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GEOPHYSICAL MONITORING OF LARGE-SCALE LEVEE OVERFLOW EXPERIMENTS WITH ELECTRIC RESISTIVITY TOMOGRAPHY

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Large scale overflow experiments allow testing erosion resistance of levee slopes under variable conditions, such as different soil parameters, grass lengths, presence of trees and presence of animal burrows. Within the scope of the Interreg-funded project Polder2C's an extensive series of such experiments took place in Belgium and the Netherlands in 2020-2022 (Koelewijn et al. 2022). A variety of techniques was used to monitor critical parameters of those experiments, many of which were tried for the first time. One of them was Electric Resistivity Tomography (ERT) that was used to provide a time-series of images illustrating changes in the levee subsoil during testing. The experiment took place on a levee section where mole burrows had been previously detected, and where the presence of an extensive subsurface system of mole tunnels had been verified on the landward slope of the levee (figure 1).

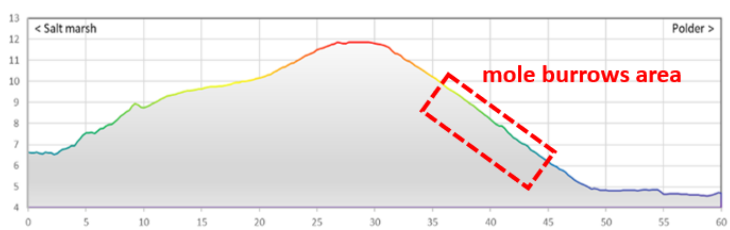

Figure 1. Levee cross section at test location with the position of the mole burrows highlighted.

Subsurface electrical properties are a function of (among others) soil type, fluid chemistry and air/fluid saturation and temperature. Changes in these properties (e.g. animal burrows that are filled with air or water) are indicative of numerous processes. Electrical geophysical methods can map the spatial distribution of these properties by utilizing the Electrical Resistivity Tomography, ERT. By using these methods in a time-lapse mode (in which surveys are collected periodically using the same cables and acquisition geometries) one can obtain data on changes in time of these properties for the surveyed area. These data in turn can be used to visualize the complex processes in the subsurface and improve our knowledge of these processes (Revil, 2012).

For the field measurements a combined configuration of gradient and dipole-dipole electrodes was used. The electrodes were installed along the experimental flume and parallel to each other, one as a main receptor and the second for back-up. On each line, 82 basic metal electrodes were placed at 10cm intervals (figure 2). These measurements were conducted using the MPT DAS-1 system, which had a maximum transmitted voltage, current, and power of 480 V, 2500 A, and 250 W, respectively. During the data acquisition process, two sets of measurements were taken for each combination of transmitter and receiver electrodes to improve the signal-to-noise ratio. Five data sets were collected. The first one was a static, reference dataset before the experiment started. The other four are time series that correspond to four different flow rates that were tested. The data was pre-processed performing a geophysical inversion using Res2DINV (Loke 2010) software packages.

This analysis aimed to evaluate the effects of various inversion options, such as applying smoothing techniques to control the sharpness of transitions between different geological layers, and to identify common features in the results for confident interpretation.

Four types of phenomena were recorded;1) existing mole tunnels in the subsurface being filled with water; 2) creation of new cavities (i.e. gaps filled with air or water in the subsurface); 3) collapsing of cavities; 4) cavities starting to connect with each other (see e.g. in figure 3). The measured changes were well above noise level, hence can be considered reliable. This provides confidence that the method is suitable for monitoring subsurface changes during overflow levee experiments.

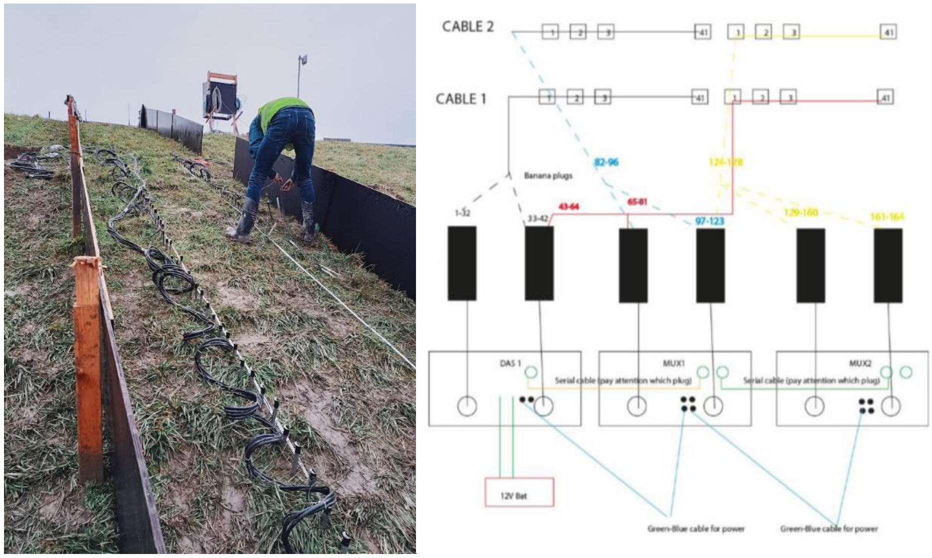

Figure 2. Left: Installation of the ERT cables. Right: Detailed sketch of the ERT unit used to measure and the pin locations.

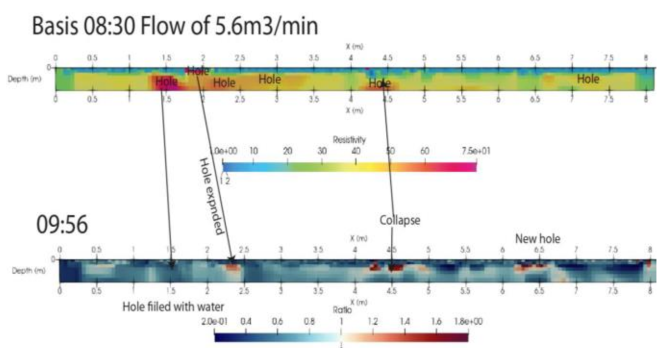

Figure 3. ERT images after a testing interval of 1 hr and 26 min. Top figure shows the resistivity structure of the subsurface, where high resistivity values (red) indicate the presence of multiple holes. The ratio images show that we have water infiltration in the top 25cm of soil.

A preliminary analysis of the results shows a correlation between flow rate and rate of observed changes in the subsurface. The detailed recording of the development of the four abovementioned phenomena over time and space provide information that appears to be promising for simulation of internal erosion processes. A systematic collection and analysis of such data in the future can be a valuable resource for model validations.

Any attempt to apply this method in the future requires attention to the presence of metal objects in the experimental set-up. The metal frames that were used for the sensors and cameras of the overflow experiment did not influence the results at this instance. But larger metal objects in the flume could have influenced the quality or results.

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