# A Quantitative Review of 1D Airborne Electromagnetic Inversion Methods: A Focus on Fresh-Saline Groundwater Mapping

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## ABSTRACT

An accurate understanding of the fresh-brackish-saline distribution of groundwater is necessary to characterise salt water intrusion in coastal areas. Compared to traditional ground-based techniques, airborne electromagnetic (AEM) surveys offer a rapid and cost-effective method with which to achieve this. To convert observed AEM data into Electrical Conductivity (EC) (and ultimately groundwater salinity), an inversion is undertaken. As geophysical inversion is an ill-posed problem, these inversion algorithms need stabilisation (otherwise known as regularisation). A number of algorithms are available for this purpose, however recent research has shown that the inversion process adds significant uncertainty into groundwater mapping results. This study quantitatively analyses eight commonly used inversion methods using real data from the Province of Zeeland, the Netherlands. Available data includes ~1000 line km of frequency domain airborne electromagnetic data, ground data comprises more than 40 drillholes - measuring bulk EC using electrical cone penetration tests (ECPT) and electrical borehole logging. Ground data were used to select parameter inputs and quantify results, rather than to constrain the inversions. Inversions tested were both 1D, and comprise UBC1DFM code and quasi-2D laterally constrained techniques. Input parameters in these schemes were varied and run iteratively over one test line. Selected parameters were based on closest fit to nearby ground constraints, and a reasonable misfit to the observed data. Subsequently, each inversion was run over the entire data-set and interpolated into a 3D volume of EC. Using available geological data and empirical EC and water salinity relationships, 3D volumes for each inversion were converted into groundwater EC and split into fresh-brackish-saline regions. The result is a detailed 3D map of the groundwater salinity distribution for each of the eight inversion results, with a horizontal and vertical resolution of 50m and 0.5m respectively. Qualitatively, inversion methods tested were generally consistent with one another, and were effective at resolving a number of hydrological features such as fresh-brackish-saline volumes and interfaces. A quantitative analysis indicated that the choice of inversion code has a notable effect on groundwater mapping outcomes. For volume estimates, the primary factor in the inversion process was the choice of smoothness, which affects the thickness of the brackish interval (0.18 – 1.8 S/m). Here it was found that a fresh (< 0.18 S/m) groundwater volume estimate could differ by as much as 7% between algorithms - a difference of 195 million $m^3$ in an area of only ~15x15 km. Interfaces between fresh-saline-brackish regions were consistently mapped by all methods within an absolute error of around 3 m. As the greatest vertical conductivity contrast exists in the brackish zone, this zone was mapped with greater accuracy overall. Few layer methods were less successful at resolving smoothly varying salinity distributions, however, these methods were on the contrary shown to be more successful at mapping the centre of the brackish zone (0.54 S/m) at greater depth.