ΒΙΟΓΡΑΦΙΚΟ

Μάριος Καραούλης

DELTARES The Netherlands

1. Εμπροσθόφυλλο

Contents

2. Επιστολή αίτησης

2.1 Επιστολή κινήτρων

Αξιότιμη επιτροπή,

Δια της παρούσας επιστολής εκδηλώνω το ενδιαφέρον μου για την θέση αναπληρωτή καθηγητή του τμήματος Γεωλογίας και Γεωπεριβάλλοντος, με γνωστικό αντικείμενο «Εφαρμοσμένη γεωφυσική – Τεχνική και Περιβαλλοντική Γεωφυσική».

Επιχειρώντας να συνοψίσω την ακαδημαϊκή και επαγγελματική μου πορεία στα έτη που επακολούθησαν της αποφοίτησής μου από το Αριστοτέλειο Πανεπιστήμιο και την ολοκλήρωση της διδακτορικής μου διατριβής, θα ήθελα να θέσω υπόψη σας τα ακόλουθα:

Μετά την αποφοίτηση μου έχω παραμείνει ενεργός ερευνητής έχοντας συμμετοχή σε πολλά διεθνή ερευνητικά προγράμματα, με καινοτόμες ιδέες και δημοσιεύσεις.

Ειδικότερα, μετά την κτήση της διδακτορικής μου διατριβής συνέχισα τη σταδιοδρομία μου μου ως μεταδιδακτορικός ερευνητής στο Colorado School of Mines, όπου σύντομα απέκτησα θέση λέκτορα.. Παρόλο που το θέμα της μεταδιδακτορικής έρευνας μου, ήταν θεματικά οριοθετημένο, επεκτάθηκα, κατά τη διάρκεια της έρευνάς μου - και σε νέα ερευνητικά επίπεδα και εφαρμογές, ώστε να έχω αποκτήσω μια ευρύτερη άποψη της γεωφυσικής. Στο πλαίσιο αυτό, ξεκίνησα μια συνεργασία με

αρκετά Αμερικανικά ινστιτούτα και εργαστήρια, συνεργασία η οποία οδήγησε στη συμμετοχή μου σε αρκετά ενδιαφέροντα προγράμματα και εργασίες. Καθόλη την διάρκεια αυτής της περιόδου, συνεργάστηκα με ερευνητές από διαφορετικά επιστημονικά πεδία. Αποτέλεσμα των συνεργασιών αυτών ήταν ότι απέκτησα επιπλέον γνώση επί νέων επιστημονικών θεματικών και κατανόησα τις προκλήσεις που τα νέα αυτά επιστημονικά αντικείμενα συνεπάγονται. Συγχρόνως μου διανοίχθηκαν και άλλες επιστημονικές προοπτικές, καθώς κάθε πρόγραμμα, κατέληγε σε καινοτόμο τρόπο αντιμετώπισης του και άνοιγε δρόμο για περαιτέρω συνεργασία μια έρευνα. Κατά την διάρκεια της παραμονής μου στο Colorado School of Mines, επέβλεψα αρκετές μεταπτυχιακές και διδακτορικές εργασίες, παρέχοντας συμβουλές, ιδέες και βοηθώντας στην ανάλυση των αποτελεσμάτων. Διάφορες θεματικές με τις οποίες ασχολήθηκα εκτενώς περιλαμβάνουν ERT, EM, σεισμική διάθλαση, γεωθερμία, περιβαλλοντολογική γεωφυσική.

Εν συνέχεια, αποδέχτηκα την θέση του ερευνητή γεωφυσικού στο Illinois Geological Survey, με προγράμματα που αφορούσαν μεγάλης έκτασης γεωφυσικής έρευνα. Σε αυτή την θέση εργασίας, βελτίωσα περαιτέρω την γνώση μου και την ικανότητα επικοινωνίας – συνεργασίας μεταξύ διαφόρων επιστημόνων, καθώς επίσης και τον τρόπο συντονισμού και οργάνωσης προγραμμάτων με κυβερνητικούς σχηματισμούς.

Ακολούθως, μεταπήδησα στον τομέα της ιδιωτικής έρευνας, εντασσόμενος στο επιστημονικό δυναμικό της της Deltares στην Ολλανδία στην οποία και εργάζομαι στα τελευταία 6 έτη. Στο παρόν εργασιακό μου περιβάλλον βρήκα μια όμορφη ισορροπία μεταξύ έρευνας και εφαρμογής θεμάτων όπου έως τότε είχα αντιμετωπίσει σε θεωρητικό μόνον επίπεδο, σε προβλήματα πραγματικού κόσμου, βελτίωσα τις γνώσεις μου για την υδρογεωλογία, την τεχνική γεωλογία καθώς και αερο-γεωφυσική και θαλάσσια-γεωφυσική και χειρίστηκα ως συντονιστής προγράμματα με συγκριμένο αντικείμενο.

Παρόλο που εξακολουθώ να βρίσκω το παρόν εργασιακό μου περιβάλλον ενδιαφέρον, αναπολώ τα ερευνητικά χρόνια στο πανεπιστήμιο και την στενότερη συνεργασία με τους φοιτητές. Στον ακαδημαϊκό χώρο μπορούσα να συζητήσω επιστημονικά θέματα σε βαθύτερο επίπεδο, με απόψεις και καινοτόμες ιδέες που πηγάζουν από φοιτητές, χωρίς την πίεση των εργατοωρών και του προϋπολογισμού.

Στο παρόντα εργασιακό μου χώρο, εξακολουθώ να συνεργάζομαι με φοιτητές σε προγράμματά μου και να παρέχω εκπαιδευτικά σεμινάρια στη μεθοδολογία αλλά πάντοτε υπό το πρίσμα της παραγωγής συγκεκριμένου αποτελέσματος για συγκεκριμένο πρόβλημα, με αποτέλεσμα εν μέρει να απομακρυνόμαστε από την εις βάθος έρευνα που προσφέρει πολλαπλές λύσεις, αντικείμενο και ικανοποίηση που μόνο ο ακαδημαϊκός χώρος μπορεί να προφέρει.

Θέλοντας να επανασυνδεθώ με την ικανοποίηση και τα αποτελέσματα της επιστημονικής έρευνας όπως αυτή διεξάγεται στην ακαδημαϊκή κοινότητα, επιθυμώ την επιστροφή μου σε ακαδημαϊκό ινστιτούτο, όπου η συνεργασία με φοιτητές, διδασκαλία και εύρεση νέων καινοτόμων ιδεών είναι πιο ελεύθερη.

Εκτιμώ ότι η εμπειρία μου σε διαφορετικά ερευνητικά πανεπιστήμια και ινστιτούτα, ως αυτή εκτίθεται κατωτέρω, με καθιστά κατάλληλο υποψήφιο για την προκηρυχθείσα θέση.

2.2 πρόσφατα ερευνητικά ενδιαφέροντα

Τα πρόσφατα κύρια ερευνητικά ενδιαφέροντά μου είναι:

2.2.1 Drone based EM

Σε αυτό το ερευνητικό πρόγραμμα, αναπτύσσω ένα drone ηλεκτρομαγνητικό σύστημα με έμφαση στις ακόλουθες εφαρμογές και πλεονεκτήματα:

Εφαρμογές

- Χαρτογράφηση και παρακολούθηση φρέσκου θαλασσινού νερού
- Ποιότητα επιφανειακού νερού (ποτάμια/κανάλια)
- Αγροτικές εφαρμογές (ποιότητα εδάφους, ρύποι, υγρασία)
- Προάστια φραγμάτων από διάβρωση
- Γεωλογικές/ μορφολογικές εφαρμογές

Κύριες ερευνητικές ερωτήσεις?

Οι κύριες ερευνητικές ερωτήσεις, τις οποίες καλούμαι να απαντήσω είναι οι ακόλουθες:

- Χρήση συστήματος με πολλαπλές συχνότητές λειτουργείας με χαμηλό βάρος (<5 κιλών) ,
- Μείωση/αποφυγή ηλεκτρομαγνητικού θορύβου από το drone,
- Βελτιστοποίηση συνθηκών πτήσης (σήμα/θόρυβο, υψόμετρο, κτλ),
- Ευέλικτο σύστημα για εφαρμογή σε διαφορετικά drone, μαζί με άλλες συσκευές μετρήσεων.

Σε αυτό το πρόγραμμα, συμμετέχουν διάφοροι συνεργάτες: PhD φοιτητές από TU Delft, Data scientists' συνάδερφοι, εταιρείες διασκοπίσεων and εταιρίες υλικού. Νέοι αλγόριθμοι πρέπει να αναπτυχθούν, να λαμβάνουν υπόψη 3d χαρακτηριστικά, να ενσωματώνουν δεδομένα από άλλες συσκευές μετρήσεων, προγράμματα ερμηνείας κτλ.

2.2.2 Fancy-Fusion

Σε αυτό το πρόγραμμα αναπτύσσουμε τρόπους και μεθοδολογίες για συγχώνευση πολλαπλών τύπων δεδομένων, με στόχο την αύξηση της ακρίβειας της ερμηνείας των μοντέλων. Ως δοκιμή, επιλέχθηκε η χρήση γεωφυσικών (EM), γεωτεχνικών (γεωτρήσεις) και δεδομένων από δορυφόρους (inSAR) κατά μήκος φραγμάτων.

Τα εργαλεία που χρησιμοποιούνται είναιMachine Learning και έξυπνη παρεμβολή. Οι αλγόριθμοι πρέπει να αναγνωρίζουν σχέδια στα δεδομένα και να έχουν πολλαπλές παραμέτρους για μείωση των πολλαπλών μοντέλων. Στα πλαίσια αυτού του προγράμματος επιβλέπω MsC φοιτητή και data science intern.

2.2.3 BackScatter ανάλυση

Τα Multibeam echo sounders (MBESs) είναι χρήσιμα εργαλεία για τη χαρτογράφηση του πυθμένα της θάλασσας. Τα τελευταία έτη έχουν παρουσιαστεί μέθοδοι ανάλυσης και χαρακτηρισμού του εδάφους που συνδέονται με τη μελέτη της δύναμη του σήματος καθώς και τη χρήση machine Learning. Σε αυτό το πρόγραμμα, συνεργάζομαι με PhD φοιτητή από το TU Delft.

3. Ακαδημαϊκό βιογραφικό

Προσωπικές Πληροφορίες

Όνομα	**Μάριος Καραούλης**
Ρόλος	Γεωφυσικός / Ερευνητής
E-mail	Marios.Karaoulis@gmail.com
Τηλέφωνο	+31 (0) 621286149
Εθνικότητα	Ελληνική
Ημ. Γεννήσεως	16-10-1979
Χώρα Κατοικίας	Ολλανδία

Επαγγελματική εμπειρία

Ερευνητής /Γεωφυσικός,
Ιαν 2014 - Σήμερα
Deltares, Ολλανδία.

Γεωτεχνική και περιβαλλοντική έρευνα
Λίστα με κύρια ερευνητικά προγράμματα.
•European Space Agency (ESA) : Μέθοδοι για χαρακτηρισμό εδάφους με αισθητήρες από drone.
•Ανάπτυξη μεθόδων για τον εντοπισμό γεωμεμβράνων.
•TEM μετρήσεις στο Dubai για χαρακτηρισμό καταλληλότητας υδροφόρου (ASR)
•Θαλάσσιες ERT διασκοπίσεις για αρχαιολογικό χαρακτηρισμό.
•Διαχρονική παρακολούθηση φραγμάτων για αποφυγή εισροής θαλασσινού νερού με χρήση ERT.
•Διαχρονική παρακολούθηση Sand Engine για αποφυγή διάβρησης με χρήση ERT.
•Διαχρονική παρακολούθηση σε πραγματικό χρόνο έγχυσης υγρού αδιαβροχοποίησης .
•Εύρεση Vs υπεδάφους με χρήση MASW, και σεισμικά διάθλαση και ανάκλησης.
•Αερομαγνητικά TEM δεδομένα και ανάλυσης στα παράλια Βελγίου (φρέσκο-θαλάσσιο νερό, μοντέλο).
•Αερομαγνητικά TEM δεδομένα και ανάλυσης στα νησιά Zeeland, Netherlands (φρέσκο-θαλάσσιο νερό, μοντέλο)
•Αερομαγνητικά TEM δεδομένα και ανάλυσης στη Νέα Ζηλανδία (υδροφόρος).
•3D θαλλάσια σεισμικά ανάκλασης.
•Διαχρονική μελέτη leeve για διάβρωση (piping) με ERT και SP.
•Sonar και ρηχά σεισμικά ανάκλασης για εντοπισμό άμμου.
•Ανάλυση και machine Learning σε δεδομένα echosounder (MBES) για χαρακτηρισμό εδάφους.

Ερευνητής /Γεωφυσικός
Αυγ 2013-Δεκ 2013
Illinois State Geological Survey

Γεωφυσικές έρευνες για διαχείριση νερού για καλλιέργειες.
Συμμετοχή στο αερομαγνητικό TEM πρόγραμμα της πολιτείας του Ιλινόις.

Λέκτορας
Οκτ 2012 – Ιουλ 2013
Colorado School of Mines

•Γεωφυσική έρευνα και ανάπτυξη.
•Ανάπτυξη αλγορίθμων αντιστροφής
•Διδασκαλία μαθήματων και διαλέξεων σε θέματα αντιστροφής και υδρο-γεωφυσικής.

Μεταδιδακτορικός ερευνητής
Απρ 2010- Σεπτ 2012
Colorado School of Mines

•Υδρογεωφυσικά θέματα με έμφαση στο Spectral Induced Polarization.
•Ανάπτυξη αλγορίθμων αντιστροφής πολλαπλών τύπων δεδομένων.

Γεωλόγος
Ιαν 2009- Ιαν 2010
Νομαρχία Έβρου

•Επίβλεψη γεωτρήσεων
•Ψηφιοποιήσεις γεωτρήσεων και λοιπών γεωλογικών δεδομένων.

Γεωφυσικός **Μαρ 2008 – Ιαν 2010** Geomorph instruments	•Παροχή γεωφυσικών σεμιναρίων
Χαρτογράφηση 2018 Navteq	•Ψηφιακή χαρτογράφηση

Εκπαίδευση

2006 - 2009	Ph.D – Αριστοτέλειο Πανεπιστήμιο Θεσσαλονίκης, Γεωφυσική. Ανάπτυξη αλγορίθμων διαχρονικής αντίστροφής γεωηλεκτρικών δεδομένων.
2003 - 2006	Ms.C - Αριστοτέλειο Πανεπιστήμιο Θεσσαλονίκης, Γεωφυσική. Ανάπτυξη αλγορίθμων αντίστροφής γεωηλεκτρικών δεδομένων.
1998 - 2003	Bs.c - Αριστοτέλειο Πανεπιστήμιο Θεσσαλονίκης, Γεωλογία

Διδακτική εμπειρία

2014-σήμερα	Επίβλεψη PhD και Msc (University of Utrecht, TU Delft και Αριστοτέλειο Πανεπιστήμιο Θεσσαλονίκης. Αναλυτικός πινακας βρίσκει στην ενότητα 7 του παρόντος εγγράφου.
Άνοιξη 2013	Ground Water geophysics (Co-Teaching, GPGN 574) Colorado school of Mines, Department of Geophysics Inversion theory (co-teaching)
2010-2013	Εργασίες υπαίθρου (GPGN 486) Colorado school of Mines, Department of Geophysics Βοηθός καθηγητή στο Colorado School of Mines (hydrogeophysics courses)
2006-2008	Βοηθός καθηγητή στο Αριστοτέλειο Πανεπιστήμιο Θεσσαλονίκης Αριθμητικές μέθοδοι ανάλυσης.

Γλώσσες

	Χρήση γραπτού λόγου	**Χρήση προφορικού λόγου**	**Επίπεδο κατανόησης κειμένου**
Ολλανδικά	Βασικό	Βασικό	Βασικό
Αγγλικά	Άριστα	Άριστα	Άριστα
Ελληνικά	Μητρική	Μητρική	Μητρική
Ιταλικά	Βασικό	Βασικό	Βασικό

Εργασίες

Αναφορές: 1787
h-index: 25
i10-index: 33
https://scholar.google.nl/citations?user=Q_K_Kp4AAAAJ&hl=en&oi=ao
https://www.researchgate.net/profile/Marios_Karaoulis

Άλλα

Μέλος of Local Chapter EAGE.

4. Λίστα εργασιών

Οι εργασίες, τις οποίες έχω εκπονήσει, κατηγοριοποιούνται σε τρεις τύπους:

a) Αριθμητικές μέθοδοι, νέοι αλγόριθμοι.

b) Υδρογεωφυσικές εφαρμογές, όπου μελετώ τη χρήση της γεωφυσικής σε υδρογεωλογικά περιβαλλοντολογικά και γεωθερμικά θέματα.

c) Μηχανικές εφαρμογές, όπου μελετώ τη χρήση γεωφυσικής σε τεχνικά έργα.

Με βάση τον τύπο εργασίας, το περιεχόμενο τροποποιείται αναλόγως. Επί παραδείγματι, σε αριθμητικές εργασίες, προσπαθώ να καταδείξω όλα τα απαραίτητα βήματα και εξισώσεις που χρειάζονται, ώστε να μπορεί ο αναγνώστης να επαναλάβει τα αποτελέσματα. Σε τεχνικές εργασίες, δείχνω εν συντομία την μέθοδο με αναφορές για περαιτέρω ανάλυση και εστιάζω στην εφαρμογή και στο τι ιδιαίτερο έλαβε χώρα, ώστε να εξαχθεί ένα συγκεκριμένο αποτέλεσμα, καθώς και στον τρόπο με τον οποίο ο αναγνώστης θα μπορέσει να την εφαρμόσει σε αντίστοιχο δικό του πρόβλημα.

Τα αντίστοιχα επισυναπτόμενα αρχεία, βρίσκονται στο ΑΠΕΛΛΑ με όνομα αρχείου, όπως φαίνεται στον παρακάτω πίνακα (π.χ Abdulsamad, F., A. Revil, A. Soueid Ahmed, A. Coperey, M. Karaoulis, S. Nicaise, and L. Peyras. “Induced Polarization Tomography Applied to the Detection and the Monitoring of Leaks in Embankments.” *Engineering Geology* 254 (2019): 89–101. https://doi.org/10.1016/j.enggeo.2019.04.001 είναι το αρχείο 01.pdf)

Κωδικός αρχείου (xx.pdf)	**Βιβλιογραφία**
01	Abdulsamad, F., A. Revil, A. Soueid Ahmed, A. Coperey, M. Karaoulis, S. Nicaise, and L. Peyras. “Induced Polarization Tomography Applied to the Detection and the Monitoring of Leaks in Embankments.” *Engineering Geology* 254 (2019): 89–101. https://doi.org/10.1016/j.enggeo.2019.04.001.
02	Araji, A. H., A. Revil, A. Jardani, B. J. Minsley, and M. Karaoulis. “Imaging with Cross-Hole Seismoelectric Tomography.” *Geophysical Journal International* 188, no. 3 (March 2012): 1285–1302. https://doi.org/10.1111/j.1365-246X.2011.05325.x.
03	Coelho, Bruno Zuada, and Marios Karaoulis. “Data Fusion of Geotechnical and Geophysical Data for Three-Dimensional Subsoil Schematisations.” *Advanced Engineering Informatics* 53 (2022): 101671. https://doi.org/10.1016/j.aei.2022.101671.

04	Delsman, Joost R., Esther S. van Baaren, Bernhard Siemon, Willem Dabekaussen, Marios C. Karaoulis, Pieter S. Pauw, Tommer Vermaas, et al. “Large-Scale, Probabilistic Salinity Mapping Using Airborne Electromagnetics for Groundwater Management in Zeeland, the Netherlands.” *Environmental Research Letters* 13, no. 8 (July 2018): 084011. https://doi.org/10.1088/1748-9326/aad19e.
05	Haas, A. K., A. Revil, M. Karaoulis, L. Frash, J. Hampton, M. Gutierrez, and M. Mooney. “Electric Potential Source Localization Reveals a Borehole Leak during Hydraulic Fracturing.” *GEOPHYSICS* 78, no. 2 (2013): D93–113. https://doi.org/10.1190/geo2012-0388.1.
06	Huizer, S., M. C. Karaoulis, G. H. P. Oude Essink, and M. F. P. Bierkens. “Monitoring and Simulation of Salinity Changes in Response to Tide and Storm Surges in a Sandy Coastal Aquifer System.” *Water Resources Research* 53, no. 8 (2017): 6487–6509. https://doi.org/10.1002/2016WR020339.
07	Ikard, S. J., A. Revil, M. Schmutz, M. Karaoulis, A. Jardani, and M. Mooney. “Characterization of Focused Seepage Through an Earthfill Dam Using Geoelectrical Methods.” *Groundwater* 52, no. 6 (2014): 952–65. https://doi.org/10.1111/gwat.12151.
08	Karaoulis, M. C., J.-H. Kim, and P. I. Tsourlos. “4D Active Time Constrained Resistivity Inversion.” *Journal of Applied Geophysics* 73, no. 1 (2011): 25–34. https://doi.org/10.1016/j.jappgeo.2010.11.002.
09	Karaoulis, M., A. Revil, and D. Mao. “Localization of a Coal Seam Fire Using Combined Self-Potential and Resistivity Data.” *International Journal of Coal Geology* 128–129 (2014): 109–18. https://doi.org/10.1016/j.coal.2014.04.011.
10	Karaoulis, M., A. Revil, B. Minsley, M. Todesco, J. Zhang, and D.D. Werkema. “Time-Lapse Gravity Inversion with an Active Time Constraint.” *Geophysical Journal International* 196, no. 2 (November 2013): 748–59. https://doi.org/10.1093/gji/ggt408.
11	Karaoulis, M., A. Revil, P. Tsourlos, D. D. Werkema, and B. J. Minsley. “IP4DI: A Software for Time-Lapse 2D/3D DC-Resistivity and Induced Polarization Tomography.” *Computers & Geosciences* 54 (2013): 164–70. https://doi.org/10.1016/j.cageo.2013.01.008.
12	Karaoulis, M., A. Revil, J. Zhang, and D. D. Werkema. “Time-Lapse Joint Inversion of Crosswell DC Resistivity and Seismic Data: A Numerical Investigation.” *GEOPHYSICS* 77, no. 4 (2012): D141–57. https://doi.org/10.1190/geo2012-0011.1.
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5. Συνέδρια

Τα αντίστοιχα επισυναπτόμενα αρχεία, βρίσκονται στο ΑΠΕΛΛΑ με όνομα αρχείου, όπως φαίνεται στον παρακάτω πίνακα (π.χ Bauman, Paul, Franklin Koch, Rosa La, Landon Woods, Marco de Kleine, Marios Karaoulis, Jelle Buma, et al. "LONG TERM MONITORING OF UNDERGROUND ENERGY STORAGE USING FIBRE OPTICS." In *Symposium on the Application of Geophysics to Engineering and Environmental Problems 2016*, 324–33, 2016. https://doi.org/10.4133/SAGEEP.29-058. είναι το αρχείο c02.pdf)

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6. Εξωτερικά ερευνητικά προγράμματα

Παρακάτω παρατίθεται μια λίστα με την περιγραφή των προγραμμάτων στα οποία έλαβα μέρος. Η παράθεση ακολουθεί τον τρόπο με τον οποίο τα προγράμματα αυτά έχουν καταχωρηθεί στο εσωτερικό σύστημα αναφορών της DELTARES ή όπως έχουν επικοινωνηθεί στον πελάτη (στην Αγγλική γλώσσα). Ορισμένες από τις αναφορές δεν περιγράφουν ονομασία περιοχής, ή δεν περιλαμβάνουν αναφορά στα αποτελέσματα, κατόπιν απαίτησης του πελάτη. Η παράθεση αφορά μέρος της πραγματοποιθείσας έρευνας των τελευταίων 8 ετών και η παράθεση είναι ενδεικτική και όχι περιοριστική. Στον παρακάτω πίνακα παρατίθεται η λίστα, ενώ για υποτμήμα αυτών των προγραμμάτων παρατίθεται και με εικονογραφημένο τρόπο.

Κωδικός αρχείου (pdf ή docx)	Brief summary
11200173-002	In this report we descibre the geophyscial field activities that took place in Kota Bhary, at August 2018. Deltares surveyed the area using seismic reflection method, transitent electromagteic methos and borehole looging, to understant the geological background of Kota Bharu. Alll results analyzed and joint evaluated to evalute the feasibility of the area for water storage.
11200185-001	Deltares has carried out a phased method development for determining the location of a foil construction in the subsoil, originally for the purpose of widening the A27. The method is based on electrical resistance tomography (ERT) due to the high electrical resistance of the foil relative to the surrounding substrate. Modeling of ERT has shown that two types of electrode configurations are useful: configurations sensitive to the presence of the foil and configurations sensitive to background electrical resistance.
11200306-005	The aim of the first three sub-assignments of the TOPSOIL: FRESHEM for GO-FRESH Flanders project is to realize a three-dimensional electrical conductivity distribution of the groundwater based on airborne EM measurements in combination with a-priori data, advanced model techniques, knowledge of the groundwater system and hydrogeology. This combined approach is necessary to achieve the desired end result.
11200415-003	Condidential - The Scoping & Feasibility Study has identified Electrical Resistivity Tomography (ERT) and Fiber Optical Monitoring (FO) as possibly valuable technology for Smart Dike monitoring. There are however several aspects that require further investigation
11200482-003	During the construction of a new primary flood defense system in Perkpolder in 2014, thermally cleaned soil (TWA) was used. This report describes a set of geophysical measurements that were performed on two stretches of the barrier in Perkpolder: at the location of a west-east oriented dike (W-E dike), where thermally cleaned soil (TWA) was applied in the western part; and on the north-south oriented old dyke (N-S dyke), where no TWA material has been applied. The aim of the geophysical measurements is to investigate whether the TWA material differs from natural sand material.
11200537-011	The main goal of the project is to determine if the system (as configured) will be able to record and monitor fluctuations in the local electric field that are caused by changes in subsurface seepage/ground water flow (and any related changes to streaming potential signals, e.g. Revil at al, 2012). Ultimately, Deltares would like to use these passive geophysical data to evaluate the length of the pipe feature, and to determine if the seepage/pipe is worsening (backwards propagation).
11201350-002	This part of the IVO-O is performed as a combination of geophysical survey methods. With the Electrical Resistivity Tomography measurement system (ERT), the layer structure of the underwater bed of Extraction wells 3 and 4 has been mapped to 16 m –NAP (Pleistocene subsoil). With the data from CPTs performed especially for this purpose, the measurement results of the ERT have been validated and the NAP height of the layer units mapped by ERT has been determined.

11201808-008	This report is part of a comprehensive analyses for PUB to improve understanding of the behaviour of the Singapore groundwater system in a regional context. It describes analyses of a diverse range of geophysical data that were initially executed and straightforward processed by Kiso-Jiban in 2017 for five research locations in Singapore; the re-processing of these data; and the interpretation of these re-processed results towards subsurface insights. The objectives of this report are to determine the efficacy of these geophysical data to inform on the geohydrological system; whether these data are of high enough quality; and how they should be further used and developed to best fill in the hydrogeological knowledge gaps in the complex hydrogeological system of Singapore.
11202072-005	EM measurements to undestand the heterogenity wihin a levee system
11202189-011	This report presents measurements and monitoring of piping at two pilot locations (Herxen and Hellauw, the Netherlands), using the geoelectrical technique.In this work we study the feasibility of Electrical Resistivity Tomography (ERT) and Self potential (SP) into the measure and monitoring piping. The Self Potential was reported in 2017 (TITLE). The ERT is reported here.
11202460-006	The aim of the measurements presented here is to map the spatial and temporal variation of the leaching of fertilizer salts. This gives us more information and insight into the factors (such as crop choice and soil properties) and events (such as harvesting and rainfall) that lead to nutrient losses. The results provide starting points for improving existing leaching models and for taking the right measure in the right place.
11202663-005	In august 2017 Deltares conducted an infiltration test at a dike section along the 'Kattendijk' at 'Gouderak'. The purpose of this field test was to investigate the amount of infiltration water into the dike body due to wave overtopping. The test which was scheduled for 10 hours had to be stopped after 1 hour due to an occurring instability. The instability could afterwards be contributed to a sand inclusion (appr. 3x3x0.8m). After this first infiltration test Deltares was asked to conduct a second infiltration test along a different dike section along the 'Groenendijk' between 'Klein Hitland' and 'Groot Hitland'. The geophysical site investigation was conducted in order to identify a suitable dike section without such sand inclusions in the clay body. The geophysical site investigation consisted of a GPR and EM survey. The historical data revealed a clay dike which should be relative clear of sand inclusions. However the 'Groenendijk' between 'Klein Hitland' and 'Groot Hitland' was severely dikeaged after the 1953 storm and historical data cannot exclude possible sand reinforcements as emergency measures in the immediate aftermath of the 1953 storm. Hence the necessity of a 3D investigation methods in addition to the more 'classical' site investigation methods like CPT's and borings.

11202743-002	The distribution of sea bed sediments is relevant in understanding both physical processes and ecology in the marine environment. Modern and innovative techniques allow for high-resolution measurements for sediment mapping. In this project, we collected multibeam bathymetry and backscatter data, as well as box core samples for ground truthing, in and around the two sand extraction pits for Maasvlakte 2, offshore Rotterdam, Netherlands. We applied a Bayesian bed classification technique, as developed by Delft University of Technology, in order to create a high-resolution acoustic sediment classification map. This project is meant to be a pilot study, also aimed at knowledge exchange. Therefore, bed classification results are preliminary. The acoustic bed classification results in 4 acoustic classes. Assigning sediment characteristics, as derived from grain-size analyses of the box core samples, to the acoustic classes results in an acoustic sediment map. Differences in sediment characteristics in the study area are subtle, and yet the acoustic techniques are able to differentiate between these characteristics. The correlation of sediment characteristics to acoustic classes revealed that median grain size and mud content alone were not fully discriminative and that sediment sorting and gravel content correlated well to the acoustic classes. The influence of gravel content and other sediment and/or bed characteristics, such as thin mud drapes or benthic fauna, are discussed in this report. The absence of mud layers at the bed in 19 of 21 box core descriptions, grain-size analyses and 4 water samples suggest that the pit is not being filled in with mud at a significant rate. However, two fine-grained samples in the eastern part of the pit fall within an acoustic class that occurs in the eastern area that was first abandoned for dredging activities, which could imply that fine sediments are slowly accumulated. More rigorous interpretation of the method, resulting bed classification map and assignment of samples is required to fully understand the sedimentological conditions of these sand pits.
11202748-002	The objective of 'Train your Model' is to test the applicability of two data-driven algorithms capable of constructing spatially complex geoscientific models and at the same time are apt to match measured data and which are computationally fast. Test results for a selection of suitable cases for which borings, geophysical data and training images are available will be analysed and software will be implemented for subsequent use.
11203285-006	Salt intrusion of surface waters in the Netherlands poses a problem for fresh water resources, for example at drinking water intake points. Currently, the tools and instruments to monitor and understand salt intrusion are insufficient. The point sensors of the monitoring network provide valuable information, but only at specific locations where measurements are made. RWS is looking for new technologies to gather (2D or 3D) information about salinity variations in fresh, brackish and salt-water bodies. Two promising techniques are Electrical Resistivity Tomography (ERT) and Distributed Acoustic Sensing (DAS) with fibre optic cables. This report describes the results of a laboratory test using ERT. The results of a laboratory test using DAS

	are described in a separate report (Kruiver et al., 2019).
11203394-002	Geophysics, in the broadest sense, is the application of physics to investigate Earth. The specific part of geophysical exploration, to determine properties of the upper crust and near surface is usually called applied geophysics. 'Applied geophysics" covers everything from geophysical experiments to determine the thickness of the crust to geophysical studies of shallow structures for civil engineering, exploration for groundwater and minerals, where in general the total depth of investigation is the first few hundreds of meters. Out of many geophysical applications that can be used for groundwater exploitation, soil properties, storage and monitoring, the low frequency electrical field measurements have the most applications. In this work, we utilize a newly developed tool to image the interface between water and mud, in sewer systems. This system is designed to image the boundary between water and mud, by performing a tomographic inversion. This report presents the findings from the 1st phase of the tool design, numerical analysis and measuring scheme in a lab environment. This is a progress report.
11203454-002	In the past decade drones have become available and affordable for civil applications, including mapping and monitoring the earth with geophysical sensors. In 2017 and 2019, the feasibility of executing frequency domain electromagnetic (FDEM) surveys using an off the shelf drone, was investigated at Deltares. This reports firstly, the preparatory tests executed to determine the optimal instrumental configuration, flight path, data processing and inversion schemes and secondly, the three field validation tests executed to demonstrate the feasibility of the drone-borne electromagnetic survey in real-scale applications.

11204060-002	With current developments like sea level rise and climate change jeopardizing fresh groundwater reserves, Aquifer Storage and Recovery (ASR) is becoming increasingly important to safeguard freshwater supply in the Netherlands and other coastal areas over the world. Within the project 'Drainstore', KWR is currently investigating the potential for ASR at one of the fields of the agricultural company Meulwaeter, near Kruiningen (Zeeland). For site characterization, Deltares has carried out an Electrical Resistivity Tomography (ERT) survey at this site and analyzed these and other geophysical and geological data. The different types of measurements generally point out the presence of a freshwater lens with a thickness of about 20 m. At the top of the aquifer a clayey layer exists, which generally thins out towards the south of the channel. In the sandy aquifer below, the increase in resistivity towards the southwest as revealed by the ERT data indicates an increase in grain size and a lower clay content. At various locations within the sandy aquifer, thin clay/peat layers can be recognized from the cone penetration tests.
11204565-002	In this report we present the results from the Electrical Resistivity Tomography (ERT) for detecting piping growth under a levee. In the test site an induced piping experiment took place and permanent electrodes are installed for the duration of the study. We collect a series of ERT (time-lapse) data and we perform a tomographic inversion from the data. The results show that the ERT method can image the piping location. The location is in good accordance with direct measurements from the installed piezometers installed. Visual validation after the experiment, where trenches were made, indeed show the location of the piping. The results allow us to provide a model with all the dynamic changes on the subsurface. By observing those changes, we cluster the subsurface in 3 areas: the area where we observe the increase in the water level, an area that remains stable during the experiments and the piping. A time series analysis can make possible a predict the piping location and time occurrence before it actually happens. To validate this prediction, more data from other sites will be required.
11204843-002	Electrical Resistivity Tomography (henceforth referred to as ERT) measurements were performed at the Wetterskip Fryslân field site near the village of Hallum on the 15th and 16th January of 2020. These measurements are part of the medium-scale piping experiment which aims to validate and extend the knowledge obtained from small-scale laboratory piping tests, with the aim to further assess the resistance of tidal sand to the failure mechanism of piping

11204986-004	River dunes occur in low-land rivers worldwide and are vital in estimating sediment transport and deposition within fluvial systems. River management and maintenance requires the information of the bed dynamics and sediment budgets. Dune sizes vary in space and time and therewith may interfere with inland shipping, and sediment transport in rivers determines aggradation and degradation of the bed and dune migration, as well as the stability of dykes. Analysing bed morphodynamics from multibeam bathymetry time series allows for determining spatio-temporal variations in size and migration rates of individual dunes, as well as the large-scaled, longer-term trends in river-bed elevation. However, merely dune tracking does not fully explain sediment storage/reactivation in river systems. Observing sedimentary structures in the shallow subsurface of the river bed will enable us to reconstruct the preservation and reactivation of river dunes over time, and therefore the spatio-temporal sediment storage and fluxes.
11205160-007	The new Dutch government pursues a rigorous climate policy to achieve the objectives of the Paris climate agreement. Surface water and groundwater are key sources of heating, cooling and thermal energy storage systems. In this work we explore the DAS (distributed acoustic sensing) and ERT (electrical Resistivity Tomography) geophysical methods, to monitor the development and performed of collective heating systems, when hot water in injected to the ground for storage. In practice DAS allows measuring acoustic wavefield that provides valuable information on the dynamic characteristics is geothermal borehole systems. In geothermal wells the high temperatures can modify the elastic properties of the solid media around the well, which can be captured via traditional acoustic surveys. ERT allows measuring the electrical properties of the subsurface and it's mostly sensitive to the water content. The electrical properties of the water, among other parameters, depend on the temperature and thus making ERT a suitable tool to monitor the warm water evolution (Munoz et al, 2013, Karaoulis et al, 2019). In this project we perform a laboratory experiment that is compounded by partially saturated sand where an injection and extraction well were installed. Similarly, we installed on a 4-well set-up electrodes on each borehole to allow a 4D tomographic inversion of the resistivity data. By imaging the changes on the electrical properties of the subsurface, we can image the evolution of the warm water front.
11205308-002	In December 2019, Deltares carried out a field test where green field vibrations from several sources were measured by both accelerometers as well a buried glass fibres. The final target of the work is to determine the possibility to use glass fibres in the soil to measure vibration levels and th expected accuracy. This reports gives a preliminary comparison of the results. This report contains a literature review on the subject, the development of basic technics to process the registered fibre optics data and the comparison of the results from fibre optics measurements with traditional accelerometers. It is concluded that the results of each equipment show good similarity. This means that the applicability of fibre optics for soil identification seems possible. The application of fibre optics for traditional vibration measurements where an accurate determination of the maximum value is essential, requires further research.

11205313-001	Between November 9 and 13, spectral induced polarization (SIP) measurements will be carried out at two locations in the Netherlands (Figure 1) by Lund University and Deltares. The SIP 256C instrument of Radic Research will be employed, facilitated by Lund University. Based on the results and field procedure, Deltares will further evaluate this hardware as well as future research goals related to SIP. Lund University will use the field data to compare SIP with time-domain inducted polarization (TDIP) data. All data collected will be shared between Deltares and Lund University. Furthermore, the date at site 2 will be share with the water supply company Dunea, which will facilitate site access and hydraulic and lithologic data of the area. Deltares and Lund University will jointly intend to publish the results.
11205665-002	The demonstration project Usage of glass fibre optics measurements along railways" targets on showing the applicability of measurements of fibre optics for improving the effectiveness of the activities by ProRail, by getting insights of geotechnical parameters of the subsurface and the control of environmental vibrations
11205817-002	This report describes and discusses the measurement setup and results of an Electromagnetic Survey (EM) conducted under a drone for the Rivierenland Water Board with the aim of determining the cover layer thickness in 5 areas in the floodplains near Vianen. The derived top layer thickness from the measurements shows a picture of gradual thickness variation in the floodplains. A comparison with field measurements (bores) of the coating thickness shows that the derived EM coating thickness is generally overestimated by about 0.5 meter. This is partly due to heterogeneity such as thin clay layers at the top of the sand pack. On the other hand, the thickness of coatings over 4 m is underestimated with the measurement set-up used. It is possible that for individual areas a better match can be obtained between actual coating thickness and inferred coating thickness by calibrating areas individually using a few field measurements.
11206203-002	In the Houtrakpolder in Noord Holland, municipality of Haarlemmermeer, Staatsbosbeheer, at the request of the Port of Amsterdam, has been commissioned to conduct a feasibility study into the construction of a water storage facility. For this, an area of 2 ha with a maximum depth of 2 - 2.5 meters must be excavated. Part of the feasibility analysis is to assess the current soil, mechanical and hydrological aspects i.r.t. the realization of water storage. Important points for attention are: (A) The (permanent) stability of the adjacent Groene Schip storage complex (approx. 35 meters high). (B) Prevention of bottom cracking in a seepage-prone zone (along the North Sea Canal). In order to carry out this research and to answer the questions, existing information was examined, groundwater monitoring points were installed and geophysical investigations were carried out with the aim of better understanding the shallow subsurface: (a) geological structure, (b) the salinity of groundwater and surface water (c) phreatic groundwater level and hydraulic head distribution in the deeper groundwater.
11206328-003 - Opzet ERT Metingen brakwaterwinningen Dunea Deltafondssubsidie	Monitoring extraction wells due to salt water upconig

11206720-002	In 2006, ProRail built a roof near Barendrecht station with a green slope on the west side consisting of a lightweight core of expanded PolyStyrene (EPS) and cover soil. Since it was built in 2006, the slope has subsided, resulting in holes in the topsoil. ProRail, on behalf of the Municipality of Barendrecht, has commissioned Deltares to investigate the situation and to submit proposals for temporary and definitive measures. This report contains the reporting of a feasibility study on the detection of cavities with Electrical Resistivity Tomography (ERT), the investigation of the slope with camera soundings, field measurements during the excavation of the slope, analysis of the observations, calculations of future settlement and recommendations for final measures. The letter report 'Assessment of measures for rail slope Barendrecht' [9] contains advice on temporary measures.
11206854-001	This report uses geophysical research to provide an initial estimate of the location and dimensions of the hollow at Muntplein that led to a hole in the road surface on 4 January 2021. The purpose of the examination is furthermore to determine the possible presence and extent of other cavities. The following research questions were answered in this study based on the information and analyses presented: Answer question 1: Can the location and dimensions of the cavity under the road surface be determined with the proposed electromagnetic measurements? The research has resulted in ERT and ground radar (GPR) measurements that are of sufficient quality for further interpretation. The results of the EM measurements are not suitable for further analysis because the GPS sensor is disturbed and the positioning of the measurements is therefore insufficiently accurate. The combined application of ERT and GPR appears to be valuable for the research question. The ERT measurements provide a first estimate of the area, the location of anomalies that may be associated with the object of study (in this case a cavity) and has a sufficiently large depth range for the application in question. The GPR is a more direct measurement of possible interfaces, as are also the case with cavities. The contour and underside of the sand-filled cavity can be clearly seen on the GPR images.
11206875-022	This report shows the performance of various inSar processing algorithms to monitor landslides

11206883-002	This methodological programme entails the fundamental and quantitative analysis of risks, the development of (probabilistic) methods applicable in projects or processes involving risk management, as well as the development and improvement of risk management frameworks for both natural disasters and infrastructure. As such, the programme contributes significantly to the Deltares mission areas 'Safe deltas', 'Resilient infrastructure' and 'Future Deltas'. Risk management plays an essential role in making delta areas safe and sustainable and is hence relevant to many Deltares projects. The probabilities and consequences of adverse or even disruptive events (such as flooding, other climatological events or unavailability of critical infrastructure) need to be reduced as much as possible. At the same time, risk reduction measures need to be taken with societally acceptable costs and often within scarce space. That is the reason why quantitative knowledge of risk and risk reduction measures is essential in managing risk. Risk quantification entails a variety of probabilistic tools. These tools enable us to quantify risk as well as the effect of mitigating measures. These tools quantify the probability of events (e.g. 'probability of failure') and the consequences in terms of life loss, economic damage (direct and indirect), availability of (critical) infrastructure or social disruption. Relevant risk indicators are then based on a combination of probabilities and consequences. Reliability analysis has important advantages in assessing and designing infrastructure assets. Often the probability of failure of unavailability can be assessed less conservatively using reliability-based approaches, leading to extended life-time of aging infrastructure or cost savings in new construction. For managing risk in governance contexts, various Disaster Risk Management Frameworks are being developed. Currently, incorporating resilience and social inclusiveness important developments within these frameworks. This program produces essential modules (methods and tools) for research areas as covered in the programmes Flood Risk, Natural Hazards, Infrastructure Networks and Renovation and Replacement, among others.

11206883-012	This document describes the outlines of the 2021-programme of Enabling Technologies. The objective of Enabling Technologies is to support our mission enabling delta life by implementing key technologies in data science, modelling and (remote) sensing. We do this at three levels. We scan specific technologies, often applied in other disciplines, and assess their applicability in our mission areas. Next, we implement promising technologies in specific applications and fields of work and take care of knowledge transfer to a wide group of experts in the sector. At last we aim for a leading role in the digitization of the water and subsurface sector through existing and to be established partnerships. Concerning specific technologies, Enabling Technologies will focus in 2021 on: • AI-algorithms for an advanced utilization of earth observation data • Combination of spatial and in-situ data to improve the reliability of models and forecasts. • Exploring data fusion technologies and digital twins • Data acquisition and data assimilation from experiments • The use of autonomous platforms for monitoring. Through the utilization of keytechnologies, we aim at providing new perspectives for the societal programs 'Infrastructure Systems', 'Water resources (drought)', 'Replacement and Innovation Task', 'Ecosystems and Health' and 'Energy Transition'. These 5 research programs have agreed to pilot a new approach to speed up the uptake of key technologies in society driven programs. We will commit ourselves actively to let the Digishape network grow further and realize, through Digishape, the cooperation with the AI NL-coalition in order to utilize and further strengthen our role in the digitization of the water and subsurface sector.
11206887-026	InSar data for hygrogeological applications. Report in progress
11207357-052	Data fusion of ERT/IP and CPTs data, th characterize clay.
11207628-001	In this work we explore to what extent Electrical-Resistivity-Tomography (ERT) monitoring can be used to study the influence of holes (animal burrows) on internal erosion in a levee during an overflow experiment. The electrical properties of the subsurface over time are used to assess the time needed the holes to be water filled and possible development of new holes. This is the factual report and no interpretation of the results is given, besides some key observations.
11208057-026	AI and machine learning to 3d stochastic schematize soil. In progress
1204096-001	The survey campaigns, carried out in the intertidal zone on the beach of Raversijde, had multiple objectives within the scientific part of the SeArch project: · Test seismic methods using shear waves and surface waves, both on land (on the beach during low tide) and under water (during high tide) and their ability to cope with biogenic gas. · Test marine electrical resistivity tomography (ERT) and assess its ability to obtain useful subsurface information in the presence of biogenic gas. · Compare marine to land ERT in the intertidal setting.

1209220-003	FRESHEM Zeeland is short for FREsh Salt groundwater distribution by Helicopter ElectroMagnetic survey in the Province of Zeeland. The FRESHEM project established a detailed, spatially consistent and validated image of the fresh-salt distribution of the groundwater system, based on helicopter-borne electromagnetic measurements (HEM). Compared to previous large scale HEM mapping campaigns, FRESHEM additionally provides (1) a quantitative translation of HEM-measured resistivity profiles to groundwater salinity, (2) a novel approach to interpolation of measurements to a 3D result, aimed at preserving small-scale linear features in the data (creek ridges), (3) a rigorous approach to quantitatively assess the uncertainty of the end-result and (4) a validation with different ground truth measurements.
1210624	The measured Vs profiles were converted to VS30 values (the time averaged Vs for the first 30 m below the surface) and compared to the modelled VS30 map of GMPE V3 (Bommer et al., 2016, Kruiver et al., 2016b), which represent regional VS30 values for geologically similar zones. The measured VS30 values lie within two standard deviations of the modelled VS30 for all stations. The measurements, however, provide more accurate data on a local scale. This stresses the importance of acquiring local Vs profiles for the purpose of determining local ground motions, e.g. for the calibration of the GMPE.
1210713	The aim of this research is to develop a strategy for monitoring the injection of WEEC bottom ash in a dredging depot. Based on the analysis of the measurement methods, measurement configurations and parameter testing in the laboratory are some potency methods selected. A distinction is made here between monitoring during the injection phase and during the subsequent curing phase.
1210915	During the construction of the highway tunnel close to the Marina Barrage, seepage of seawater under the barrage was observed. In the near future a metro tunnel will be built north-west of the Barrage. This activity could cause similar problems. A reliable monitoring system detecting sea water seepage is therefore highly desirable. The scope of this work is to evaluate the performance of a system for monitoring the dynamic behavior of saline water intrusion in a fresh water reservoir. This report describes the results of a pilot survey employing a remote controlled monitoring system using Electric Resistivity Imaging technique. The system clearly shows the dynamic behavior of saltwater intrusion close to the Marina Barrage. This monitoring system for salt water intrusion can be deployed at other locations and data could be used in an operational setting for real time monitoring.
1220339-004	Long term morphological development of the tidal inlet systems in the Dutch Wadden Sea

1221107	A literature survey and assessment has been conducted into the possibilities to estimate soil behaviour for locomotion in planetary terrains, so as to to provide a critical assessment of existing techniques and to identify the most meaningful options to be discussed with ESA. The document has been prepared in conjunction with [RD04], “Literature Survey and Assessment, Rover and Soil Interaction”, prepared by RUAG Space, and the chapter 4 of this report contains a paragraph prepared largely by RUAG Space. It was found that parameters for locomotion performance on soil can be derived from in situ wheel tests using a model developed for ESA in previous work. Remote sensing and geophysical measurements can provide information to characterize terrains to be traversed by a rover in planetary missions. Orbital remote sensing provides data to be used as contextual information for terrain analysis. Rover based remote sensing provides data with high spatial resolution that can be used for soil identification. The data can be analysed using simple algorithms that make use of signatures of spectral absorption and reflection of the soil surface, and of specific terrain morphologies. Analysis of rover based remote sensing of soil surface temperature variation provides information on porosity and thickness of soil covers, and thus a first approach for locomotion properties. Geophysical measurements, notably ground penetrating radar and possibly acoustic measurements provide information on the soils. Off line characterization of trafficability of the terrains with soil covers requires the foreward looking capabilities of rover based remote sensing, and determination of the locomotion parameters for the soils to be encountered using in situ tests. A summary of components involved in a system for off line characterization for trafficability is provided. A limited set of components to support the current practize, which relies on experts analysis, would comprise a dedicated standardized in situ wheel test, and remote sensing data on thermal behaviour with a framework for analysis of such data. Additional information from tests is required for the development of a dedicated in situ wheel test, and for assessment of the uncertainty ranges that rover based soil surface temperature analysis provides on porosity and soil cover thickness.
1230049-005	In this work we explore the optimization of 3D ERT (Electrical Resistivity Tomography) measuring protocols in the case of a 3D borehole grid. Those measurements are used to monitor ground conditions for geotechnical purposes in a time lapse monitoring mode. The ERT monitoring set-up involved in the current application requires the collection of multiple cross-hole measurements in a fully 3D mode. There is not a known standard measurement scheme that could be used for such a measuring setup. Additionally, the involvement of such a large amount of electrodes and possible cross-borehole configurations can end up with a huge amount of electrode combinations that can be measured, without any control on how many of these measurements are significantly contributing to the formation of the final model. Within this work we propose a 3D measurement optimization approach that will result in an efficient measurement scheme which will produce optimum inversion while minimizing measurement and processing resources. Note that the optimization weights drops on the minimization of acquisition time, rather than optimal results.

1230282	For the 'Markerwadden' nature development project, which is currently being carried out in the Markermeer, large-scale earthmoving will take place (including the construction of a sand extraction pit). This earthmoving may affect any archaeological values in the subsoil. To gain insight into the presence of archaeological values in the underwater bed of the plan area, an Inventory Field Study was carried out in the form of drilling (Huizer, 2016). In order to obtain a flat and efficient picture of the relief of the Pleistocene sand surface for the Stone Age forecast (to avoid 'river dunes'), geophysical measurements were performed in addition to the drilling research. Three measurement systems were tested, that of the Chirp Sub Bottom Profiler (Chirp), that of the Sparker system (Sparker) and that of the Electric Resistivity Tomography (ERT). The investigation revealed that the Chirp system provided no information regarding the depth of the Pleistocene surface. The Sparker's measurement results could only be interpreted using the existing bores, because the reflection patterns in the measurement profiles were not unambiguous. The ERT measurements yielded the best geological contrasts, but the depth range of the measurements performed (about 14 m below the water surface) was just a little too small to get a good picture of the top of the Pleistocene deposits. In future research into the relief of the Pleistocene surface in the underwater bed of the Markermeer, it is recommended to use the ERT system in combination with the Boomer system so that mutual comparison and control between the systems is possible and a better result is obtained. Compared to the measurements performed in this study, the ERT system requires a number of adjustments to be made with regard to measurement settings and the measurement protocol performed so that the subsurface up to 20 m - NAP is also properly observed.
1230623-002	An inventory and assessment of geophysical shellfish bed detection methods has been carried out for Rijkswaterstaat. The inventory included literature, a shellfish bed definition and detection criteria, interviewing geophysical service companies on current and near-market technologies and reviewing shellfish bed detection pilot experiments. Our analysis has resulted in an overview of promising geophysical techniques for detection of epifauna and infauna shellfish beds at potential sand production locations below 20 meters depth in the North Sea. Recommendations are given for future steps to test and build confidence in the technologies proposed.

1230663-002	For the 'Marker Wadden' nature development project, which is currently being carried out in the Markermeer, large-scale earthmoving is taking place, including the construction of sand extraction pits for the work. This earthmoving may affect any archaeological values in the subsoil of the Marker Wadden planning area. In this report, the underwater bed of this area has been investigated for the purpose of the prospective archaeological preliminary investigation of the Winput Zuid. The focus was specifically on the top of the buried Pleistocene surface. In particular, the high parts of the surface are archaeologically promising for preserved heritage from the Stone Age. The survey was conducted as a combination of geophysical survey methods, namely: CPTs, the Boomer Seismic Measurement System, and the Electrical Resistivity Tomography Measurement System (ERT). Using CPT's and Boomer seismics, 4 geological lines were first placed over the sand extraction area. With the acquired insight into the profile structure, a map of the top of the Pleistocene surface was subsequently produced, mapping an erosional area of Holocene tidal channel cuts (low archaeological expectation) and a non-erosive area of the Pleistocene surface. The Pleistocene surface has its highest elevation in the eastern part of the Winput South, at a depth around 12 m - NAP. The ERT measurement results confirm the location of the Holocene trench incisions, but in the non-erosive Pleistocene region the ERT resistance measurements fluctuate (too) strongly. The ERT large measurement results are not confirmed there by the CPT and Boomer measurements and are therefore not used for the Pleistocene contour line pattern for the Pleistocene non-erosive top sand area.

1231021-006	In the context of increasing the capacity of the Wilhelmina Canal for shipping, the canal will be widened and deepened and the level may be lowered between Sluis II and III in Tilburg. The lowering of the water level may lead to an undesirable lowering of the groundwater levels in the area. The latter can be prevented by a water-inhibiting layer that is so deep under the channel floor that the chance of bursting due to seepage pressure is negligibly small. Rijkswaterstaat (WVL, GPO and PPO project Wilhelminakanaal) has asked Deltares and Van 't Hek foundation techniques to accelerate the development of the PLAID-IJzeroer method (PLAat Injection Deltares) to enable possible application as a water-retarding layer near Tilburg. In the PLAID Iron Rule method, a water-inhibiting layer is applied under the channel floor. For this purpose, a mixture (the 'brownie') is injected of basic chemical substances that are available in bulk on the world market and that occur naturally in the (Dutch) subsoil. The mixture is liquid during the injection and precipitates fairly quickly in the pores of the sand due to chemical reactions. This clogs the pores and creates a water-inhibiting layer. This so-called young-iron layer will within a period of years further converted by bacterial activity into a layer of a naturally similar crystal form of iron rock, whereby the water-inhibiting effect further increases. The layer takes on a plate shape because it is three-dimensionally bounded by a hydrological water shield during application. The water barrier and the water shield are generated between rows of lances that are placed at the required depth below the channel floor. The development of the iron layer can be monitored during and after the injection. Because ferric iron is highly electrically conductive, the three-dimensional growth over time (i.e. in 4D) of the layer during injection can be monitored (ERT technique), and controlled on the basis of the observations. Because the iron layer has a relatively large mass after installation, its size can also be monitored acoustically for a long time after application. If necessary, the layer can be maintained or strengthened in a targeted manner – even after years.

	Τίτλος		SENSING TECHNIQUES TO CHARACTERIZE LOCOMOTION ON SOILS TO BE TRAVERSED BY A ROVER					
Εταιρεία	**Χώρα**	**Overall project value (EUR)**		**Αριθμός προσωπικού**	**Πελάτης**	**Πηγή Χρηματοδότησης**	**Ημ.**	**Συνεργαζόμενος**
Deltares	Netherlands	150000		3	European Space Agency	European Space Agency	2016-2017	RUAG

Περιγραφή του προγράμματος

The scientific success of rover-based exploration is a result of the rovers' capability to access diverse terrains and surface materials. Previous Mars and Moon missions based on surface mobile elements have demonstrated very well the importance and criticality of locomotion performances. Engineering expertise and modelling capabilities in the area of mobility performances are therefore important to support the rover design phase, locomotion qualification testing and ultimately mission operations planning.

Using mathematical models for this purpose implies the need to know the parameters which dominate tractive performances, and their values. However, soil conditions can vary significantly in a natural terrain, which has also been observed on Mars. Therefore not only mathematical modelling tools of vehicle–terrain interaction processes, but also specific knowledge of the relevant properties of the terrain are needed before the terrain is actually traversed.

The purpose of the ESA UNDERSTAND activity is to investigate and report the most meaningful options of techniques to characterize locomotion on soils in terrains. This study uses as much as possible the existing on-board assets for characterization of the terrain, in particular in view of the avoidance of temporary or permanent immobilization of a rover on Martian and Lunar surface.

The rover designed for the ESA ExoMars 2020 mission is taken as an example. Included in the scheme that is sketched are the necessary facilities of the rover, their functions, the data to be collected and handled, and the processing of the data and information to determine the nature of the soils in the terrain to be traversed. This work includes preliminary concept validation of two selected on-board experiments: monitoring a wheel digging into a soil and the data processing of surface temperature variation based on infrared imagery.

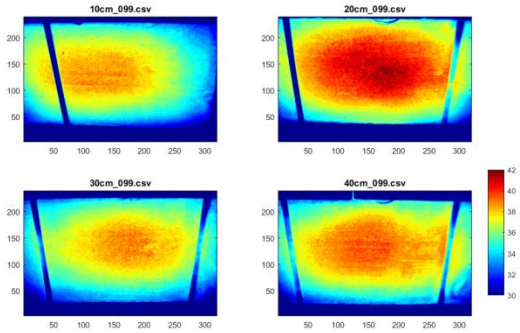


Figure: Thermal test to validate simulation. Thicker sands have different temperature characteristics.

	Τίτλος		Inversion of HEM data in New Zeland					
Εταιρεία	**Χώρα**	**Overall project value (EUR)**		**Αριθμός προσωπικού**	**Πελάτης**	**Πηγή Χρηματοδότησης**	**Ημ.**	**Συνεργαζόμενος**
Deltares	New Zealand - Netherlands	75.000		1	NZ Ministry of Business Innovation and Employment (MBIE)	NZ Ministry of Business Innovation and Employment (MBIE)	4-2014/ 5-2014	NZ Ministry of Business Innovation and Employment (MBIE)

Περιγραφή του προγράμματος

EM data were collected with Fugro's helicopter-borne RESOLVE electromagnetic (HEM) system, in a series of parallel lines, each 300m from the last. 52,000 lines kilometres were collected, with 2-3 m resolution approximately along the survey lines. Thus, 18,144,974 data points were collected and each point is considered as a typical 1D sampling-sounding. This is a typical approach for HEM data due to the computation weight of Maxwell equation in 2D or 3D combined with the large number of data points. Additional post-processing is possible in order to remove part of the 1d uncertainties and they will be discussed in a latter chapter. Frequency used for inverting the data EM data is shown in the next table. This range of frequencies is suitable for imaging in the range of 100+ meters. Additional specifications for the EM survey can be found in the previous reports.

The multifrequency AEM data were inverted using the code Airbeo (P223f suite, Australia). The data was processed on collaboration with GNS Science in the New Zealand Smart Aquifer. Characterisation Programme, funded by the NZ Mininstry of Business Innovation and Employment (MBIE)

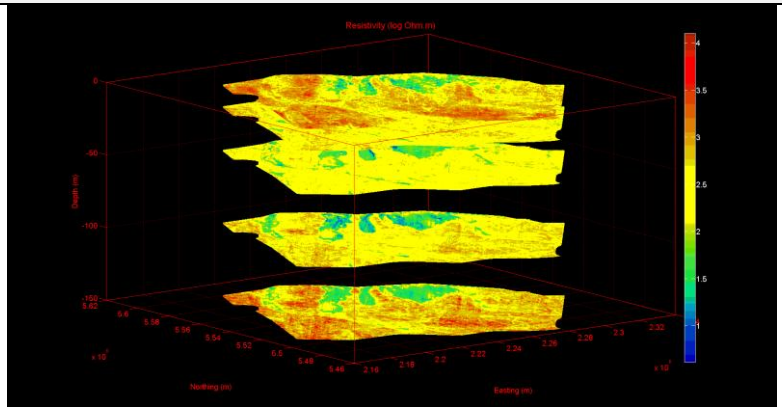


Figure : Resistivity slices from the 3D interpretation of EM data.

	Τίτλος		Inversion of HEM data in New Zeland					
Εταιρεία	**Χώρα**	**Overall project value (EUR)**		**Αριθμός προσωπικού**	**Πελάτης**	**Πηγή Χρηματοδότησης**	**Ημ.**	**Συνεργαζόμενος**
Deltares	Netherlands	58500		1	Zealand stakeholders	Zealand stakeholders	2015-2017	TNO, BGR

Περιγραφή του προγράμματος

Coastal lowlands are inhabited by around a quarter of the global population, owing to their low relief, fertile soils and easy transport. The availability of freshwater, however, presents a clear challenge in these coastal lowlands. The Province of Zeeland, in the Netherlands, is a prime example. In this island province, surrounded by saltwater estuaries and the North Sea, groundwater resources have been largely salinised by marine incursions and freshwater is scarce. As a result of land reclamation and subsidence, 25% of the area currently lies below mean sea level. The area is both an agricultural and tourism hotspot, putting stress on the available freshwater resources. Successful freshwater management, however, requires a clear and detailed picture of available fresh groundwater resources.

From its first successful application in the late 1970s, airborne electromagnetic induction (EM) surveys have since become increasingly common to map saltwater intrusion, delineate freshwater occurrences, or detect the presence of buried valleys. Airborne EM is especially suited to these kind of surveys, as the electrical conductivity of the subsurface is determined by (1) the salinity of the groundwater, and (2) the conductivity of the host material, with clay being a conductor and sand not . The airborne EM systems currently in use have been shown to yield good results when compared with ground-based geophysical and borehole measurements.

Type of services provided

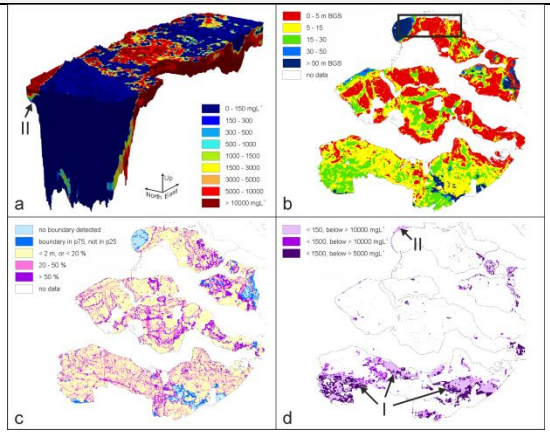


Figure : a) Slice from voxel model (p50 chloride concentration), showing a section from a dune area with deep freshwater to the hinterland with generally shallow occurrence of saline groundwater. Extent is indicated by black rectangle in b), b) Depth of median 1500 mgL-1 chloride contour, c) uncertainty in depth of 1500 mgL-1 contour (defined as (p25-p75) / p50 * 100%), d) freshwater occurrence below saline groundwater. Roman numerals are referred to in the text.

	Τίτλος		Real time monitoring using ERT with buried cables.					
Εταιρεία	**Χώρα**	**Overall project value (EUR)**		**Αριθμός προσωπικού**	**Πελάτης**	**Πηγή Χρηματοδότησης**	**Ημ.**	**Συνεργαζόμενος**
Deltares		60000		2	Απόρρητο	Απόρρητο		

Περιγραφή του προγράμματος

During the construction of the highway tunnel south-east of Barrage, seepage of seawater under the barrage was observed. This was probably caused by a hole under the barrage. In the near future a metro tunnel will be built north-west of the barrage. This activity could cause similar problems; therefore a monitoring system detecting sea water seepage is highly desirable for all critical areas in the area. This report describes the monitoring tool which is used to image the dynamic behaviour of saltwater intrusion in the Reservoir close to the Barrage.

The method we used to detect the presence of salt water is called Electrical Resistivity Tomography and it is based on the imaging of the resistivity of the subsurface.

Starting from gate G2 and towards gate G1 (47.5m length), we installed the monitoring cable. We used 96 electrodes with 0.5m spacing, with a Wenner-α array. Date acquisition is 20 minutes. Data repetition is 1 hour.

Here we present two snapshots from the whole monitoring period. Figure shows the inverted model and associated sea level and reservoir level, at 11 of March at 13:15 and 23:15 (UTC +2) time. We observe that the area at x=12m from gate G2, shows significant resistivity changes, an indication that the fresh/salt water interface is dynamic in the region and possible to be mapped with this method. Additionally, changes in the thin zone, between 0 and 2m (below fresh water), are associated with changes to the salinity of the water. Moreover, we observe that the sea level is lower at 13:15.

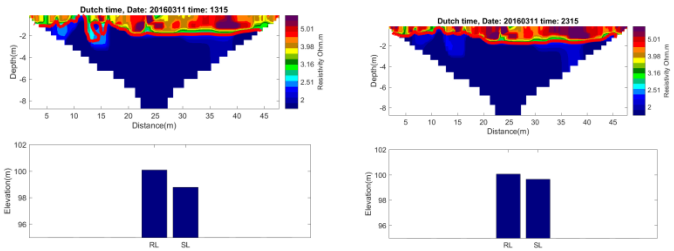
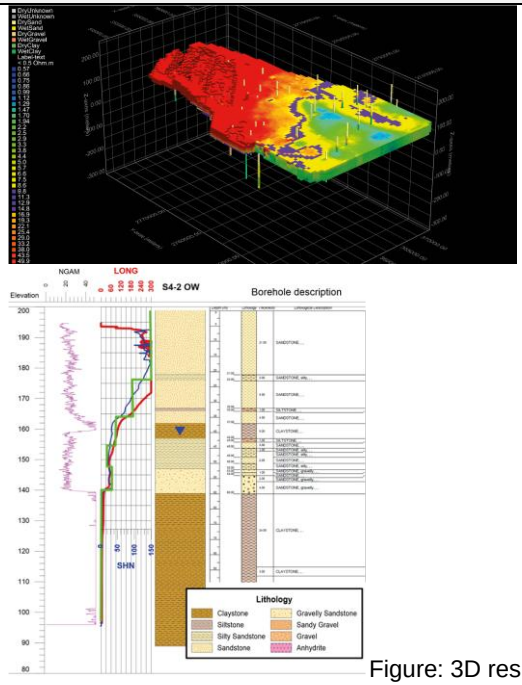


Figure: Monitoring results between 13:15 and 23:15 (UTC+2), at 11th of March. We observe a dynamic changing fresh/sea water system at distance= 10m. RL= Reservoir Level; SL = Sea Level

	Τίτλος		TEM measurements for aquifer storage and recovery					
Εταιρεία	**Χώρα**	**Overall project value (EUR)**		**Αριθμός προσωπικού**	**Πελάτης**	**Πηγή Χρηματοδότησης**	**Ημ.**	**Συνεργαζόμενος**
Deltares		800000		2	Απόρρητο	Απόρρητο	2017-	Απόρρητο partners
Περιγραφή του προγράμματος								
Deltares has executed a Time Domain EM (TDEM) survey .The target of the survey was acquiring a data set to be used for determining the suitability of the subsurface for an Aquifer Storage and Recovery (ASR), selecting the optimal location for such a project and supply data which can be used for the final design of the ASR system. Resistivity is correlated to the lithology (porosity), the water content and the water quality of the subsurface. The correlation between the inversion and the borehole data allows us to use a geological steer inversion, where lithology is used as information to the geophysical data.						 Figure: 3D resistivity area and borehole logging used to perform a geological steer inversion		

	Τίτλος		Real time monitoring of coal fires.					
Εταιρεία	**Χώρα**	**Overall project value (EUR)**		**Αριθμός προσωπικού**	**Πελάτης**	**Πηγή Χρηματοδότησης**	**Ημ.**	**Συνεργαζόμενος**
Deltares		Απόρρητο		2	Colorado state	Colorado State		

Περιγραφή του προγράμματος

The remediation of coal seam fires requires, as a first step, the precise localization of the burning front. Various geophysical methods can be employed for this purpose but not all of them can provide an unambiguous localization of this type of target. We propose a combined inversion of self-potential and resistivity data and the use of joint attributes (characterizing the target) to localize the burning front of a coal seam fire. This new methodology is applied to the 3D reconstruction of a shallow coal seam fire in Boulder, Colorado. The coal seam fire is located in the Gorham subbituminous coal formation at a depth comprised between 10 and 15 m. The self-potential survey comprises 160 stations (5 profiles and 32 stations per profile) located at the ground surface with self-potential anomalies amounting +70 to -50 mV with respect to an arbitrary reference located further away from the burning front. The resistivity survey comprises 5 resistivity profiles with 118 measurements per profile (590 measurements in total). The burning front is associated with very low value of the electrical resistivity (<15 Ohm m) and source current density probably of thermoelectric nature. The combined inversion and interpretation of the self-potential and resistivity data indicates clearly the position of the coal seam fire, which is corroborated by a thermal anomaly observed at depth of 30 cm and indicating that the minimum depth of the thermal source is approximately 9 m. This methodology can be easily extended to greater depths using resistivity derived from galvanometric or airborne electromagnetic methods and large-scale self-potential surveys.

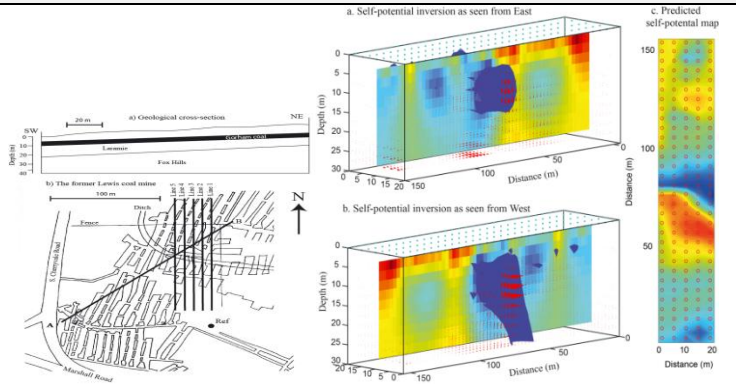
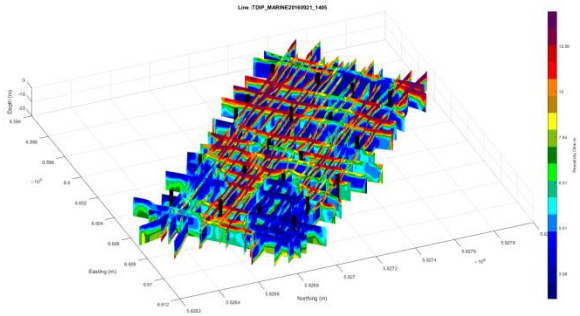


Figure: 3D ERT resistivity profiles and SP profiles on top of a coal fire.

	Τίτλος		MARINE ERT METHOD					
Εταιρεία	**Χώρα**	**Overall project value (EUR)**		**Αριθμός προσωπικού**	**Πελάτης**	**Πηγή Χρηματοδότησης**	**Ημ.**	**Συνεργαζόμενος**
Deltares		Several Projects 25.000		2			2014-Ongoing	
Περιγραφή του προγράμματος								

Since 2014, I have developed a marine imaging tool, using the ERT method. This tool has a flexible resolution and depth of investigation setting, that can be used in several sites. Additionally, I have optimized the processing of the collected data, to generate reliable 3D results. This tool is currently used in several projects.



	Τίτλος		DRONE/BOATS AUTONOMOUS BASED EM SURVEYS					
Εταιρεία	**Χώρα**	**Overall project value (EUR)**		**Αριθμός προσωπικού**	**Πελάτης**	**Πηγή Χρηματοδότησης**	**Ημ.**	**Συνεργαζόμενος**
Deltares	NL	Απόρρητο		3		TKI (Ολλανδικό πρόγραμμα χρηματοδότησης)	2019-	Skytools, Watermappers, κ.α.

Περιγραφή του προγράμματος

I a developing an EM drone. My role is design and define the sepcs. I am working with drone developers, survey companies and hardware developers in a joint effort (TKI).

There is a niche to for em surveying/monitoring because the following reasons:

- Pro: ***Drone based em surveying will be faster than land or water surveys***, it can work better in less accessible terrains; Con: drone cannot fly in some areas because of flight limitations
- Pro: the ***spatial (and temporal) resolution of drone measured data will be higher*** than airborne data (2 m2 versus 100 m2); Con: the coverage of data acquisition is higher with airborne systems (1 km2 per day versus 50 km2 a day)
- Pro: ***regularly (daily/monthly?) repeated surveys/monitoring of small areas*** is affordable due to acceptable mobilization costs of drones compared to airborne surveys; Con: for larger areas this does not hold, mobilization costs can be shared than.A new system should fill in the niche between helicopter (typically flight lines 200 m apart, speed 20 km/hour) and land/water based systems (2m apart, 2 km/hour) offering above advantages to clients. Mobilisation and survey costs should be factor 4 lower. It should be possible to buy and apply a system dedicated to a specific application area/process to be monitored (fresh water resource, levee, etc.).

Figure: Test flight

	Τίτλος		Fusion of geological and geophysical data for levee					
Εταιρεία	**Χώρα**	**Overall project value (EUR)**		**Αριθμός προσωπικού**	**Πελάτης**	**Πηγή Χρηματοδότησης**	**Ημ.**	**Συνεργαζόμενος**
Deltares	NL	50000		2		Pilot study.	2019-ongoijng	

Περιγραφή του προγράμματος

During this project we develop new interpolation methods to better follow geological structures. Those interpolation methods are using, besides typical kriging, Machine Learning , Image Inpainting and fouriier interpolation, to better predict models.
Secondly, we merge different data sets to better understand the subsurface. We use clustering algorithms, Gaussian mixture and Machine Learning to identify patterns in the different type of data.

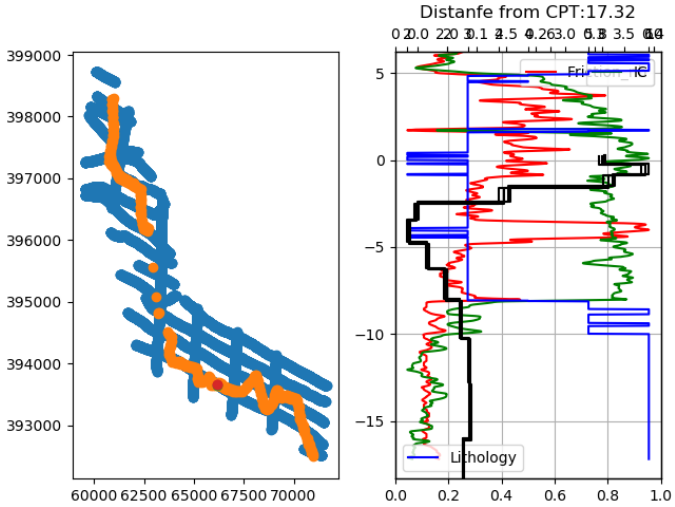


Figure: EM data and Coen Penetrations boreholes used to combine data

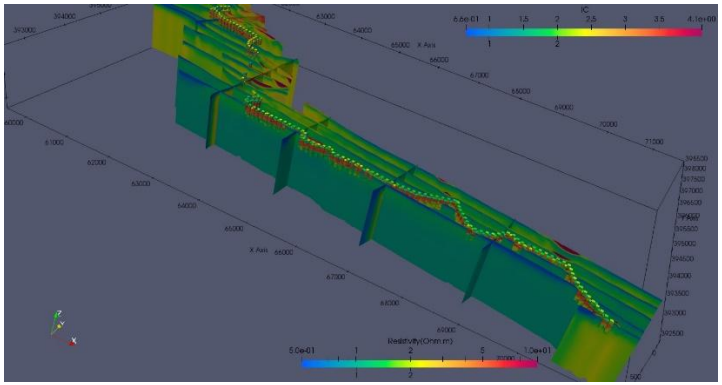


Figure: HEM data and CPTs.

	Project Τίτλος		Ground Water monitoring using ERT and Fibre Optics					
Εταιρεία	**Χώρα**	**Overall project value (EUR)**		**Αριθμός προσωπικού**	**Πελάτης**	**Πηγή Χρηματοδότησης**	**Ημ.**	**Συνεργαζόμενος**
Deltares	NL	200000		4	Vittens	Vittens	2018-	

Περιγραφή του προγράμματος

With Vittens (water company) we use innovative methodologies to image subsurface flow of infiltrated water, identify flow paths and optimize the pump operation.
We merge two types of data, ERT and Fibre Optics.
This way, we expect a better management from operational point of view
Goals:

- Avoid clogging of the wells
- Identify preferential flow patterns.

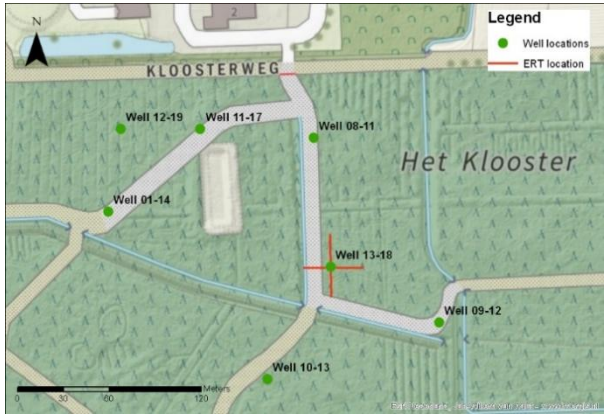


Figure: Sketch of the pupms and ert, fibre optics area if investigation

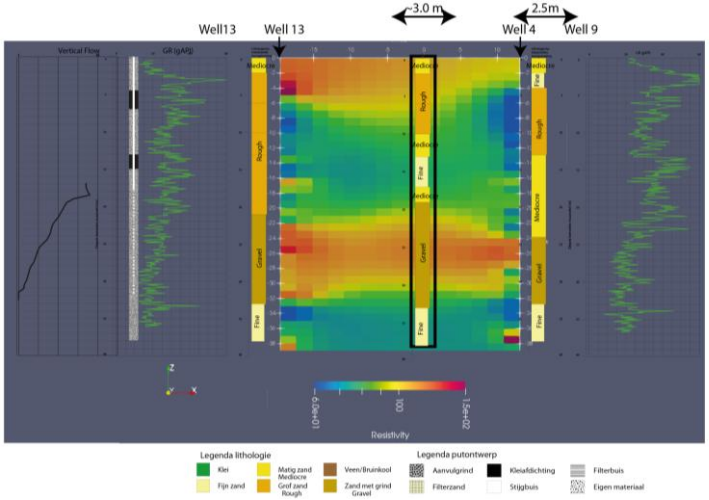


Figure: ERT and borehole resutuls from the site

	Project Τίτλος		ERT measurements of salt intrusion in the laboratory					
Εταιρεία	**Χώρα**	**Overall project value (EUR)**		**Αριθμός προσωπικού**	**Πελάτης**	**Πηγή Χρηματοδότησης**	**Ημ.**	**Συνεργαζόμενος**
Deltares	NL	Πολλαπλά 120000		4	RWS	RWS	2017-	

Περιγραφή του προγράμματος

Salt intrusion of surface waters in the Netherlands poses a problem for fresh water resources, for example at drinking water intake points. Currently, the tools and instruments to monitor and understand salt intrusion are insufficient. The point sensors of the monitoring network provide valuable information, but only at specific locations where measurements are made. RWS is looking for new technologies to gather (2D or 3D) information about salinity variations in fresh, brackish and salt-water bodies. Two promising techniques are Electrical Resistivity Tomography (ERT) and Distributed Acoustic Sensing (DAS) with fibre optic cables. This report describes the results of a laboratory test using ERT. The results of a laboratory test using DAS are described in a separate report (Kruiver et al., 2019).

Electrical Resistivity Tomography is a well-known geophysical technique used all over the world mainly on land. The technique uses electricity to image sub-surface structures of electrical resistivity. In recent years there has been application of this technique for measuring salinity in waterbodies. ERT is a suitable tool to map and monitor salt/fresh water movements both in the water column and in the subsurface.

In this study, laboratory experiments were conducted to test if the ERT technique could potentially be applied in a field setting for measuring salinity intrusion in inland waterways and to demonstrate a feasible monitoring set-up to do so. These laboratory experiments were conducted in cooperation with another ongoing laboratory test using the IJmuiden scale model, constructed in the Hydrohal facility of Deltares. Four different experiments were done, using different configurations of ERT cables.

The laboratory experiments as described in this report show that ERT can be used to monitor the intrusion of seawater into inland water systems, providing good temporal resolution and more spatial information than available from point measurements. The imaging of the salt water intrusion can be done with one horizontal electrode cable on the bottom (achievable in practice) and with two cables vertically above one another.

Some initial recommendations for conducting a field test, also in conjunction with a test of the DAS method, are provided. The recommendations include suggestions on how to set-up the sensors to obtain meaningful results with respect to relevant spatial and temporal resolution.

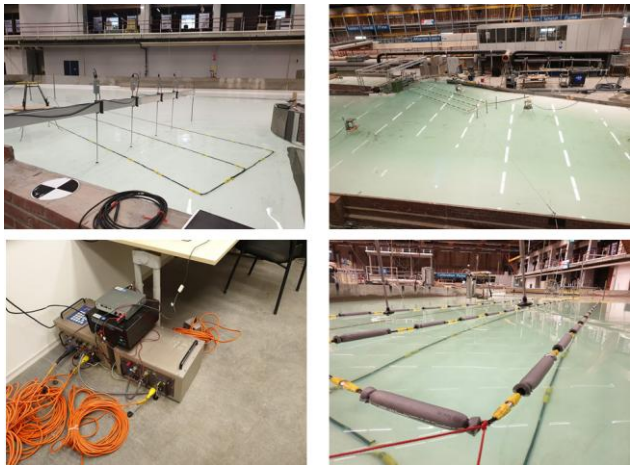
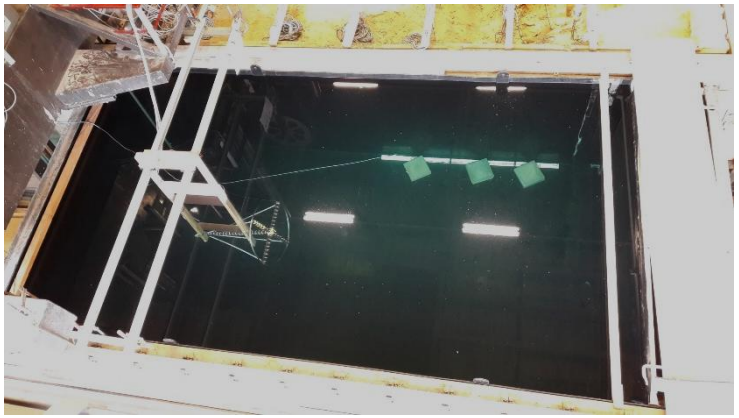


Figure: ERT setup and lab test

	Project Τίτλος		Ground Water monitoring using ERT and Fibre Optics					
Εταιρεία	**Χώρα**	**Overall project value (EUR)**		**Αριθμός προσωπικού**	**Πελάτης**	**Πηγή Χρηματοδότησης**	**Ημ.**	**Συνεργαζόμενος**
Deltares	NL	180000		3	RWS	RWS	2018-	
Περιγραφή του προγράμματος								
PVC membranes are used as groundwater barriers in infrastructure works in situations with high groundwater levels. When reconstruction works are necessary, the position of the membrane in the subsurface needs to be known. Deltares developed a method based on Electrical Resistivity Tomography (ERT) using the high electrical resistivity of the PVC membrane. Modelling showed that the PVC membrane has a profound effect on the electrical field lines. Classical ERT employed from the surface does not have sufficient spatial resolution to locate the membrane. Electrodes need to be closely spaced and within ca. 1.5 m from the membrane. To this end, a prototype tool was developed that can be pushed in the ground and measure while approaching the membrane. This prototype was tested in the laboratory. Measurements at different distances from the membrane showed that the tool can detect the distortion of field lines. Inversion was used to pinpoint the position of the membrane within 10 cm. The next step is to develop a tool that can be used in the field.						 Figure: ERT (TBM) setup and lab test		

7. Επίβλεψη και διδασκαλία

Στην Deltares
Επίβλεψη PhD Student (University of Utrecht) : Monitoring and simulation of salinity changes in response to tide and storm surges in a sandy coastal aquifer system (2017). Sebastian Huizer
Επίβλεψη MsC Student (TU Delft): Geologically steered inversion of Time Domain Electromagnetics (2017). Maarten Diels
Επίβλεψη PhD student (TU Delft): ERT and Fibre optics to image subsurface flow (2018-ongoing). Wiecher Backx
Επίβλεψη PhD (University of Utrecht): A quantitative review of 1D airborne electromagnetic inversion methods: A Focus on Fresh-Saline Groundwater mapping. (2019). Jude King.
Επίβλεψη intern :Fuse and interpolation of geophysical data at FancyFysion Project. (2019-ongoing). Pieter Zitman
Επίβλεψη MsC :Groundwater flow imaging (2020-), using ERT and Fibre Optics. Alexander Van Ballaer.

Στο Colorado School Of Mines
Ground Water geophysics (Co-Teaching, GPGN 574).
Colorado school of Mines, Department of Geophysics
Inversion theory (co-teaching)
Εργασίες υπαίθρου (GPGN 486)
Colorado school of Mines, Department of Geophysics
Βοηθός καθηγητή στο Colorado School of Mines (hydrogeophysics courses)
Συν-επίβλεψη PhD : Image Guided Inversion. Jiehi Zhou (2013)
Συν-επίβλεψη PhD : Crosswell EM inversion. Kris MacLennan (2014)
Συν-επίβλεψη MsC : Groundwater flow in Pagosa Springs. Joyce Hoops (2012).
Συν-επίβλεψη PhD : Couple hydrogeophysical inversion (2013).
Συν-επίβλεψη PhD : Self Potential measures for well leakage. Allan Haas (2013)

Στο Αριστοτέλειο Πανεπιστήμιο Θεσσαλονίκης
Βοηθός καθηγητή στις αριθμητικές μεθόδους ανάλυσης.