Gravimetric Detection of Subterranean Fuel Tanks

Jeffrey Kucerak, Max Mendiola, Department of Geological Sciences

GENESEO
THE STATE UNIVERSITY OF NEW YORK

- Abstract -

Non-intrusive geophysical imaging is a major source of information used in a variety of applications, including environmental and construction surveys. This imaging has long been successfully performed through several techniques such as ground-penetrating radar and seismic tomography. In this work, we collected and analyzed data with a spring-based gravimeter to explore the variation in gravity across two subterranean fuel tanks used by Facilities here at the College. We began by establishing a base station for comparison, then measured the gravity relative to that base station at ten points along a thirty-meter line. When viewed in relation to the expected gravitational value of an undisturbed subsurface, negative anomalies were visible at locations where the tanks are stored, which is consistent with what would be expected from a subterranean space that was less dense than the surrounding ground. Three separate analyses were performed, with varying results. The horizontal position of the pair of fuel tanks was derived with sufficient accuracy, but determining their dimensions and depth was less successful. Nevertheless, these results were promising. Expanding our surveyed points from a single line to a two-dimensional grid would be the next logical step with this research.

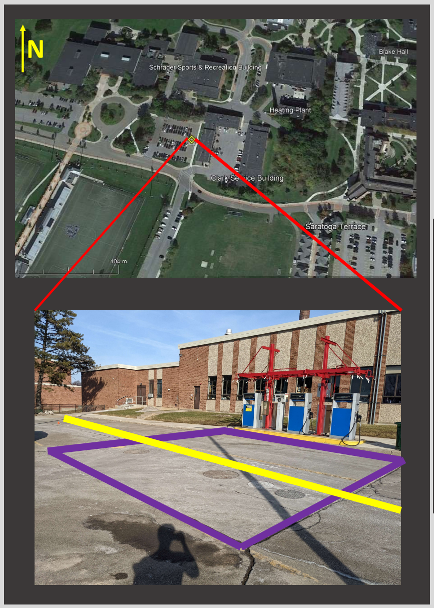

Fig. 1. Facilities Services building and adjacent fuel depot in lot K. Located directly southwest of the Student Union. A 30 meter line (yellow) was drawn parallel to the pictured gas pumps and bisecting the concrete pad (purple).

Fig. 2. SUNY Geneseo Geosciences Worden Gravimeter

- Introduction -

The capability to see what is buried under the surface without directly digging into the ground is an important aspect of environmental surveys. It is more often than not cheaper, quicker, and less destructive to use ground penetrating radar or other indirect methods to determine what lies beneath the surface than to contract out a crew with a backhoe. With our research, we sought to determine whether a gravimeter (a device that measures the relative strength of the gravitational field), could be used for this purpose.

Geneseo's Facilities Services has a fueling station on Lot K for the various vehicles they use around campus. Fuel for this station is stored in two cylindrical tanks stored underground on the east side of the lot. Given that the density of diesel fuel is known, we used this in conjunction with measurements from the gravimeter to first estimate the depth at which the tanks are buried, and second estimate the tanks' height, length, and width.

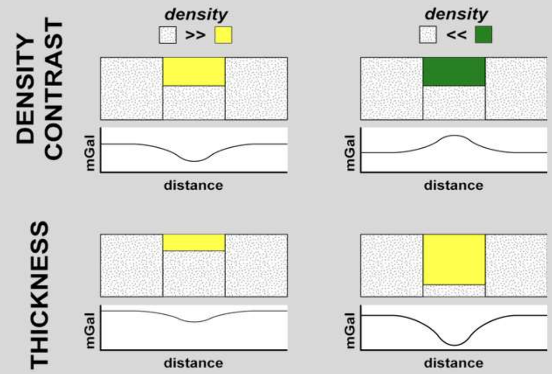

Fig. 3. A simplified diagram of the factors that can create a gravitational anomaly waveform. White dotted sections represent a uniform "normal" ground material. Yellow sections represent parts of the ground that have been replaced with material of lesser density than the "normal". Green sections are parts that have been replaced with material of greater density. A less dense material between the gravimeter and the center of the Earth corresponds to a negative gravitational anomaly while a denser material does the opposite, it results in a positive anomaly. A greater volume of yellow (less dense) or green (more dense) material results in a greater amplitude in the anomaly.

- Methods -

A 30m line was drawn over the known location of the fuel tanks. This line bisected the fuel tanks in order to maximize the magnitude of any differences in gravitational force that could be measured. This line was split into 16 equidistant markers that serve as measuring points, including a base station. A base station is required for an initial measurement to serve as a standard value to compare all others against. All measurements were completed over a span of two hours.

The gravimeter is an analog device that uses spring tension in order to measure the relative gravitational force at a location. This value is translated to a dial which must be manually adjusted in order to give a numerical value of the gravitational force. The measurement is complete when the operator, looking through the gravimeter's aperture lens turns a dial and overlaps a light beam and a pointer within the device.

Gravimetric values were plotted and fed into mathematical formula's using Microsoft Excel's solver tool in order to estimate the depth and dimensions of the fuel tanks.

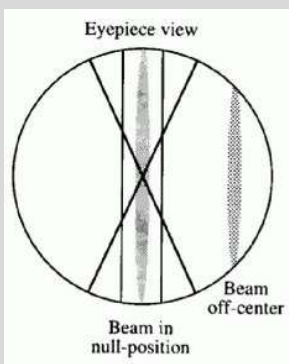

Fig. 4. A dial is turned in order to center the beam (null-position). Depending on which direction and how much the dial is turned, a gravitational anomaly value is then recorded. (Burger, 1992)

- Results -

After plotting our gravitational anomaly data, two distinct dips were visible over the suspected locations of the fuel tanks. This is consistent with the reduction in density, and therefore the local gravitational field that replacing undisturbed Earth with a fuel storage structure would bring about. The depth and dimensions of the structure were more difficult to determine with the limited data that was gathered, although in principle it is possible to do so.

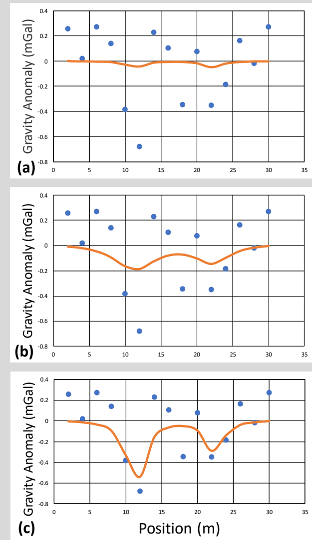

Fig. 4. Three gravimetric anomaly plots with controls on three separate variables. Blue points represent our raw measured anomaly values. The orange line represents the calculated density contrast, as explained in figure 3.

(a) Fuel tank *radius* and *depth* are assumed constant, while *position* was assigned as a variable.
(b) Fuel tank *depth*, *radius*, and *position* were assigned as variables.
(c) Fuel tank *radius* is assumed constant, while *position* and *density* contrast were both variables.

Position was easily derived with all three methods, with tanks at 12m and 22m. The magnitude of density contrasts was much less clear, with (c) implying an unreasonably massive density contrast.

- Discussion -

Locating the subterranean fuel tanks along the horizontal axis was successful. However, accurately determining the depth and dimensions of the fuel tanks was more challenging. Future research could include the collection of gravimetric data along a two-dimensional grid, rather than a single line. At the same time, the addition of this data would greatly increase the complexity of the mathematical models involved. At the very least, we have shown that a gravimetric determination of subterranean features close to the surface is possible and can be used to identify locations of interest during a survey.

Several assumptions were made and factors minimized in the performance of this experiment. For example, the density of the fuel tanks did not take into consideration the actual steel or lining of the tanks themselves, only the fuel. Also, the tanks were assumed to be completely surrounded by soil, when it is likely that there exist small gaps and spaces for servicing them. Full consideration of these factors are targets for future research

- Conclusion -

The gravimetric method of mapping subterranean features is somewhat viable, but at present needs to be paired with other techniques to be truly useful in a real-world construction or environmental survey like setting.

- Acknowledgements -

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