Team TBL # 2: High-Resolution Magnetic Survey in Locating Abandoned Brine Wells in Hutchinson, Kansas: Xia and Williams

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Overview

Many improperly abandoned wells exist in Canada and the US. They are difficult to find as they are often covered by soil so they are not visible by eye. Their small diameter makes them difficult to locate by direct probing of the ground. In this case study, the authors use magnetic surveys to locate abandoned wells.

Instructions

Answer the following questions within the context of the 7 step framework. Your answers should be brief, and point form can be used where appropriate.

Team exercise:

- Discuss the case history amongst yourselves
- As a team, answer the following questions
- You will hand this in at the end of the class

Resources

- GPG: Magnetics
- Jupyter Notebook App
- Instructions for downloading and using the Jupyter Notebook: here

Q1. The following questions make use of the Mag App.

a. In Hutchinson, Kansas, the inducing field has an inclination of 66° and a declination of $\sim 4°$ (found using the Natural Resources Canada Magnetic field calculator). Using the default parameters for the geometry of the pipe (dx=0.08m, dy=0.08m, dz=100m, depth=1, pinc=0, pdec=0). Describe the differences in the character of the anomaly due to having a vertically oriented inducing field (inclination of 90°) and an inducing field with an inclination of 66°

b. Using the inclination in Kansas, what happens to the anomaly as you move the well deeper?

Q2. For each of the figures identified in the table below, record the maximum anomaly amplitude, the half-width, your calculation of the depth to the top of the well and the value reported in the paper. Assume the magnetometer is at a constant height of 3ft (1m) above the surface. For a monopole anomaly, the depth from the magnetometer to the top of the object is $z = 1/2x_{1/2}$, where $x_{1/2}$ is the distance from half-max to half-max, as shown in Figure below

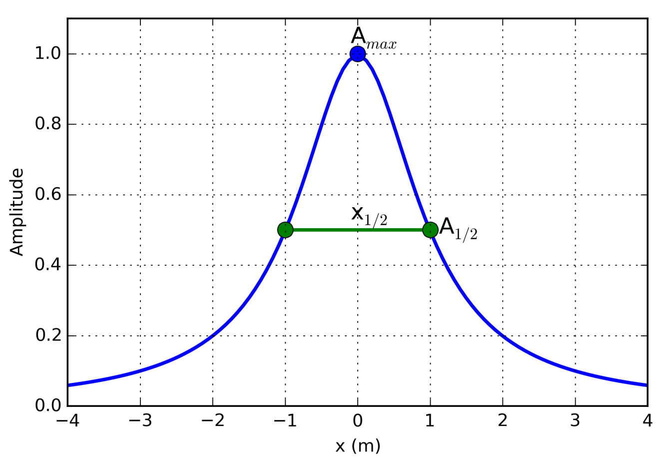

Fig #	Max Anomaly Amp(nT)	Half-Width (ft)	Calc. Depth (ft)	Reported Depth (ft)
6				
7				
8				
10				

Q3. Consider the well identified in Figure 6. To answer the following questions, use the app to simulate the expected response over the pipe. Assume that it has a susceptibility of $\kappa = 100$, the cross-sectional area for the steel is $60cm^2$. Use the parameters for the inducing field in Hutchinson, with magnitude: 53,600nT, inclination of 66°, and a declination of 4°

a. Using the depth and sensor height reported in the paper, what is the maximum expected total field anomaly amplitude? and half-width?

b. Adjust the magnetic susceptibility until the the maximum simulated amplitude is similar to that of the maximum anomaly amplitude. What did you have to use for the susceptibility?

c. Our synthetically evaluated amplitude seems much smaller than what is observed. This might be explained by having pipes that are remanently magnetized. Let's assume that the susceptibility of the pipe is known to be 100, and that it is remanently magnetized. Using the app, return the value of the susceptibility to 100. Select which direction you expect the remanence is in, and increase Q, the Koenigsberg ratio (ratio of remnant to induced magnetization). What value of Q fits the maximum observed anomaly amplitude? What was your final choice of direction of remanence?

d. Would you expect the remanence to be vertically up or down? Why?

Q4. Just like the researchers in the case study, you are given task of finding all of the brine wells within a 100ft x 100ft area. Assume the following:

- Inducing field is the same as in Hutchinson, KS (magnitude: $53,600$nT, inclination of $66°$, and a declination of $4°$)
- Magnetization is induced
- Susceptibility of steel is $\kappa = 100$
- Cross-sectional area for the steel is $60cm^2$

a. What information should be used to determine an adequate station spacing?

b. Using the second part of the app, determine whether or not the acquisition strategy used in the case history was satisfactory to characterize a pipe buried within 20m of the surface. Simulate the survey for a pipe buried at several depths between 0 and 20m and observe how the anomaly changes as a function of depth. Will a shallow target or a deep target require a smaller station spacing to characterize? Is the line spacing of 3ft sufficient to characterize the perspective brine well targets? If not provide your recommendation for a minimum line/station spacing.

c. If we assume the same data acquisition efficiency that you displayed on the beach, one reading (3 repeats but no re-occupancy of a base station) then one datum can be collected every 30 seconds. How many stations and how long would it take you to acquire the data over the 100ft x 100ft grid at the spacing you decided upon above?

d. How long did it take the contractors to collect their data over this 100ft x 100ft grid? Supposing they halved their line spacing approximately how long would it have taken for them to complete their survey?

e. In addition to capturing the character of the signal, we also need to have an amplitude of signal that is sufficiently above background noise. Use the analytic expression (GPG) that gives the magnetic field anomaly due a monopole. Assume the top of the pipe is at the surface (z=0) and the cross-sectional area of the steel is $\sim 60\text{cm}^2$. Use the strength of the magnetic field at Hutchinson and assume it is vertically down. What is the magnitude of the anomaly when the receiver (1 meter above ground) is directly over the pipe?

f. Make a case for whether or not you believe that the contractors choice of line spacing was optimal for the problem at hand. Be sure to include factors such as acquisition costs (which depend on survey time), mobilization costs (costs of putting personal and equipment into the field), and the risks involved with not detecting or mis-locating the position or depth of a target because of inadequate data resolution.

Q5. Suppose you want to be able to find and estimate the depth of any pipes whose top lies with 20 meters of the surface. What the minimum amount of data accuracy you need to capture this anomaly?

Q6. The contractors justify their decision not to use a base station to correct for diurnal variation by stating that the inducing field at the time of their survey varied by less than 15nT/hr. This equates to variations of as much ~ 3.75nT over the course of the 15 minute survey. Without correcting for diurnal variations of this magnitude what is the maximum depth at which they could still hope to accurately characterize a buried well?