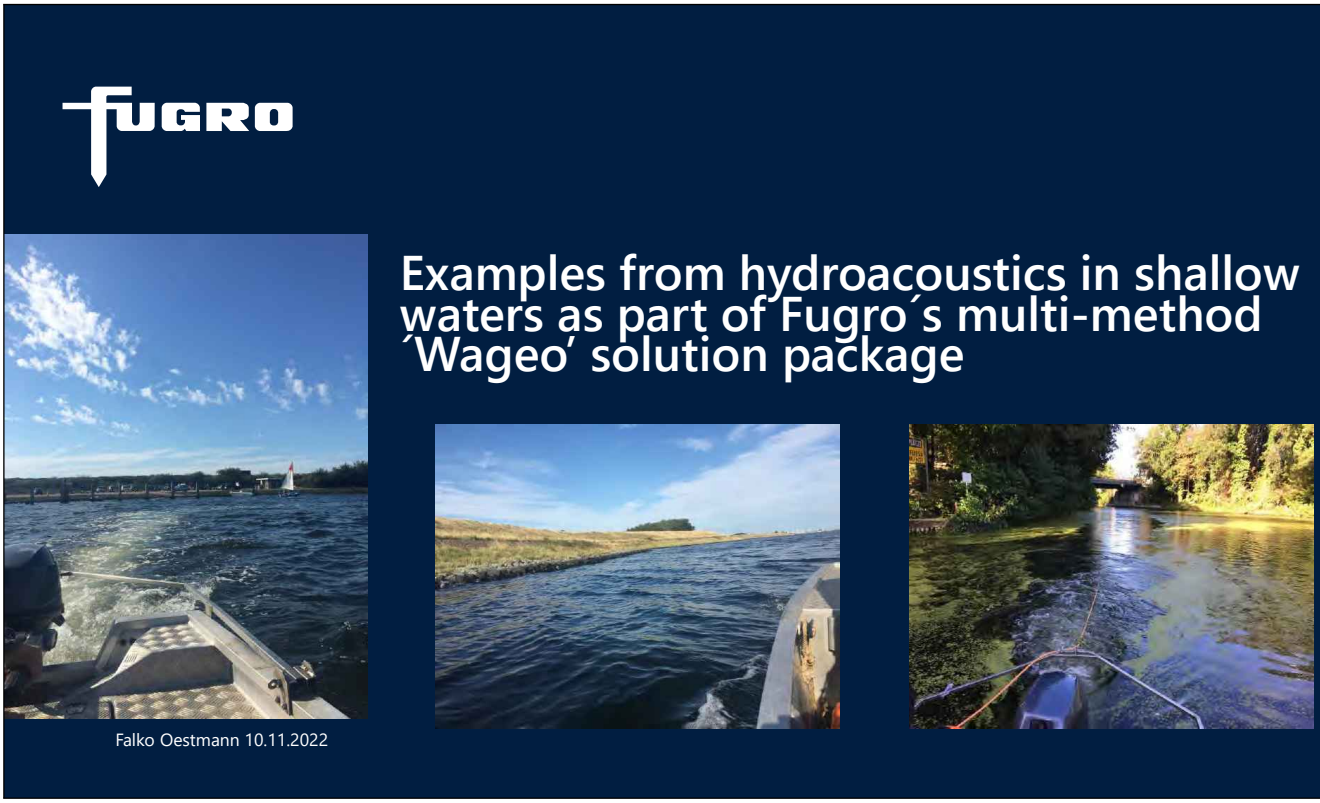
Proceedings of the 10 th Workshop "Seabed Acoustics", Presentation P07:

Examples from hydroacoustics in shallow waters as part of Fugro's multi-method WAGEO solution package

Falko Oestmann
Fugro Germany Land GmbH, Germany

10 th November 2022



Agenda

1.
WAGEO Methods

2.
Example 1:
Fluid Mud Survey
Settling Pond

3.
Example 2:
Armour Layer Survey
Hollandse Ijssel NL

4.
Example 3:
Armour Layer Survey
Hollandse Delta NL

5.
Example 4:
Storage Basin
Sediment Survey
Kinzigtalsperre D

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My record

Falko Oestmann:

Studied Geophysics at CAU Kiel, graduated in 2008 as Diplom Geophysiker:

- jobs at GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel (RV Sonne, RV Meteor),
- Marine Geophysics (RV Littorina, RV Alkor) and
- Archaeometry work group at the CAU (Russia, Poland, Turkey, Iran, Haitabuh)

Since 2009 with Fugro Germany Land GmbH : field work, processing, reporting, management etc. in Projects of following disciplines

- Engineering Geophysics (magnetics, Rx/Rf seismics, ERT)
- Borehole Seismics (DH/CH-Test, P/S-CH-Tomography, SCPT)
- Wireline logging
- Water Geophysics (´Wageo` methods)

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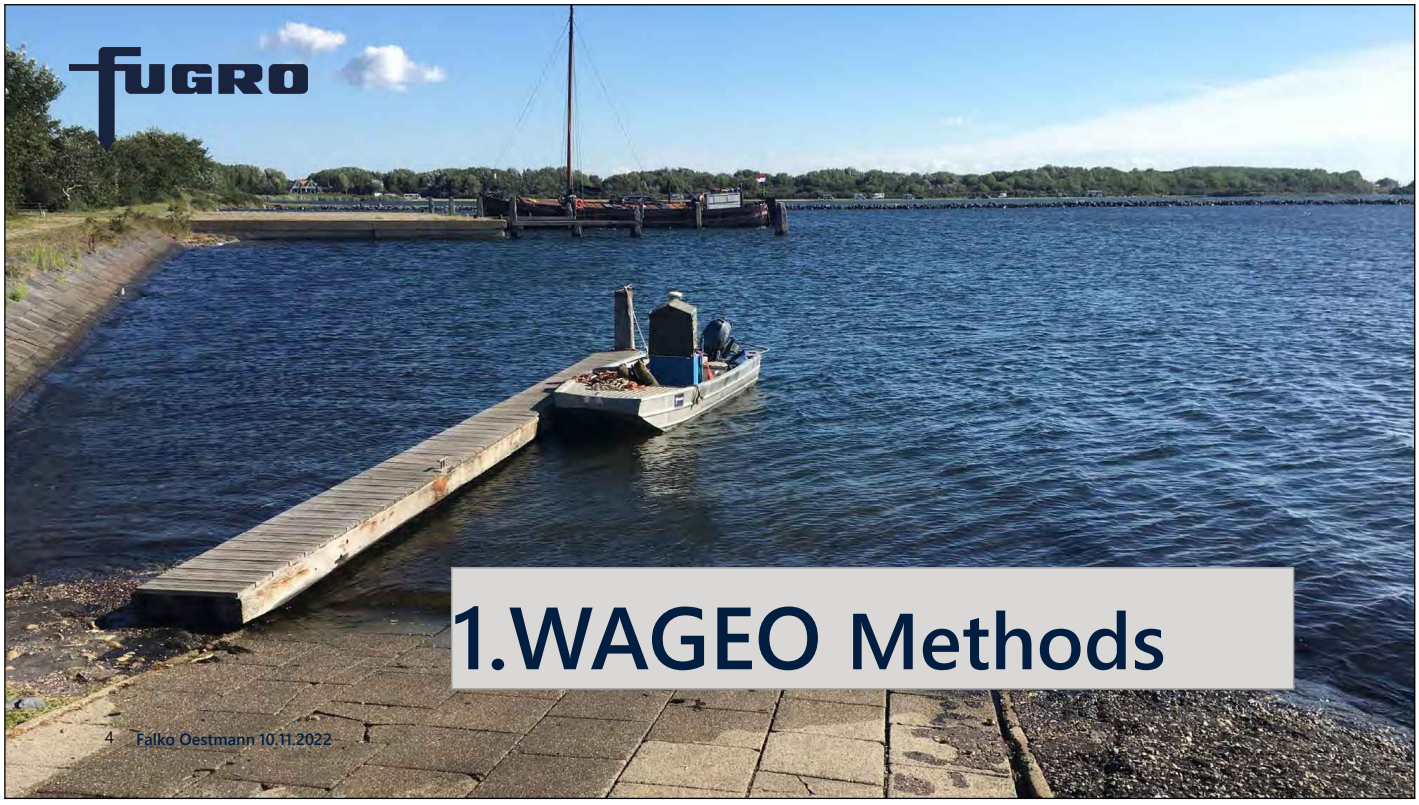
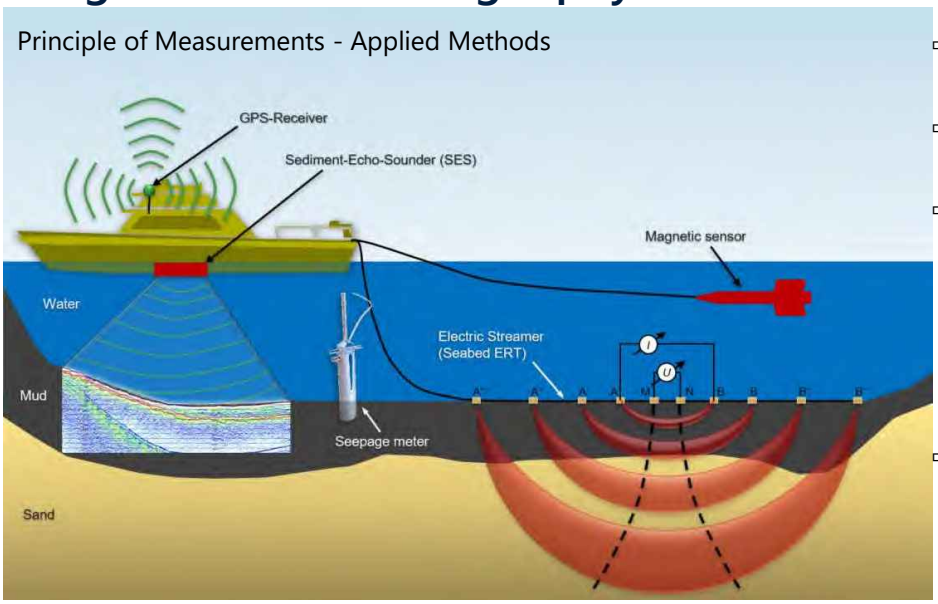


Fugro shallow water geophysics - WAGEO®



- ⇨ Application of seabed ERT, SES and positioning
- ⇨ Complex processing and interpretation
- ⇨ Seepage meter for determination of water exchange behaviour (transmission rate and direction) with ground water
- ⇨ Determination of water parameter (conductivity, temperature, redox, ph)

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WAGEO – application areas

- Channels
- Open pit mining (aktive / abandoned)
- Water storage dams
- Settling ponds
- Retention basins
- Rivers
- Lakes

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2.

Example 1 (anonym) : Fluid Mud Survey in Settling Pond

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Example 1: Settling Pond

- Consulting for this project for over a decade
- development of survey methods…
  - Water geoelectrics (VES/ERT with floating streamer)
  - Gamma-Gamm-density log
  - different SBPs…
  - Finally, SES-system in combination with probing (pumped samples from various depth levels)
- Goals:
  - Exact Fluid mud level determination
  - Prevent overflow event / burden of proof in regard to authorities
  - Estimation next desludging campaign

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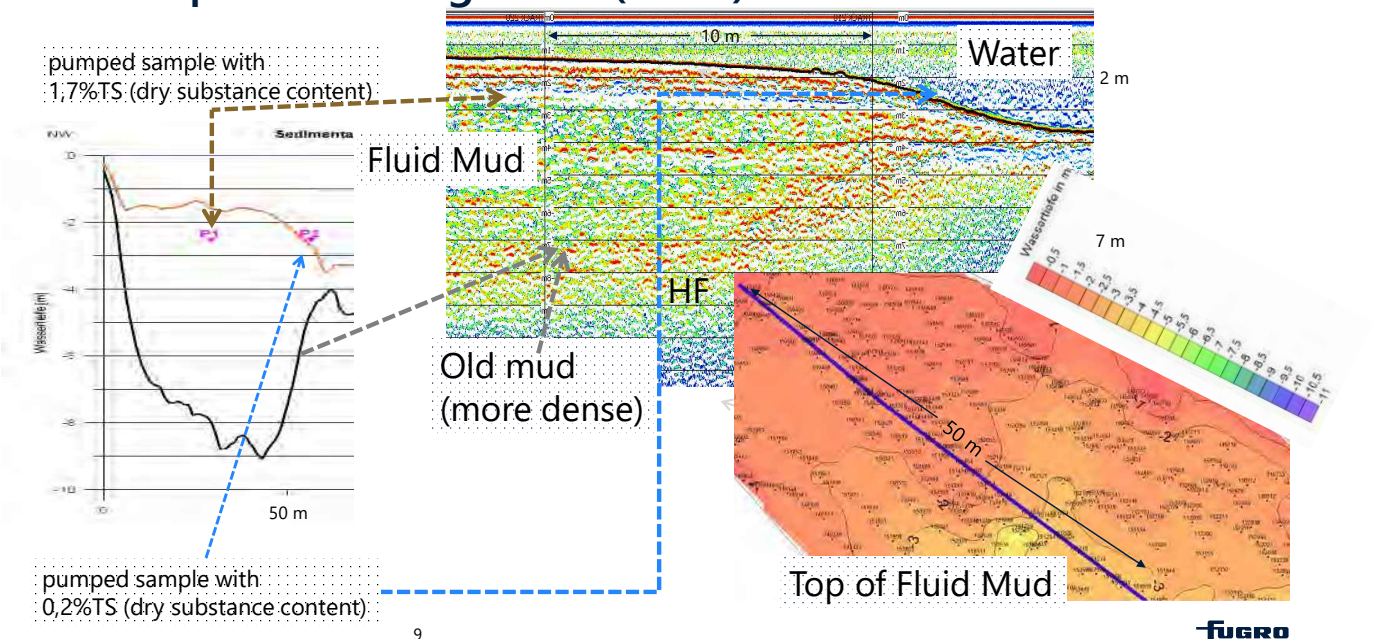
Example 1: Settling Pond (filled)



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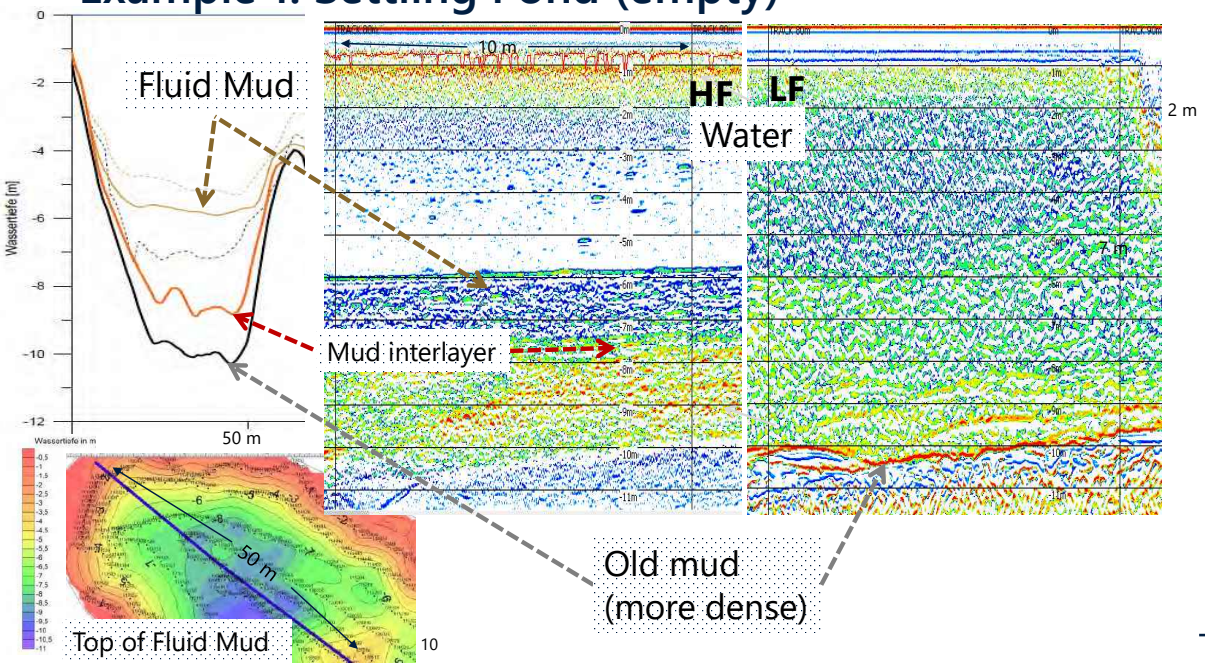
Example 1: Settling Pond (empty)



3.

Example 2 :
Armour Layer Survey
Hollandse Ijssel / Rotterdam NL

11 11

Armour layer at toe of dyke in Rotterdam

- Geotechnical problem: Assessment of "hidden" (below top mud layer) armour layer which is a main factor in the outward stability of the embankment alongside big rivers like Hollandse Ijssel
- Assessment by drilling, excavation or diving requires lots of effort, hence very expensive, also not very eco-friendly and might miss smaller-scale changes/undulations
- Geophysical approach to detect the armour layer using parametric sub-bottom profiler (SBP) and to map the soil layers (eventually further indicate the armour layer) using combined land and water electrical resistivity tomography (ERT)

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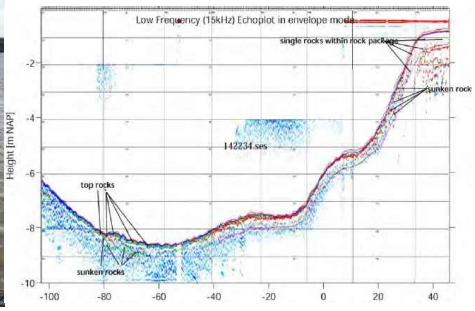
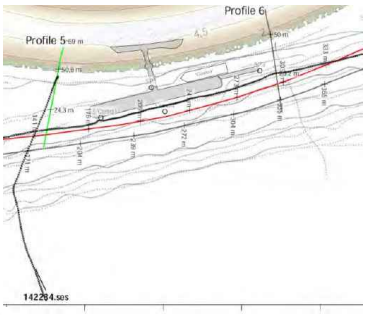
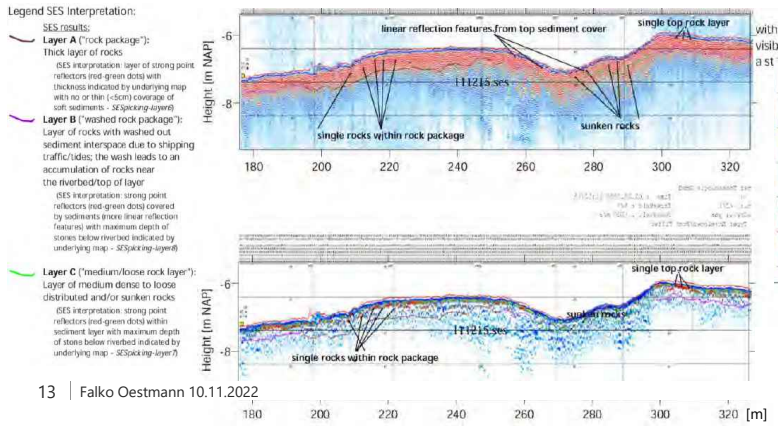
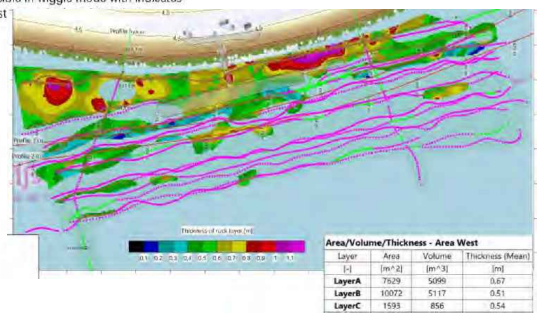
SES example Hollandse Ijssel P1/P5: LF / LF-wiggle / Interpretation









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SBP + ERT

- Combined approach as SBP penetration could be limited by multiple reflections on larger stones and ERT resolution could be too coarse to resolve thinner stone layers
- Survey using continuously acquiring in-house-developed underwater streamer design, dragged by a small boat
- Combined land and water ERT profiles to obtain cross profiles over full length
- Correlation of all geophysical results with available boreholes
- Result: Classification of armour layer condition and thickness (SBP) and overall sediment distribution (ERT)
- Very good correlation of SBP interpretation and diving inspection in similar project

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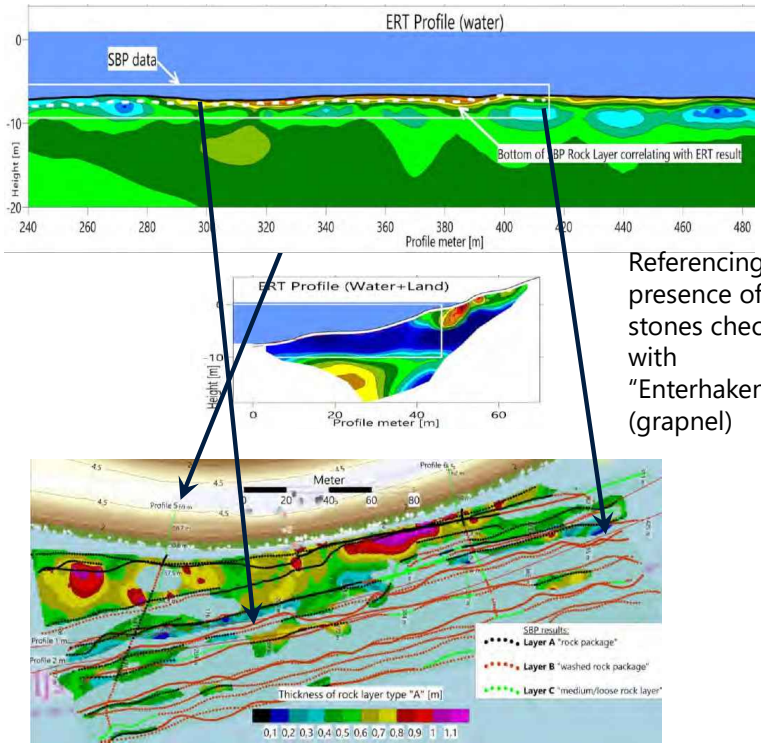

Referencing: presence of stones checked with "Enterhaken" (grapnel)

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4.

Example 3 :

Armour Layer Survey Hollandse Delta (Grevelingenmeer (salt water) NL

15 15

SES example Grevelingenmeer-P2: HF / LF LF-wiggle / Interpretation / referenced

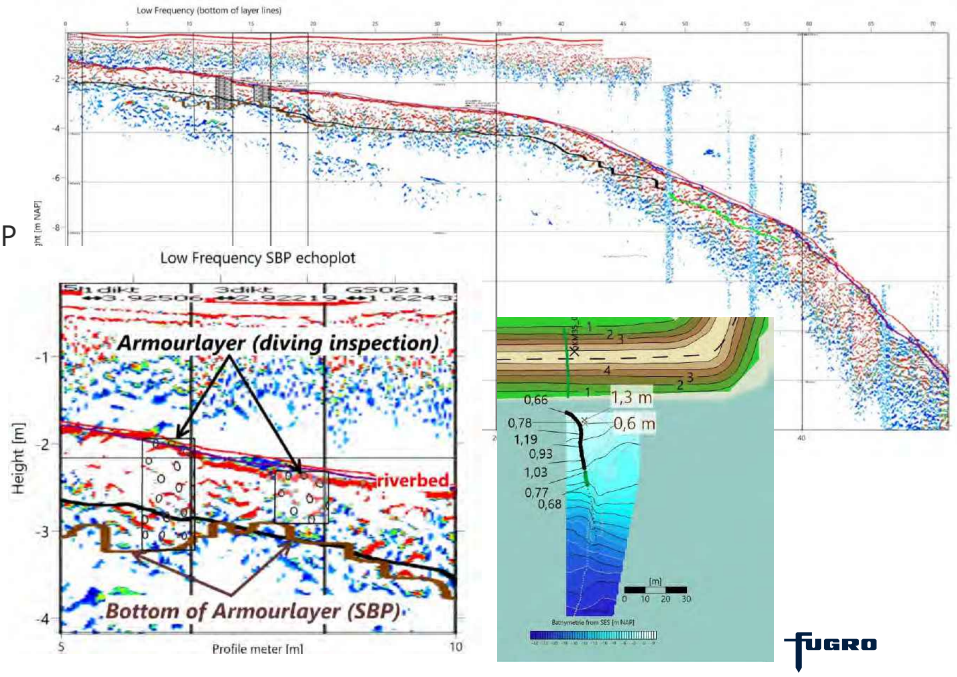
Very good correlation of SBP interpretation and diving / jetstream inspection

Legend SES Interpretation:

SES results:

Layer A ("rock package"):
Thick layer of rocks
(SES interpretation: layer of strong point reflectors (red -blue dots) with thickness indicated by underlying map with no or thin coverage of soft sediments - *SESpicking-layer5*)

Layer C ("medium/loose rock layer")
Layer of medium dense to loose distributed and/or sunken rocks
(SES interpretation: strong point reflectors (red-green dots) within sediment layer with maximum depth of stone below riverbed - *SESpicking-layer8*)



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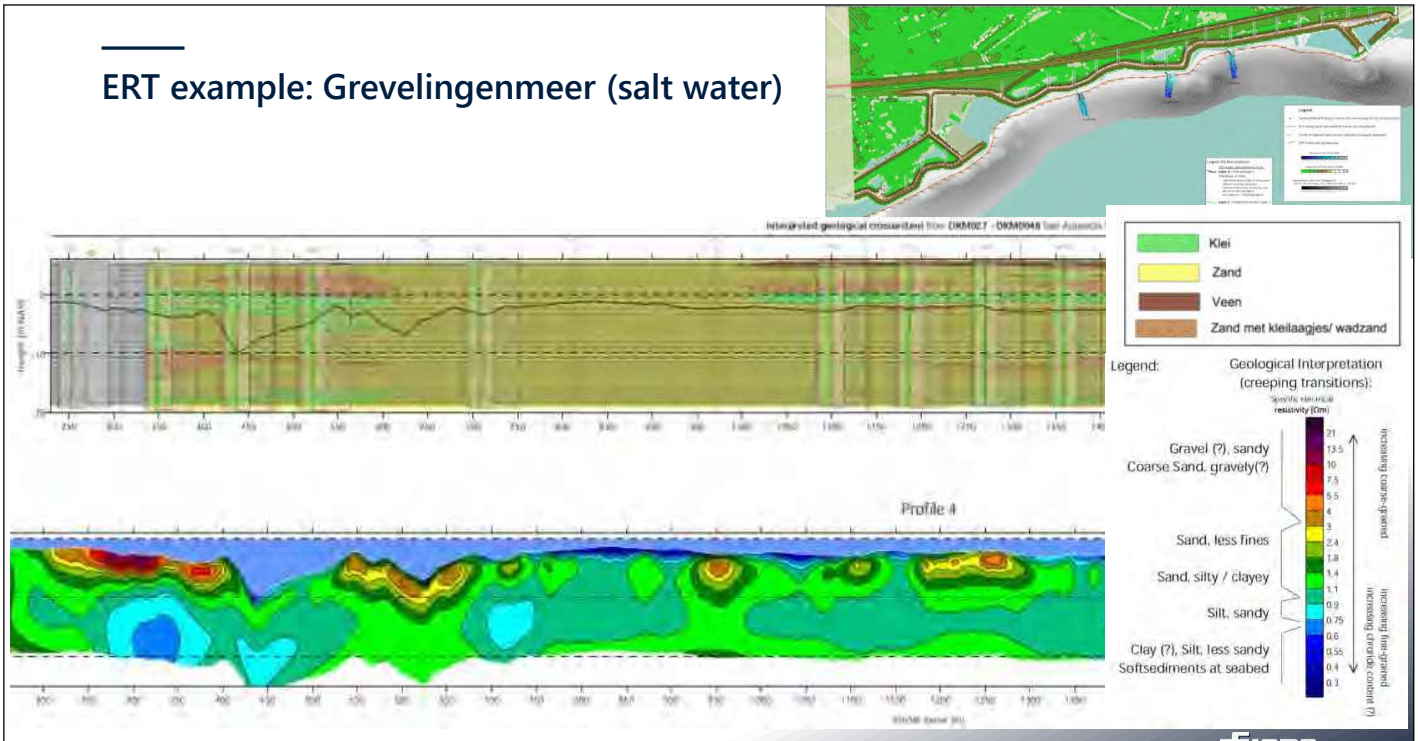
ERT example: Grevelingenmeer (salt water)



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5.

Example 4 :

Storage Basin Sediment Survey Kinzigtalsperre, Germany

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Wasserverband Kinzig
Körperschaft des öffentlichen Rechts

1. Deriving the volume of soft sediments in regards to preparing tender documents for desludging campaign
2. Utilizing SES for Bathymetrie (incl. "sunken bridge and tracks"
3. and UW-ERT + sediment probing for soft sediment thickness determination

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Storage Basin Sediment Survey Kinzigtalsperre

Wasserverband Kinzig
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SES in the moon pool below

Motion sensor (left) and GPS-pole,

SES Standard system strapped on the box

UW-ERT streamer on deck,

Navigation laptop on the blue box,

Logging laptop within the blue box

Sediment probing

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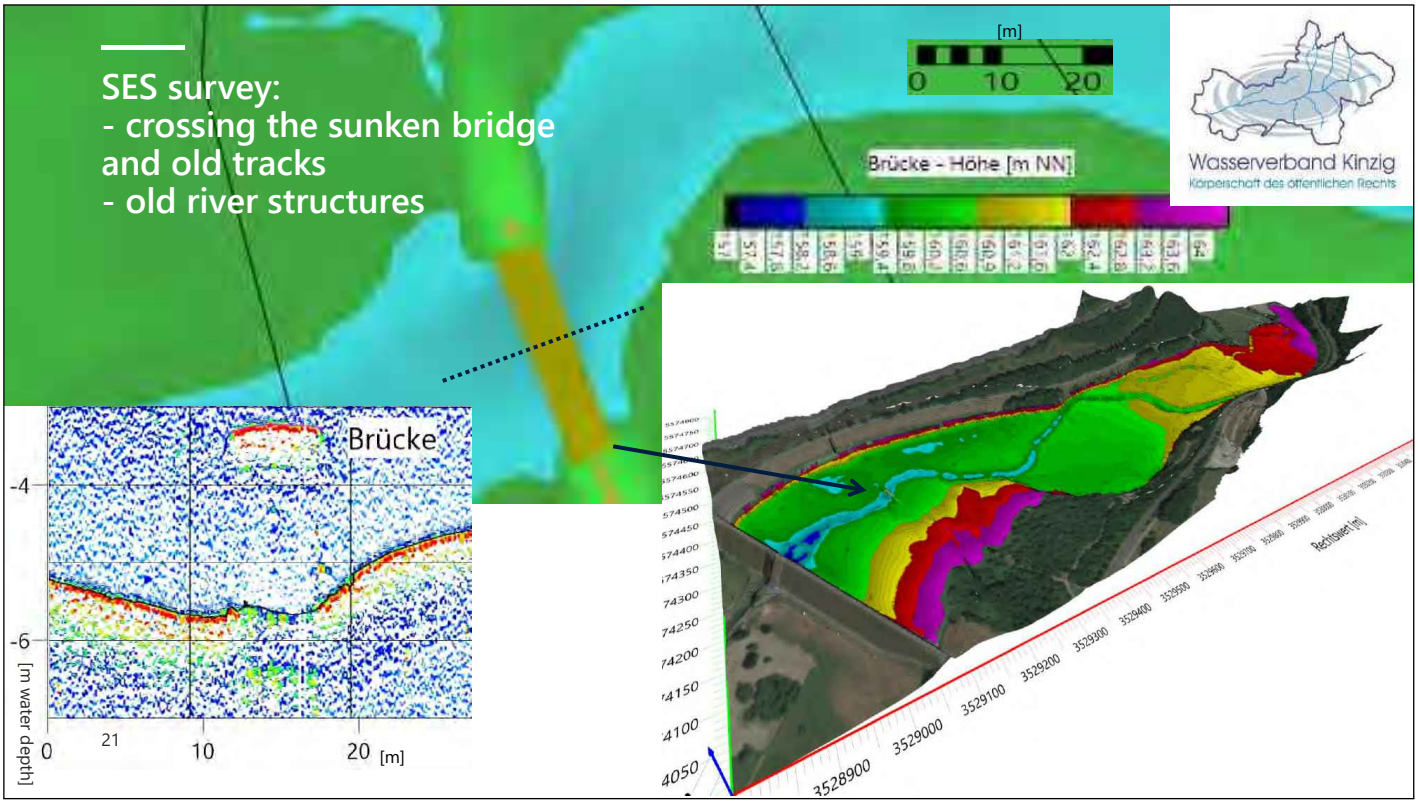
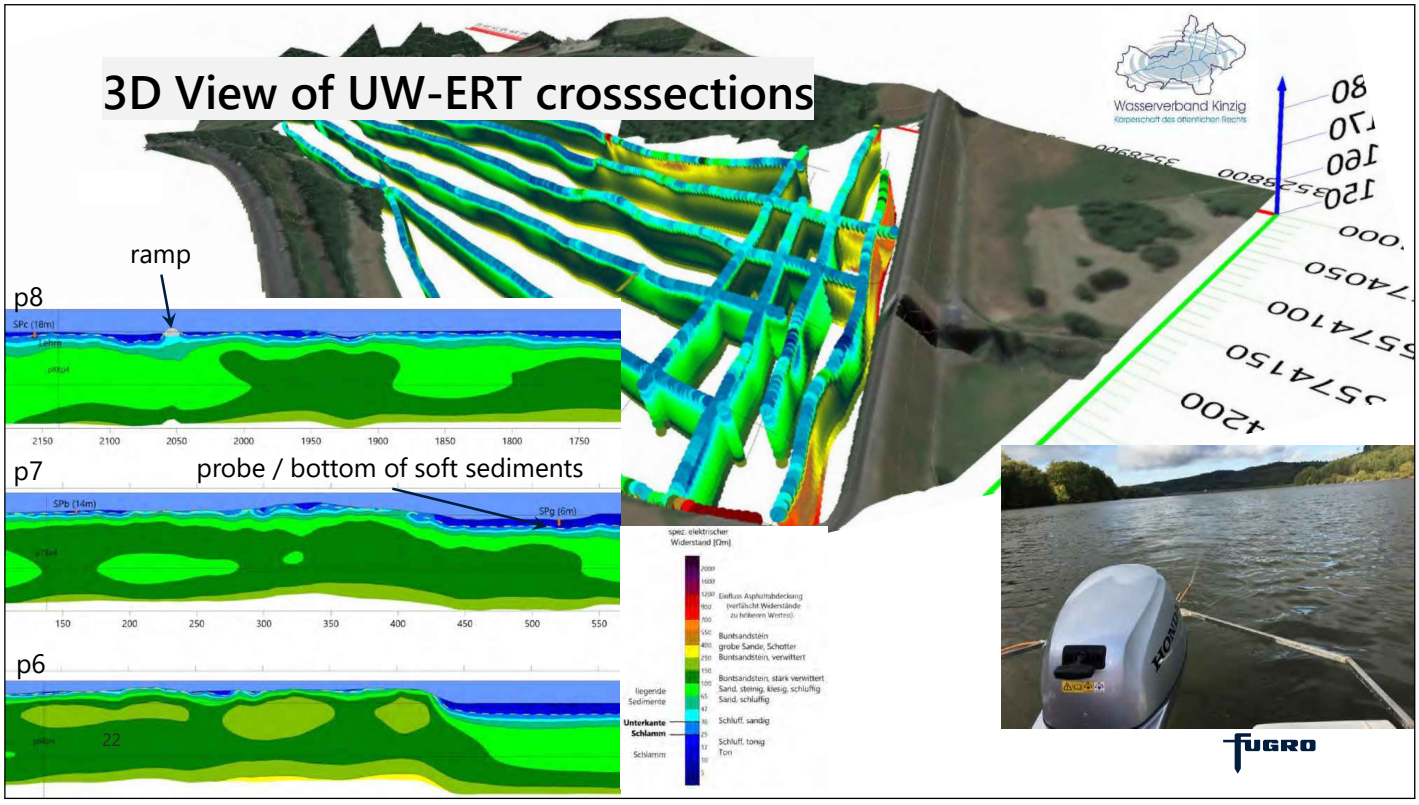
SES survey:
- crossing the sunken bridge and old tracks
- old river structures



Wasserverband Kinzig
Körperschaft des öffentlichen Rechts


3D View of UW-ERT crosssections
Wasserverband Kinzig
Körperschaft des öffentlichen Rechts
ramp
p8
p7
probe / bottom of soft sediments
p6
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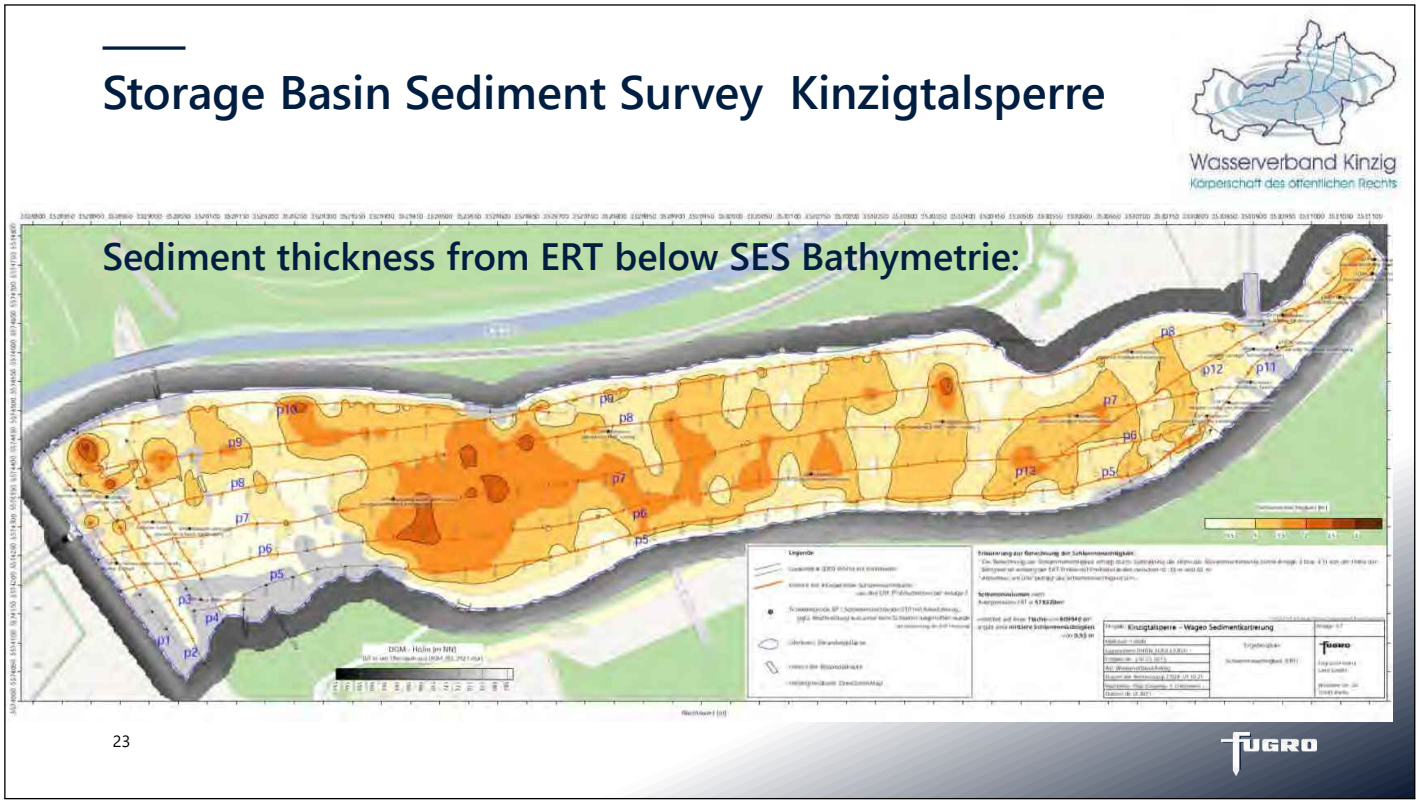
Storage Basin Sediment Survey Kinzigtalsperre
Wasserverband Kinzig
Körperschaft des öffentlichen Rechts
Sediment thickness from ERT below SES Bathymetrie:
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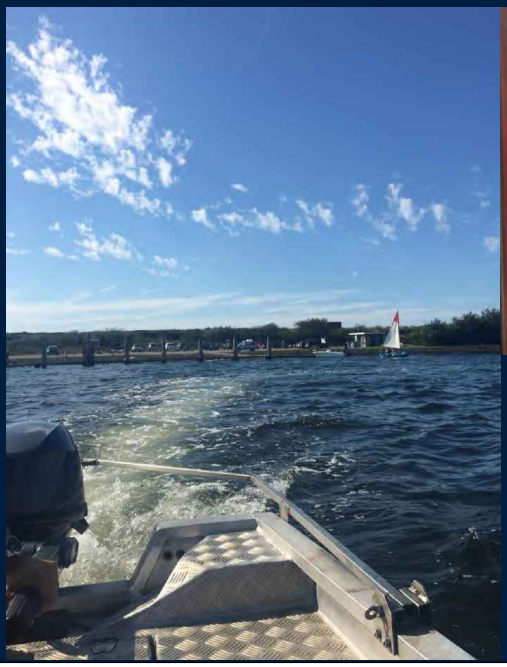
Together we create a safe and liveable world



Thanks much!

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SES examples Grevelingenmeer P1: LF / HF / LF-wiggle / Interpretation

Legend SES Interpretation:

SES results:

Layer A ("rock package"):
Thick layer of rocks
(SES interpretation: layer of strong point reflectors (red-blue dots) with thickness indicated by underlying map with no or thin coverage of soft sediments - *SESpicking-layer5*)

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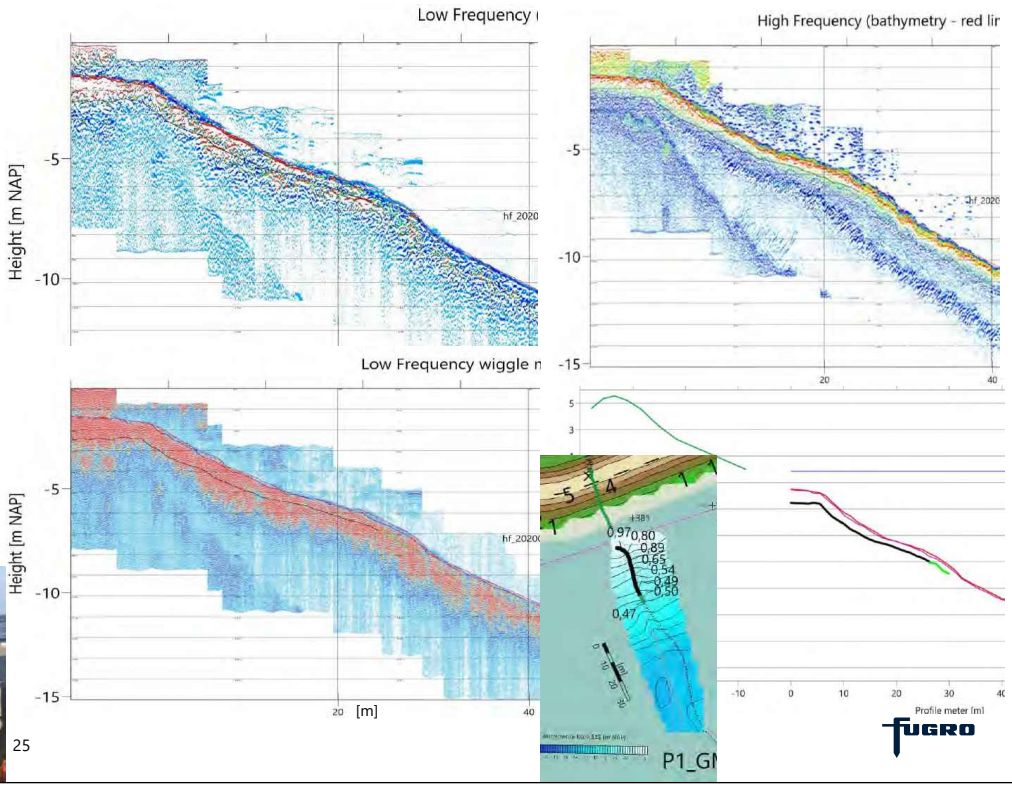

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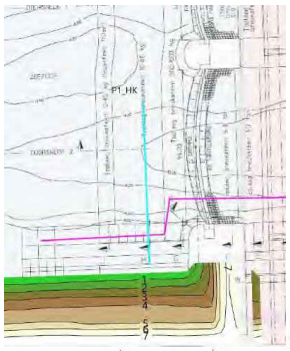
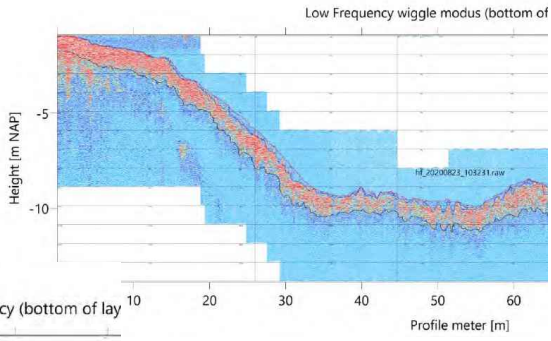
SES example Hartelkanaal-P1: LF / LF-wiggle / Interpretation / old map





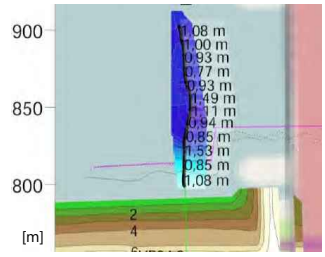
Legend SES Interpretation:

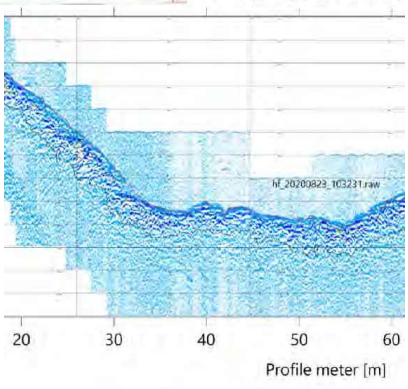
SES results:

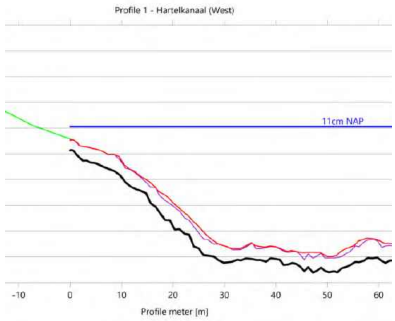
Layer A ("rock package"):

Thick layer of rocks

(SES interpretation: layer of strong point reflectors (red-blue dots) with thickness indicated by underlying map with no or thin coverage of soft sediments - *SESpicking-layerS*)







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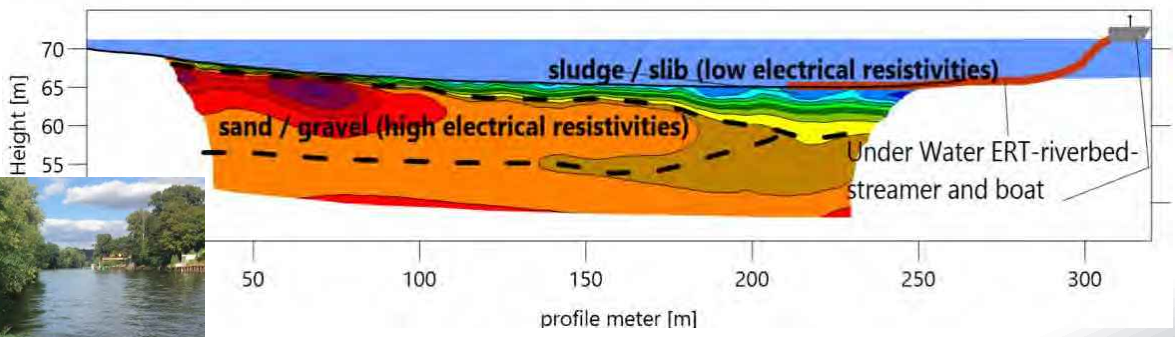
Underwater-ERT Setup and example of interpreted crosssection



Note:
Due to process related reasons (prerun of the ERT-streamer to the boat and the distance of
approx. 40m between 1. electrode at the beginning of the cable and the maximum penetration depth in the middle of the cable) "white" areas are present as shown in the ERT section where no resistivities can be measured. These "white" areas where the active cable is spread along are necessary to measure the maximum penetration in the middle of the cable.

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Case Study

Reservoir investigation at dam Kinzigtalsperre in Germany

Client
Wasserverband Kinzig

Regions
Europe

Location
Kinzigtalsperre

Project Duration
08/2021 – 12/2021

Industries
Land Site Characterisation

Solutions
Hydroacoustics, geoelectrics, sampling

22.000
EUR

Falko Oestmann[1], Alexander Eifert[1]
[1]Fugro Germany Land GmbH, contact: f.oestmann@fug ro.com / a.eifert@fugro.com

We present a multi-method reservoir investigation at dam Kinzigtalsperre in Germany.

Challenge

In preparation of a mud extraction campaign the reservoir at Kinzigtalsperre needed to be investigated to retrieve detailed information about the sediment distribution and thickness as well as the current bathymetry.

Solution

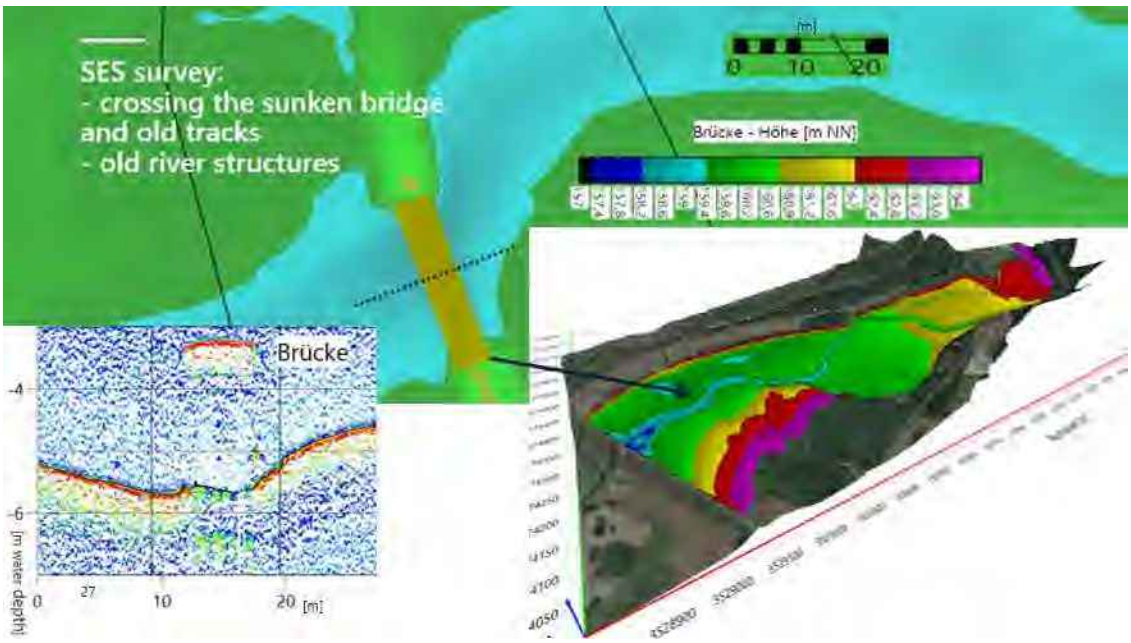
We utilized parametric sediment echo sounding (SES) in combination with our own-developed underwater geoelectric streamer to derive bathymetry and sediment distribution up to about 10-15 m below the water bottom. For correlation purposes we took some direct mud samples during the fieldworks and were provided with legacy data (drillings) from the client.

Results

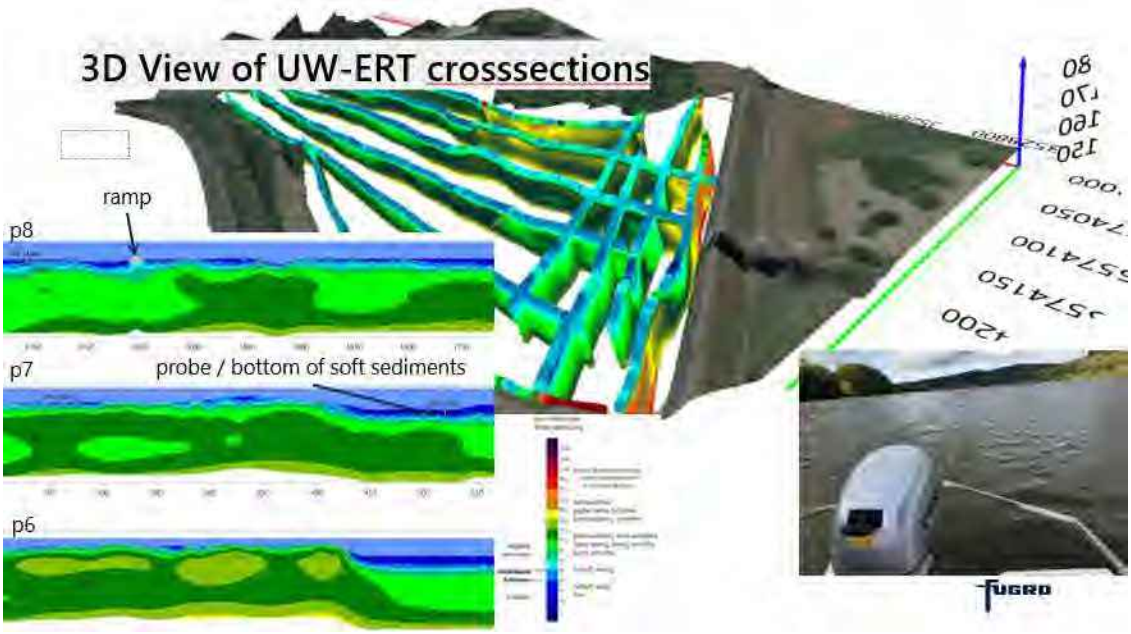
An Innomar SES-2000 compact was primarily used to retrieve the bathymetry. The mapping revealed some very interesting features like a sunken bridge and old tracks as well as the old river bed.

Case Study

Reservoir investigation at dam Kinzigtalsperre



The underwater geoelectrics showed different mud and soil strata up to about 15 m depth below water bottom. The 2.5D visualization and interpretation resulted in overview maps of sediment depth and thickness as well as volume estimations and cross-sections at representative profiles.



Case Study

Mud thickness monitoring in settling pond using hydroacoustics, Germany

Falko Oestmann[1], Alexander Eifert[1]
[1]Fugro Germany Land GmbH, contact: f.oestmann@fugro.com / a.eifert@fugro.com

We present a 20+ years mud thickness monitoring using hydroacoustics in a settling pond in Germany.

Client
Public water service provider

Regions
Europe

Location
Germany

Project Duration
2001 - ongoing

Industries
Land Site Characterisation

Solutions
Hydroacoustics, Sampling

200.000
EUR

Challenge

Sediments from mining activities are settling in a pond and must be regularly extracted/excavated. Monitoring of the mud thickness is key to keep track of the mud accumulation and to plan for the next extraction campaing.

Solution

After testing numerous survey methods including geoelectrics and density logging, hydroacoustics in the form of parametric sediment echo sounding (SES) in combination with direct mud sampling provided the most accurate and reliable results.

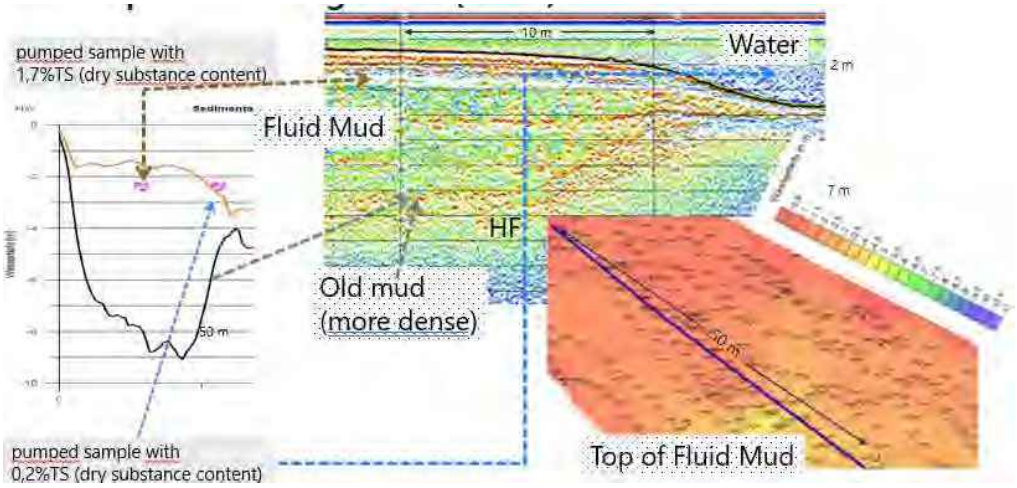
The sediment monitoring started in 2001 and is still ongoing and hence amongst our longest-running projects at Fugro Onshore Geophysics Germany. Survey campaigns take place at least once per year during the settlement periods with additional surveys directly before and after the extraction campaigns (for mud volume estimation and QC of extraction, respectively).

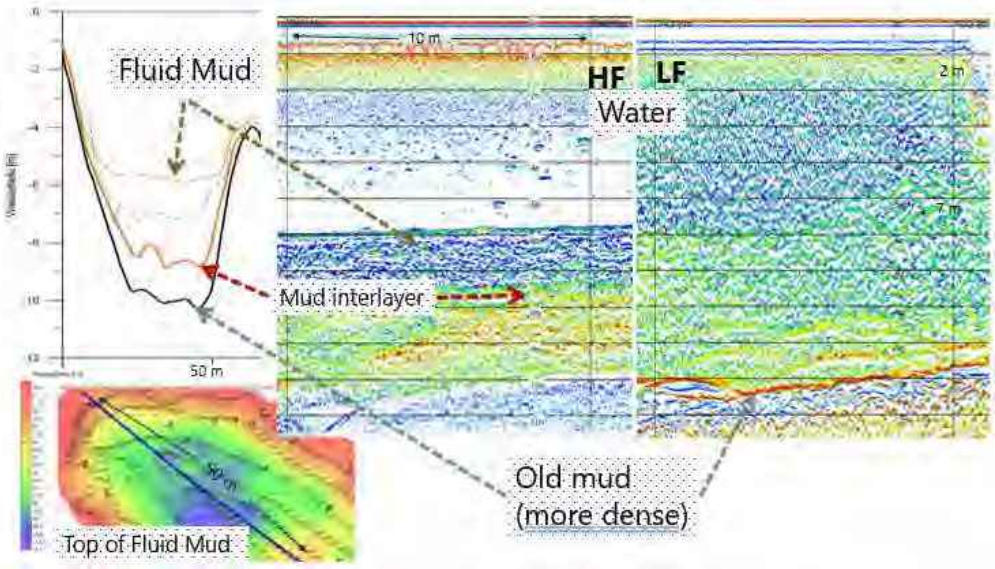
Case Study

Mud thickness monitoring in settling pond using hydroacoustics, Germany

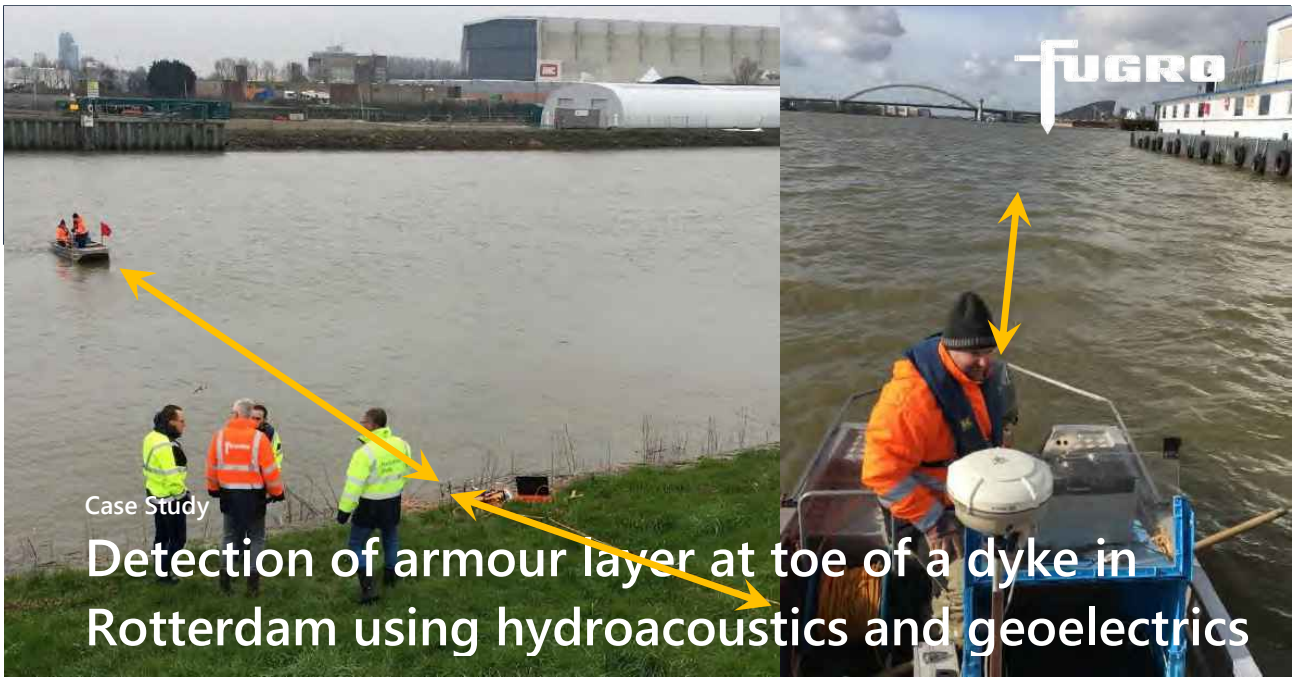
Results

Using the Innomar SES-2000 compact, we can map the complex mud strata during the settlement process in high detail and provide volume estimations. The surveys are regularly accompanied by sampling campaigns to cross-check and correlate the results with the dry-substance content of samples.





The client is finally provided with overview maps showcasing mud layer depths, mud thickness and bathymetry along with cross-sections and volume estimations which are directly converted to time estimates for the settlement process until the next extraction campaign must be carried out.



Case Study

Detection of armour layer at toe of a dyke in Rotterdam using hydroacoustics and geoelectrics

Falko Oestmann[1], Alexander Eifert[1]
[1]Fugro Germany Land GmbH, contact: f.oestmann@fug ro.com / a.eifert@fugro.com

We present a multi-method approach for the detection of an armour layer beneath the river bottom as part of the primary dyke at Hollandsche IJssel in Rotterdam.

Client
Hoogheemraadschap van Schieland en de Krimpenerwaard

Regions
Europe

Location
Rotterdam

Project Duration
02/2020 – 04/2020

Industries
Land Site Characterisation

Solutions
Hydroacoustics, geoelectrics

17.000
EUR

Challenge

A "hidden" (below top mud layer) armour layer needed to be geotechnically assessed. The armour layer is a main factor in the outward stability of the embankment alongside big rivers like Hollandse Ijssel in Rotterdam. Conventional assessment, i.e. by drilling, excavation or diving, requires lots of effort and is hence very expensive, also not very eco-friendly and will likely miss smaller-scale changes/undulations which could have a significant impact on the overall assessment.

Solution

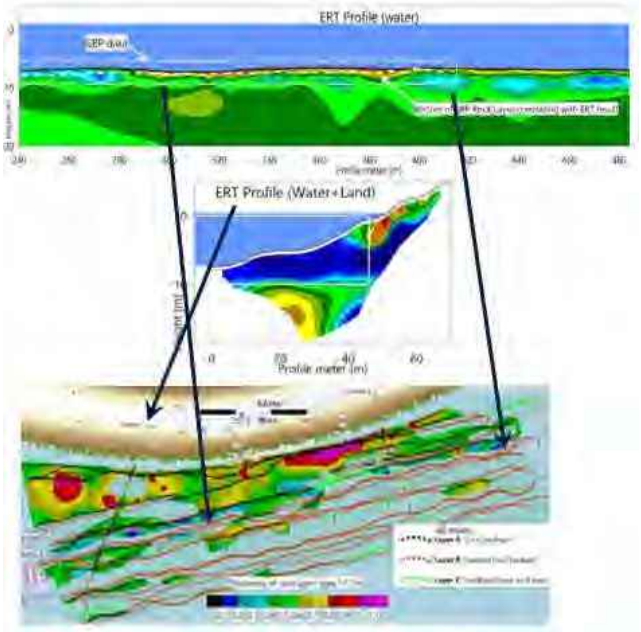
We utilized parametric sediment echo sounding (SES) in combination with our own-developed underwater geoelectric streamer and conventional land-based geoelectrics (seamless transition at the water line) to detect the boulders of the armour directly and map the soil layers, respectively. Results were also correlated to direct investigations (drillings as well as a later diving campaign).

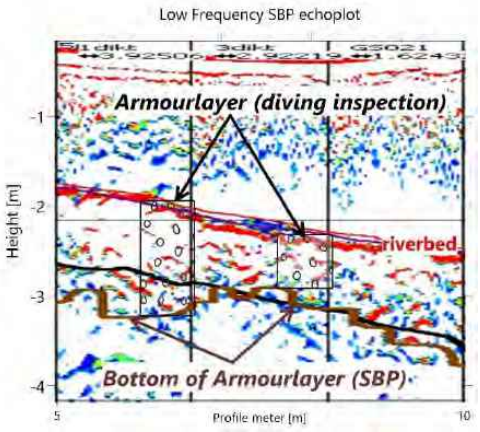
Case Study

Detection of armour layer at toe of a dyke in Rotterdam using hydroacoustics and

Results

Both methods have limitations which were expected to impact the performance on this specific task: the SES signal is likely to be scattered a lot off the top boulders while the geoelectrics typically lack the resolution in the first decimeters of the ground and the electric properties are likely to be defined merely by the mud filling between the boulders instead of the boulders directly. The combination of both methods however countered the respective limitations at least to a large part, allowing us to map the armour layer in great detail and achieving very good correlation with results of a diving campaign at a later stage of the project.





The client was finally provided with overview maps showcasing the retrieved status classification of the armour layer as well as its thickness.