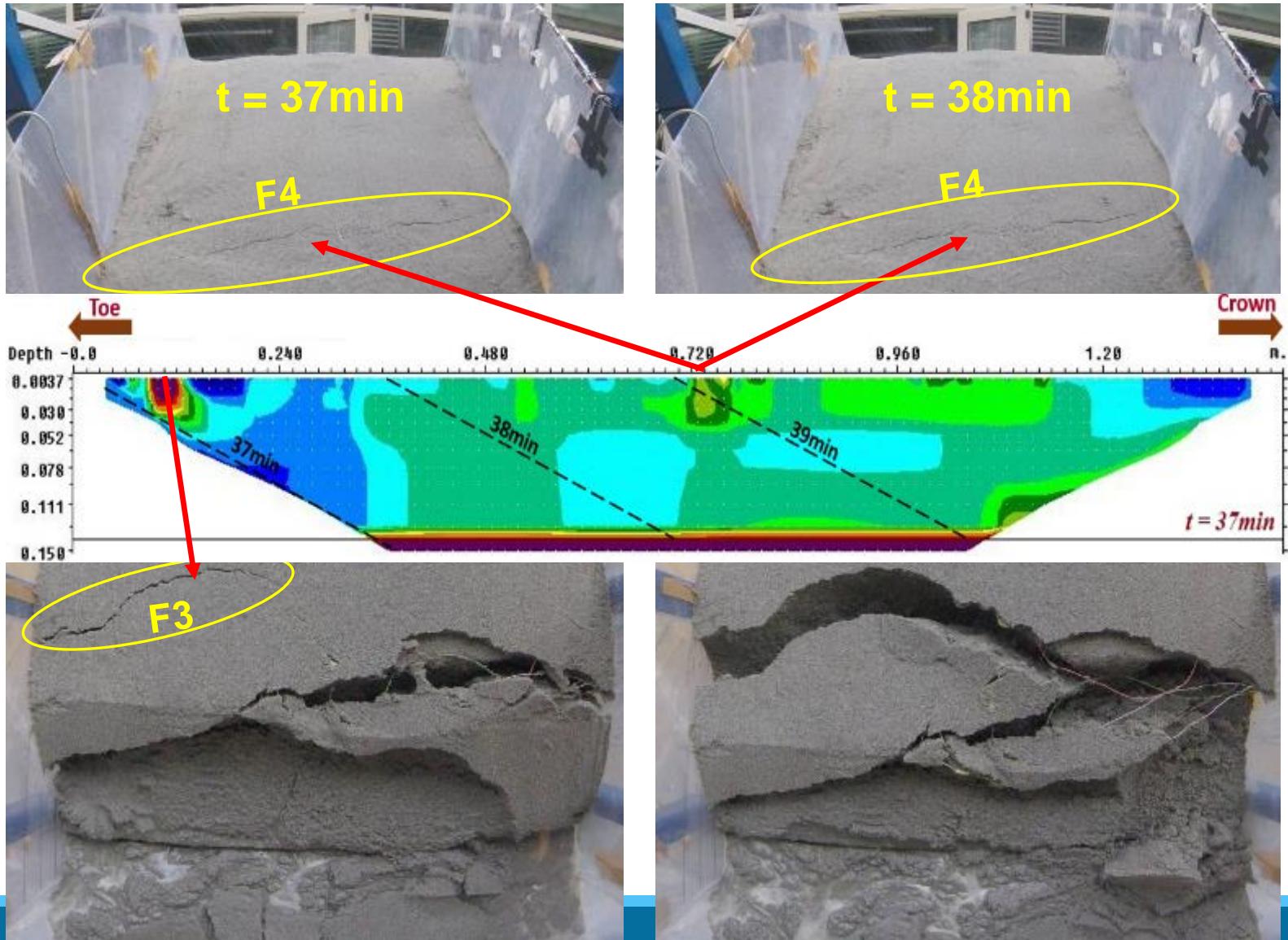
Measured pseudosections



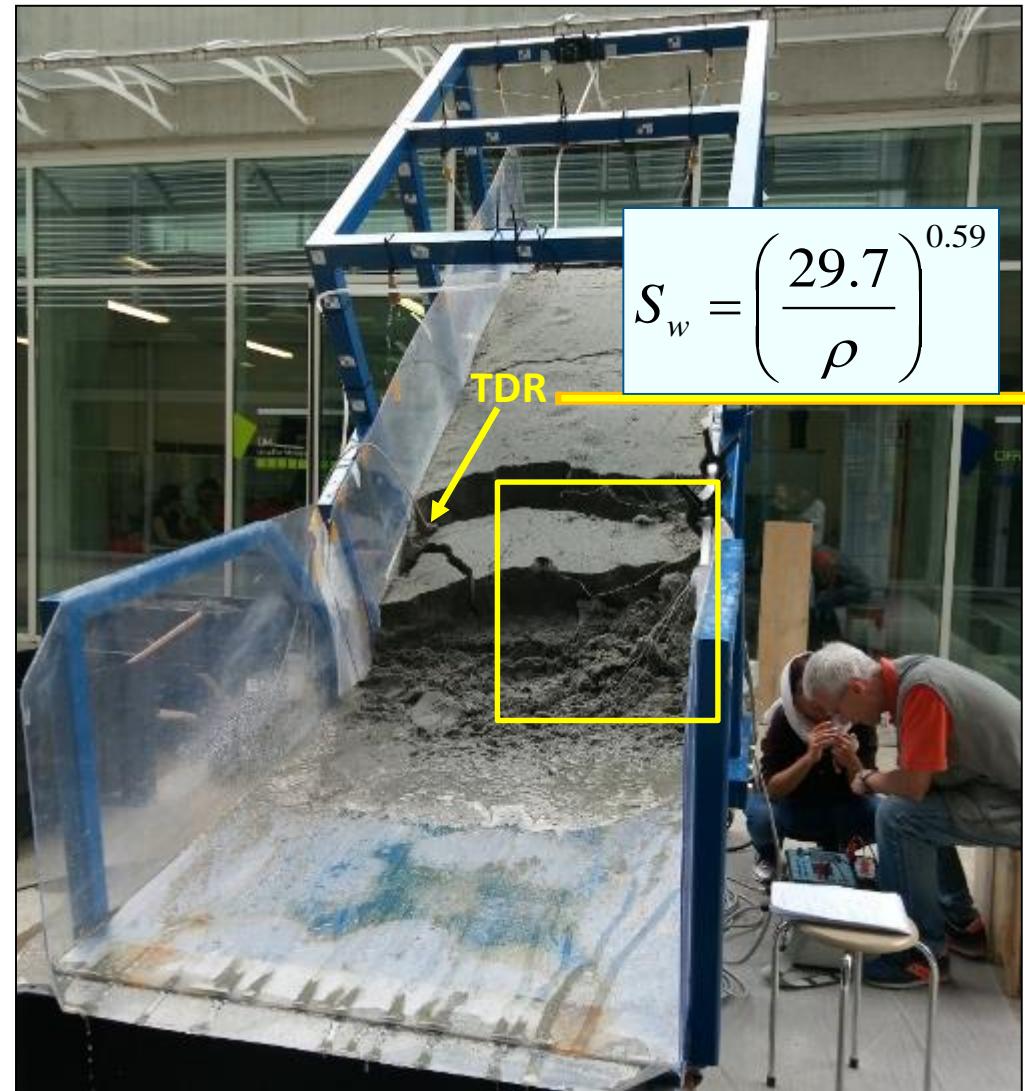
Laboratory experiments (shallow landslides)



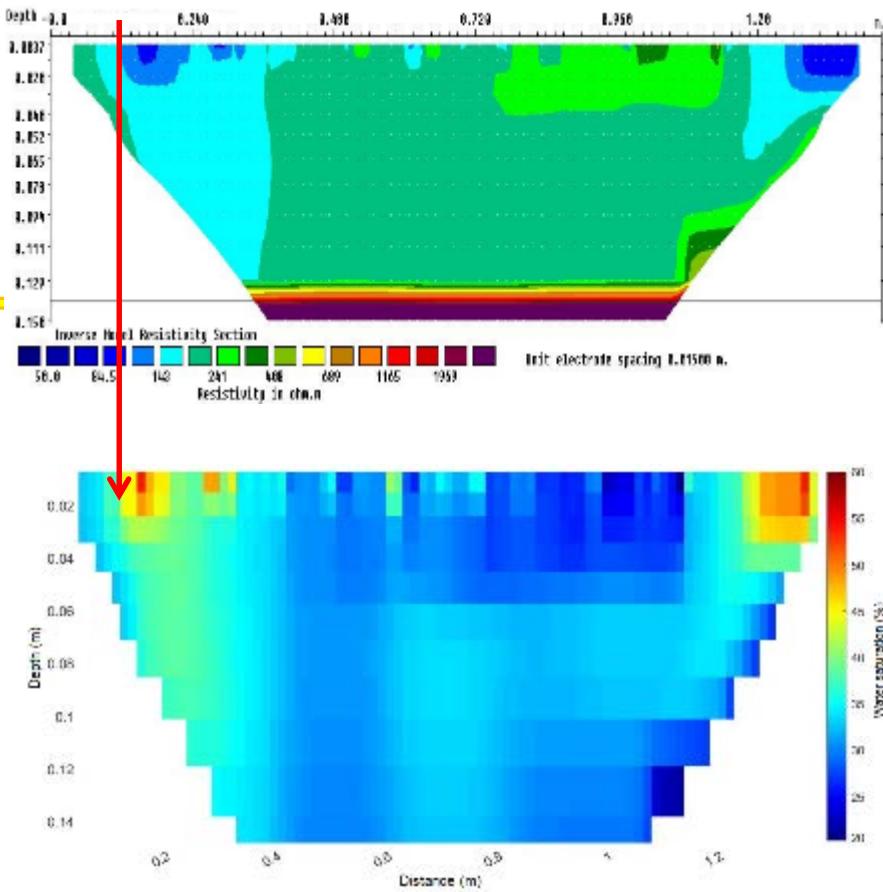
Laboratory experiments (shallow landslides)



Laboratory simulations (shallow landslides)



$$S_w = \left(\frac{29.7}{\rho} \right)^{0.59}$$



INTEGRATED SURVEYS

EM surveys



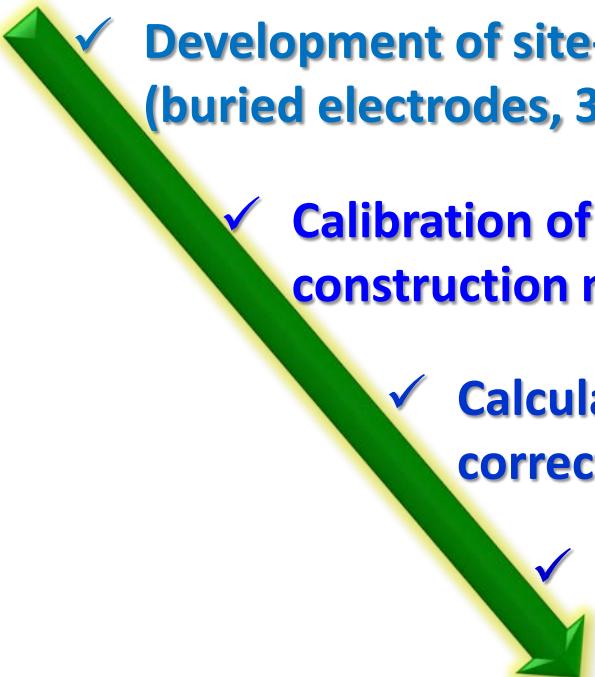
GPR surveys



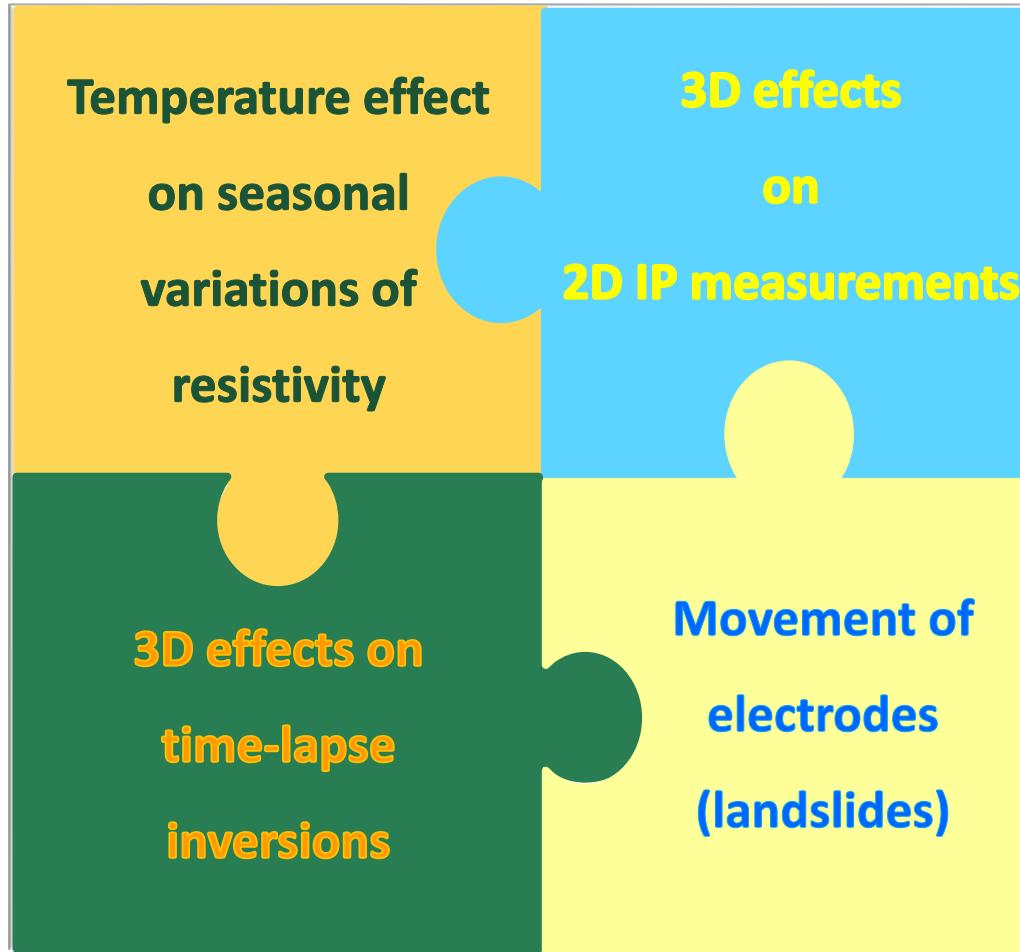
Drones



Conclusions

- Site-specific and cost-effective prototypes for permanent ERT monitoring projects can be developed and installed in critical areas of hydrogeological risks.
 - Challenges to reliably use ERT data for real-time monitoring of structures:
 - ✓ Development of site-specific data processing algorithms (buried electrodes, 3D effects, temperature)
 - ✓ Calibration of petrophysical relations based on the construction material of any specific site
 - ✓ Calculation of water content maps from corrected ERT data
 - ✓ Defining threshold values of instability
- 
- EARLY WARNING ALARM))))))**

Ongoing research



Published / Accepted

Hojat A, Arosio D, Longoni L, Papini M, Tresoldi G, Zanzi L, 2019. *Installation and validation of a customized resistivity system for permanent monitoring of a river embankment.* EAGE-GSM 2nd Asia Pacific Meeting on Near Surface Geoscience & Engineering, Kuala Lumpur, Malaysia.

Hojat A, Arosio D, Loke MH, Longoni L, Papini M, Tresoldi G, Zanzi L, 2019. *Assessment of 3D geometry effects on 2D ERT data of a permanent monitoring system along a river embankment.* EAGE-GSM 2nd Asia Pacific Meeting on Near Surface Geoscience & Engineering, Kuala Lumpur, Malaysia.

Tresoldi G, Arosio D, Hojat A, Longoni L, Papini M, Zanzi L, 2018. *Tech-Levee-Watch: Experimenting an integrated geophysical system for vulnerability assessment of levees.* Rendiconti online della Società Geologica Italiana 46: 38-43, DOI: [10.3301/ROL.2018.49](https://doi.org/10.3301/ROL.2018.49).

Tresoldi G, Hojat A, Zanzi L, 2018. *Correcting the influence of 3D geometry to process 2D ERT monitoring data of river embankments at the laboratory scale.* 37^o Convegno Nazionale del Gruppo Nazionale di Geofisica della Terra Solida, Bologna, Italy: 140-144.

Published / Accepted

Arosio D, Hojat A, Ivanov VI, Loke MH, Longoni L, Papini M, Tresoldi G, Zanzi L, 2018. *A laboratory experience to assess the 3D effects on 2D ERT monitoring of river levees.* 24th European Meeting of Environmental and Engineering Geophysics, Porto, DOI: 10.3997/2214-4609.201802628.

Arosio D, Munda S, Tresoldi G, Papini M, Longoni L, Zanzi L, 2017. *A customized resistivity system for monitoring saturation and seepage in earthen levees: installation and validation.* Open Geosciences, 9, 457-467, doi: [10.1515/geo-2017-0035](https://doi.org/10.1515/geo-2017-0035).

Arosio D, Brambilla D, Hojat A, Ivanov VI, Longoni L, Papini M, Scaioni M, Tresoldi G, Zanzi L, 2017. *Time-lapse ERT measurements to monitor rainfall triggered landslides at the laboratory scale.* In: Hoyer, S. (Ed.): *GELMON 2017: 4th International Workshop on Geoelectrical Monitoring: Book of Abstracts: November 22nd - November 24th, 2017, Vienna, Austria. Berichte der Geologischen Bundesanstalt, 124, p. 30, Vienna.*

Published / Accepted

Tresoldi G (student), Arosio D, Hojat A, Longoni L, Papini M, Zanzi L, 2017.

Sperimentazione di un sistema di monitoraggio geoelettrico permanente per la valutazione della stabilità arginale. 36° Convegno Nazionale del Gruppo Nazionale di Geofisica della Terra Solida, Trieste, Italy: 665-667.

Tresoldi G, Arosio D, Brambilla D, Hojat A, Ivanov VI, Longoni L, Papini M, Scaioni M, Zanzi L, 2017. *Sperimentazione alla scala di laboratorio per il monitoraggio di frane indotte da precipitazioni con misure geoelettriche time-lapse. 36° Convegno Nazionale del Gruppo Nazionale di Geofisica della Terra Solida, Trieste, Italy: 667-669.*

Under review

Hojat A, Arosio D, Ivanov VI, Longoni L, Papini M, Scaioni M, Tresoldi G, Zanzi L, 2019.
Geoelectrical characterization and monitoring of slopes on a rainfall-triggered landslide simulator. Under review: Journal of Applied Geophysics.

Tresoldi G (student), Arosio D, Hojat A, Longoni L, Papini M, Zanzi L, 2019. *Long-term hydrogeophysical monitoring of the internal condition of river levees. Revisions under review: Engineering Geology.*

Acknowledgements

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