

Robustness of the 2D-DC Resistivity Imaging method applied to dike survey : state of the art, limitations and outlooks

Yannick FARGIER, Sérgio PALMA LOPES, Cyrille FAUCHARD,

Daniel FRANÇOIS, Anaëlle JOUBERT, Philippe CÔTE

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Summary

Electrical Resistivity Imaging

- 2D ERI principle
- Resolution study principle

Dike survey by ERI

- Limitations
- Parametric study
- Impact of the measurement error on R_M
- InGEOHT 2D+ principle

Case study

- Presentation of the surveyed structure
- Results

Conclusion and Outlooks

Dike survey by ERI

Case study

Conclusion & Outlooks

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D Electrical Resistivity Imaging principle





Limitations:

ERI principle

Resolution study principle

1.

- non-uniqueness of the solution
- depth of investigation

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Resolution study principle

$$R_M = (J^T W_d^T W_d J + \lambda C^{-1})^{-1} J^T W_d^T W_d J$$

Gives the capacity to invert uniquely each inversion cell (robustness of the solution)

 R_M : Model Resolution Matrix

- J : Sensitivity matrix
- W_d : Matrix of data error
- λ : damping factor

ERI principle

Resolution study principle

C: smoothing matrix



Resolution study principle

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Give the capacity to invert uniquely each inversion cell (robustness of the solution)

1. ERI principle

2. Resolution study principle

- R_M : Model Resolution Matrix
- J : Sensitivity matrix
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Conclusion et perspectives

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Case study Conclusion & Outlooks	3. 4.	Impact of the error on R _M InGEOHT 2D ⁺

Dike survey by ERI

For cost effective reasons, surveys are performed longitudinaly



• For dike longitudinal surveys, 2D Hypothesis is completely wrong

Is the 3D behaviour of the dike composition has a significant impact on the measurement ?



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D Parametric study (1/2)







Parametric study (2/2) \ominus n.Ω00 Réservoir 1000Ω.m 1100 10 1000 Distance inter-électrodes (m) Topography effect 900 10000 m 800 700 40 600 45 Water reservoir effect 50 500 $\begin{array}{cccc} 8 & 10 & 12 & 14 \\ \text{distance entre le quadripôle et le réservoir (m)} \end{array}$ 2 4 16 18 20 6

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□ Impact of the measurement error on R_M





Conclusion : conventional resolution results over-estimate the robustness of an imaging result



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□ InGEOHT 2D⁺

Principle : The topography and the water reservoir is explicitly defined in the inverse problem





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InGEOHT 2D+



The resolution and depth of investigation are not reduced.

R_M can now be used to improve the interpretation of 2D ERI longitunal survey on dike.





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Presentation of the survey 1.

Results

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Dike survey by ERI

Presentation of the survey

- Homogeneous
- Concrete facing (upstream side)
- Height of 6 to 7 meters
- 475 meters longitudinal survey (96 electrodes with 5 meters inter electrode spacing)
- Wenner Schlumberger acquisition protocol



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- Electrical Resistivity Imaging
 - Dike survey by ERI
- 1. Presentation of the surveyed dike

ICSE6

2. Results

Case study

Conclusion & Outlooks

Results





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Summary

Introduction

- Problématique des Ouvrages Hydrauliques en Terre (OHT) & enjeux
- Besoin et mode d'application
- Sélection de l'Imagerie de Résistivité Électrique (IRE)
- Conclusion, problématique & démarche scientifique

Auscultation des OHT par IRE

- Le problème inverse en IRE
- IRE & auscultation des digues
- Étude numérique
- InGEOHT
- Stratégies d'acquisition et d'inversion
- **Cas d'étude**
 - DiguExpERT
 - Ouvrage réel

Conclusion & Perspectives

Conclusion & Perspectives

In general :

• An imaging result is non-unique — Questions about the robustness

For 2D ausculted medium:

• R_M (conventional) can be used to help the interpretation of the result

For 2D longitudinal survey of dikes :

- Dike geometry has a strong effect on the measurement
- The error on the measurement has an effect on R_M and limit the depth of investigation
- Conventional depth of investigation are always over estimated
- New inversion algorithm can be used to overpass this limitation



THANK YOU FOR YOUR ATTENTION



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$\Box InGEOHT 2D^+$

- Gauss-Newton inversion algorithm
- 100 < number of inversion parameter < 10 000
- Minimisation of the objective fonction :

$$\Phi = \Phi_d + \lambda \Phi_m = \|\mathbf{D}(\vec{d}_{mes} - \Gamma(\vec{m}))\|_2^2 + \lambda \|\mathbf{C}(\vec{m} - \vec{m}_0)\|_2^2$$

- Φ_d : data objective function;
- λ : damping factor;
- d_{mes}: vector of measured data;
- m : model ; m₀ : *a priori* model;
- Φ_m : model objective function
- \mathbf{D} : Data error
- Γ : forward problem
- **C** : smoothing matrix

$$\underbrace{\mathbf{G}^{T} \mathbf{D}^{T} \mathbf{D}^{\mathbf{G}}}_{\text{Hessian}} + \lambda \mathbf{C}_{m}^{T} \mathbf{C}_{m}) \Delta \vec{m}_{i+1} = \underbrace{\mathbf{G}^{T} \mathbf{D}^{T} [\mathbf{D}(\vec{d}_{mes} - \Gamma(\vec{m}_{i}))]}_{\text{Gradient of the objective function}}$$

Gradient of the objective function
Occam type regularisation of the Hessian

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