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Advancing Seismic Refraction for Hydrogeological Characterization in Unconsolidated Sediments of the Brazilian Amazon Region (Belém-PA)

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Introduction

The metropolitan region of Belém-PA is characterized by unconsolidated sediments (sands, silts, and clays) typical of alluvial deposits and the Barreiras Group. Due to their low cohesion, these materials may affect seismic wave propagation, raising questions about the efficacy of the seismic refraction method in this context. This study aims to evaluate the applicability of this technique in characterizing the water table and subsurface structures in the Utinga State Park, contributing to hydrogeological investigations in Amazonian environments. Seismic refraction, based on the analysis of P-wave arrival times, is widely used to identify velocity contrasts between geological layers. Its application in Utinga Park is justified by the need for non-invasive and reliable methods in a strategic water supply area for Belém, particularly given the increasing impacts of urbanization on groundwater resources. The results may support future research in regions with similar geology, reinforcing the role of geophysics in the environmental management of sensitive urban areas.

Method

The study employs seismic refraction surveys using a 24-channel geometrics seismograph with high-frequency geophones (4.5 Hz or 14 Hz) spaced at 2–5 m intervals, depending on target resolution. Hammer-impact (10–20 kg) will generate P-waves, with shot points positioned at offsets of 0%, 20%, 40%, 60%, 80%, and 100% along the profile to optimize first-arrival coverage. Raw data will undergo processing to remove noise, correct timing errors, and pick first arrivals using open-source tools (e.g., ObsPy or ReflexW). For inversion and modeling, the dataset will be imported into pyGIMLi (Python-based Geophysical Inversion and Modelling Library). The TravelTimeManager module will perform 2D tomographic inversion, generating velocity models through adaptive meshing and iterative regularization to resolve subsurface layering. Sensitivity tests will evaluate model robustness. Finally, results will be integrated with hydrogeological data from monitoring wells and existing resistivity surveys (e.g., ERT profiles) to constrain the water table depth and validate lithological contrasts. This multi-method approach ensures reliable subsurface characterization while leveraging open-source tools for reproducibility.

Conclusions

This study proposes a sustainable, replicable, and open-source approach for aquifer investigation in sensitive urban areas. By testing refraction seismics in unconsolidated soils and integrating it with hydrogeological and electrical data, it aims to support water resource investigations in Utinga Park while providing technical informations for similar geological settings. The combination of methods highlights geophysics potential as a tool for environmental management in complex urban contexts.