Large-scale, probabilistic airborne salinity mapping for groundwater management in Zeeland, The Netherlands

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ABSTRACT

Groundwater resources in the Province of Zeeland, the Netherlands, have been largely salinised during marine transgressions, and fresh water is scarce. The area is both an agricultural and tourism hotspot, putting stress on the available fresh groundwater resources. Climate change and sea-level rise are expected to exacerbate problems with freshwater availability. Successful management of the scarce fresh groundwater resources requires a detailed picture of their spatially variable occurrence. In FRESHEM Zeeland, we surveyed the entire Province of Zeeland using a frequency-domain helicopter-borne electromagnetic system. The large-scale airborne survey consisted of over 9000 line-km. Survey results were translated into a 3D salinity distribution using a novel probabilistic approach. This approach aimed to recognize the uncertainty associated with the different steps in the procedure. We applied a Monte Carlo procedure to incorporate three different geophysical inversion models, stochastic lithological models of the subsurface, and a range of Archie's formation factors to translate subsurface resistivity into probability distributions of groundwater salinity. Indicator kriging with locally varying anisotropy was finally applied to obtain a 3D image of groundwater salinity. This applied interpolation procedure aimed to preserve small-scale landscape features such as creek ridges, that form important controls on groundwater salinity in the area. The approach successfully resulted in a full 3D mapping of the probability distribution of chloride concentrations for an area of about 1800 km². Uncertainty analysis showed that the geophysical inversion model was the largest contributor to the uncertainty in our results. Exciting results include vast fresh groundwater volumes under saline marine deposits (salt-fresh inversions), offshore fresh groundwater, and newly discovered fresh groundwater occurrences.

FRESHEM results were well received by stakeholders and were made available to the public (https://kaarten.zeeland.nl/map/freshem). Interestingly, stakeholders were well able to handle the uncertainty in the results, after providing guidance and deriving tangible uncertainty measures. Examples of the immediate uptake of the results include: a. the guiding of farmers in their use of fresh groundwater resources, b. used as starting concentration in density dependent groundwater model of Zeeland, c. a new basis for groundwater extraction zoning, and d. updated feasibility maps of different agricultural aquifer storage and recovery measures.

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