

Groundwater Investigation Using Resistivity Surveys on a Terminal Moraine at the Bering Glacier

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Introduction

Water budget analyses (Josberger, et al., 2006) of the annual melting of the Bering Glacier in Alaska and of the surface hydrology of Vitus Lake and the Seal River, which discharges into the Gulf of Alaska (Figure 1), has led to the hypothesis of significant amounts of freshwater discharging to the Gulf as subterranean groundwater flow. This hypothesis is derived from reasonable estimates of evaporation on Vitus Lake and of the discharge of the Seal River.

These estimates indicate that the Seal River cannot discharge the amount of freshwater produced by glacial melting. The discovery of salt water at approximately 40 meters depth in Vitus Lake (Josberger, et al., 2006) further suggests that groundwater is moving through the area's unconsolidated end-moraine deposits and mixing with intruding saltwater (Figure 2).

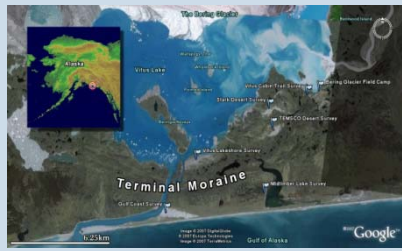


Figure 1. Site location of survey area. Specific survey locations are identified with a flag.

Objective

This investigation attempted to map the proposed interface between the freshwater table and an inferred saltwater wedge that potentially exists at depth at the terminal moraine of the Bering Glacier between Vitus Lake and the Gulf of Alaska. It also attempted to determine how freshwater from Vitus Lake might flow through the terminal moraine, and, subsequently, to identify the influence of the tides on groundwater movement in this area.

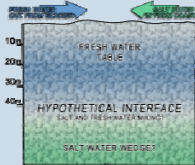


Figure 2: A simulated model of hypothetical groundwater conditions. This is only a hypothesis.

Methods and Materials

In a hydrogeological setting as depicted in Figure 2, the operative property that varies with depth is the electrical resistivity of the groundwater. The mixing of saltwater with a body of freshwater increases its salinity and density, causing it to sink. Salinity also decreases the electrical resistivity of water and thus, electrical resistivity decreases with depth. Electrical resistivity sounding was chosen as a method of measuring electrical resistivity at different depths, and may allow mapping of the freshwater-saltwater interface.

Locations were chosen based on their proximity in regards to Vitus Lake and the Gulf of Alaska. Using the Advanced Geosciences Inc. SuperSting R1/IP multiple electrode resistivity system, 56 electrodes were placed on stakes along a linear line. The depth of the stakes was approximately 10-15 cm. The survey parameters for a Schlumberger array were uploaded to the SuperSting. The SuperSting was powered by two 12 V gel-cell batteries. Before beginning the survey, two contact resistance tests were performed: once before adding the saltwater and once after. After a reliable contact between the stakes and the ground was established the survey was implemented. The surveys were conducted during the day ranging from 10:00 AM to 6:00 PM,

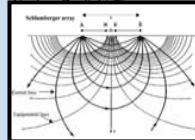


Figure 3: A depiction of the Schlumberger array (adapted from <http://www.las.ac.uk/courses/geom52004/1437.pdf>). A and B are current electrodes, M and N are potential electrodes, a is the current electrode spacing, and s marks the center of the array.

While the survey was running in automatic mode, usually taking about 90 minutes, terrain elevations at the stake locations were measured with a TruPulse 200 laser rangefinder/inclinometer (Laser Technology, Inc., Centennial, Colorado).

Data Summary

- The resistivity values do not correspond to the same colors from figure to figure.
- The times listed in each caption are in local time (AKDT).
- All data were imported into AGI EarthImager 2D and inverted using the Smooth Inversion Method with 4 or 5 mesh divisions.
- Weather conditions were overcast and raining for each survey.
- Three surveys were conducted over time at the Gulf Coast with the array in the same position.
- Two orthogonal surveys were conducted at TEMSCO Desert.
- Terrain corrections were applied to the Vitus Lake Trail and Midtimber Lake surveys using elevations measured in the field.
- The survey spread length was 220 m (4 m electrode spacing) for the Vitus Lake Trail and Gulf Coast. All other surveys used a 330 m spread length (6 m electrode spacing).

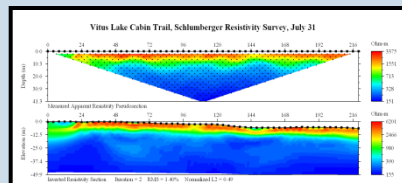


Figure 4: Date and Time: July 31, 1:00 - 3:16 PM. At approximately 10 to 13 m there is a noted drop in resistivity from 1000 to 400 ohm-m.

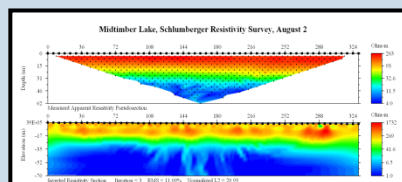


Figure 5: Date and Time: August 2, 2:30-3:50 PM. At approximately 17 to 20 m there is a noted drop in resistivity from 200 to 50 ohm-m.

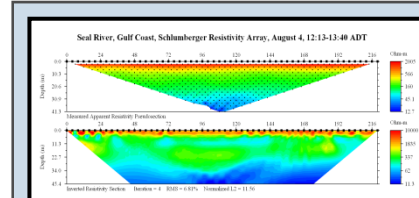


Figure 6: Date and Time: August 4, 12:13-1:40 PM. At approximately 4 to 6 m there is a noted drop in resistivity of about 1000 ohm-m. Also, at approximately 23 to 30 m there is an uneven drop in resistivity of about 250 ohm-m.

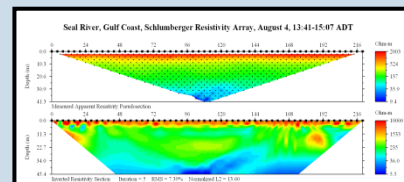


Figure 7: Date and Time: August 4, 1:41-3:07 PM. At approximately 4 to 6 m there is a noted drop in resistivity of about 1000 ohm-m. Also, at approximately 23 to 34 m there is an uneven drop in resistivity of about 200 ohm-m.

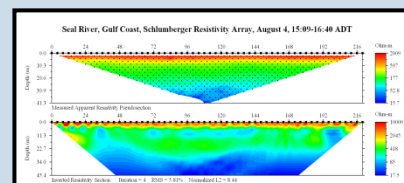


Figure 8: Date and Time: August 4, 3:09-4:40 PM. At 4 to 6 m there is a noted drop in resistivity of about 1000 ohm-m. Also, at approximately 15 to 23 m there is an uneven drop in resistivity of about 300 ohm-m.

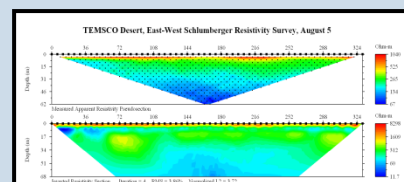


Figure 9: Date & Time: August 5, 10:44 AM-12:14 PM. At approximately 4 m there is an uneven drop in resistivity of about 200 ohm-m.

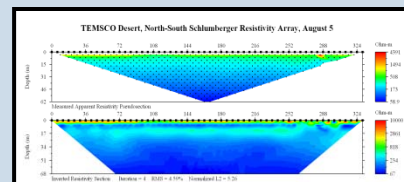


Figure 10: Date & Time: August 5, 1:26-2:57 PM. At approximately 8 m there is a drop in resistivity of about 300 ohm-m.

Interpretations

- Vitus Lake Trail Survey: The depth of the freshwater table appears to be at 13-15 m with resistivity values of 400-700 ohm-m. There is no saltwater evident.
- Midtimber Lake Survey: The survey was located near the Midtimber Lake. The freshwater table appears to be close to the surface. The strongest variations, indicating a possible interface, is located at approximately 30-35 m depth with resistivity values of about 6-40 ohm-m.
- Gulf Coast: The freshwater table appears to be at a depth of 5-6 m. Saltwater is apparent at a depth of 25-35 m and appears to be moving inland with the incoming tide.
- North-South TEMSCO Survey: The freshwater table is at about 8-10 m depth with resistivity values of 300-500 ohm-m. The resistivity values do get as low as 67 ohm-m, however there is no saltwater apparent.
- East-West TEMSCO Survey: The freshwater table is at about 3-4 m depth with resistivity values of 275-325 ohm-m. There is no saltwater evident.

Conclusions

- Saltwater is present at about 35 m depth at the Midtimber Lakeshore and also near the coast.
- The freshwater table ranges from 15m to 17 m depth in most inland areas at the time of year in early August.
- However, the freshwater table can be as shallow as 3 to 5 m below the surface in some areas. These areas include the TEMSCO Desert and the Gulf Coast.
- Contact between the freshwater and saltwater bodies is not defined as a sharp interface. Rather, there is a lot of mixing between the saltwater and freshwater, though this mixed, brackish water remains at a depth of about 35 m.
- Saltwater appears to be moving inland with the incoming tide. However, this cannot be ascertained definitively without further investigation and correlation of tide table data.
- Alternate explanation: The entire survey area used to be part of the Gulf of Alaska, before the glacier closed off Vitus Lake by depositing sediment at the terminal moraine. During this time, salt from seawater may have been deposited in the poor spaces between unconsolidated sediments.

References

- Burger, H. R., A. F. Sheehan, and C. H. Jones, *Introduction to Applied Geophysics: Exploring the Shallow Subsurface*, New York, W. W. Norton & Company, 2006.
- Josberger, E. G., Shuchman, R.A., Meadows, G.A., Savage, S., Payne, J., Hydrography and Circulation of Ice-marginal Lakes at Bering Glacier, Alaska, *U.S.A. Arctic, Antarctic, and Alpine Research*, 38(4), 547-560, 2006.

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