GLG 471; MICHIGAN STATE UNIVERSITY – INSTRUCTOR R.L. VAN DAM
PROJECT: ELECTRICAL RESISTIVITY

General information:

- This is a group (2-3 students) project requiring lab-, computer-, and fieldwork.
- Work will be spread out over 6 weeks.
- Every group will give one weekly interim presentation to discuss progress.
- End product is a 15-25 page group report.

Description of problem:

Determine the stratigraphic and hydrological (water table depth) characteristics of a layered deposit using electrical resistivity methods. The study site is a glacial till deposit south of the MSU campus (as an alternative study can be carried out in proglacial sediments south of Ludington, which requires longer travel if selected).

Tasks:

The project consists of four separate activities:

1) Use of laboratory experiments to measure the relationship between soil water content and electrical resistivity for different soil samples obtained from the sites (2-3 samples per group).
2) Use of simple modeling software to calculate the resistivity response for different geological models, based on information from well logs and the results of the laboratory measurements.
3) Design (min-max a-spacing and stepsize, based on the forward modeling results), execute, and analyze a field sounding experiment.
4) Results will be presented in class (weekly progress) and summarized in a final report.

Learning goals:

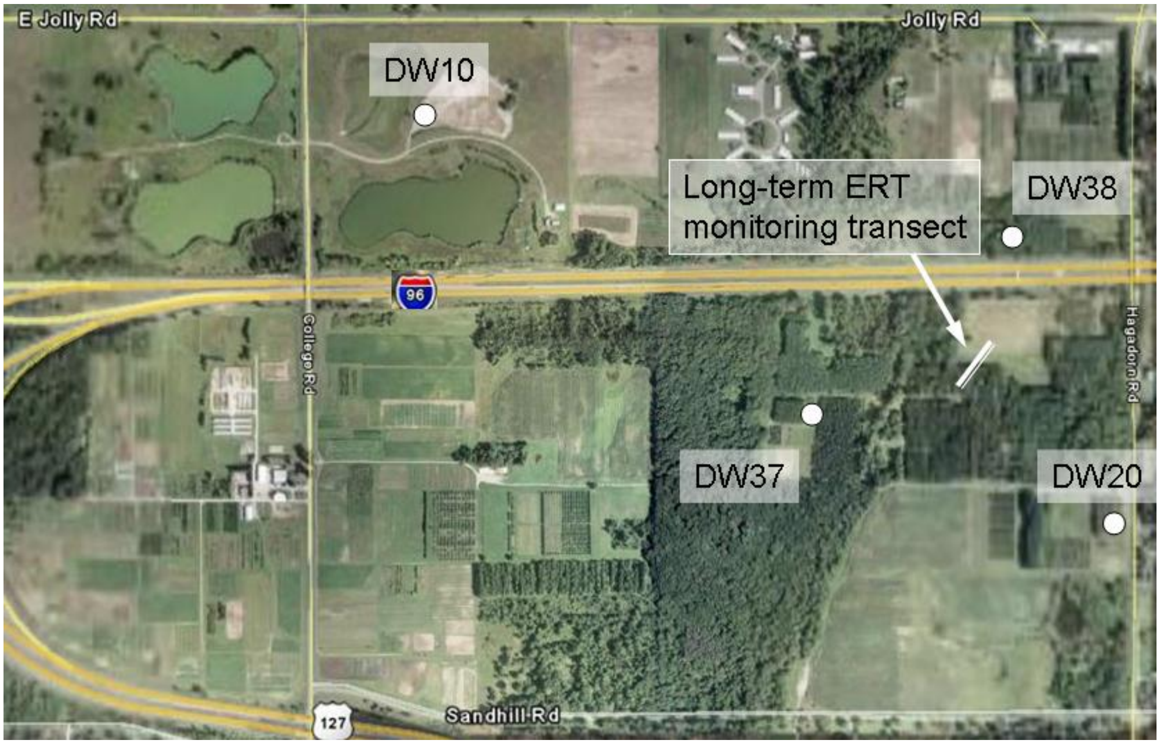
- Go through all steps involved in planning, executing, and interpreting a 1D electrical resistivity sounding.
- Understand how texture and water saturation influence bulk resistivity of soils.
- Learn to work with basic software for forward modeling and inversion of resistivity data.

Schedule:

Week 1:	Introduction to forward modeling and inversion of resistivity sounding data. Calculate resistivity response for simple layered earth models.
Week 2:	Class presentation of Week 1 results. Laboratory measurements of ρ-θ relationship for different soil types.
Week 3:	Class presentation of Week 2 results. Forward modeling and design of field sounding experiment.
Week 4:	Class presentation (and discussion) of proposed survey design. Field data collection.
Week 5:	Resistivity inversion and data analysis.
Week 6:	Final report due.

GENERAL INTRODUCTION TO THE SITE:

Below is a picture of the "Sandhill site", the location of our project. The general area, which is used for Forestry research, is bordered by Jolly road to the north, Sandhill road to the south, and College and Hagadorn roads to the west and east, respectively:



Several well logs in the area give a general idea of the stratigraphy. These wells are "Drift Observation Wells" 10, 20, 37 and 38. Generally speaking the upper 10 to 15 meters of the sequence is dominated by clay with significant but laterally discontinuous sandy layers.

Well descriptions (DTW = depth to water table):

D.W. #10/19:	D.W. #20:	D.W. #37:	D.W. #38:
Need to add the data still	Need to add the data still	0-5' Clay 5-15' Sand 15-20' Sandy Clay >20' Sandy Gravel	0-5' Sand 5-20' Clay 20-26' Sandy Clay 26-37' Clay >37' Sand
DTW Average 17'		DTW Average 14'	DTW Average 22

WEEK 1:

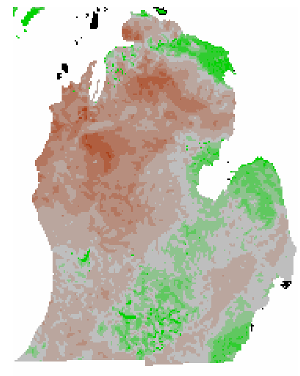
INTRODUCTION TO FORWARD MODELING AND INVERSION OF RESISTIVITY SOUNDING DATA.

For this exercise we will use the program RESIST, which is available on the CD-Rom that came with your book and installed on all computers in room 317NS. Alternative options include programs like RES1D (www.geoelectrical.com/r1d.zip) and DCINV (www.gf.oulu.fi/~mpi/Softat/Dcinv.html).

First we will build simple models for layered materials to develop an understanding how geology/stratigraphy and hydrological characteristics shape resistivity response of a 1D sounding. Also, we will analyze some real data in a qualitative sense.

This task will take place in Room 317NS; once during regular lab hour and an additional hour during regular class time. Continue on your own to finish this task if necessary.

Exercise 1: Resistivity soundings for geology/stratigraphy



Thickness of unconsolidated glacial sediments (drift) that typically covers the bedrock of Michigan (dark brown > 200m; green < 30m thick). Many of the thin drift areas of the state are underlain by carbonate bedrock.

Build a ***two layer model*** in RESIST; 19 number of spacings. First spacing = 1m. In the model, the top layer is dry sandy glacial drift, the bottom layer is Michigan Basin bedrock. Use the book or web to find representative resistivity values for these materials.

a) Calculate and plot the resistivity response when the thickness of glacial drift (d1) is 20 meters and 200 meters, respectively. Below, copy and paste your plots. In the caption, give the resistivity values assigned to the two layers (do not forget the units!!), and give the source for these values. Discuss the two plots (similarities / differences).

Save the models to your folder or flashdrive and give them recognizable names: "*res1a_20*" and "*res1a_200*".

d1 = 20m:	d1 = 200m:
$\rho1$: ______________________ $\rho2$: ______________________ source: ______________________	
Discussion:	

b) Expand the model "*res1a_20*" with a 10m-thick middle layer (top layer remains 20m thick). First, assume that this new layer is a zone of weathered bedrock (sometimes called saprolite), where $\rho 1<\rho 2<\rho 3$. Next assume that the new layer is a zone of clayey glacial till, where $\rho 1>\rho 2<\rho 3$. Below, copy and paste your plots. In the caption, give the resistivity values assigned to the layers, and give the source for these values. Discuss the two plots.

Again, save the models using recognizable names (e.g., "*res1b_sapr*" and "*res1b_clay*")

<table>
<tr><td>Layer 2 = weathered bedrock:</td><td>Layer 2 = clay:</td></tr>
<tr><td colspan="2">$\rho 1$: ______________________
$\rho 2$: ______________________
source: ______________________</td></tr>
<tr><td colspan="2">Discussion:</td></tr>
</table>

c) Comparing results is difficult when using separate plots. To facilitate your interpretation, import "*res1a_20*", "*res1b_sapr*", and "*res1b_clay*" into excel and plot all curves in a single log-log plot and past that plot below. Discuss the observed differences in terms of layer "detectability".

Plot:	Discussion:

Exercise 2: Resistivity soundings for soil moisture changes:

Consider a homogeneous sandstone material with a water table at a depth of 10 meters.

a) Use Archie's equation to calculate the bulk resistivity (ρ) for dry, moist, and saturated conditions. Archie's equation can be written as:

$$S = \left(\frac{\rho_s}{\rho} \right)^{\frac{1}{m}},$$

where S is the saturation (θ/Φ or volumetric water content divided by porosity), ρ is the bulk resistivity, ρ_s is bulk resistivity at 100% saturation, and m is an empirical constant. Assume m = 1.13 and ρ_s = 65:84 Ωm (values from Binley et al. (2002)

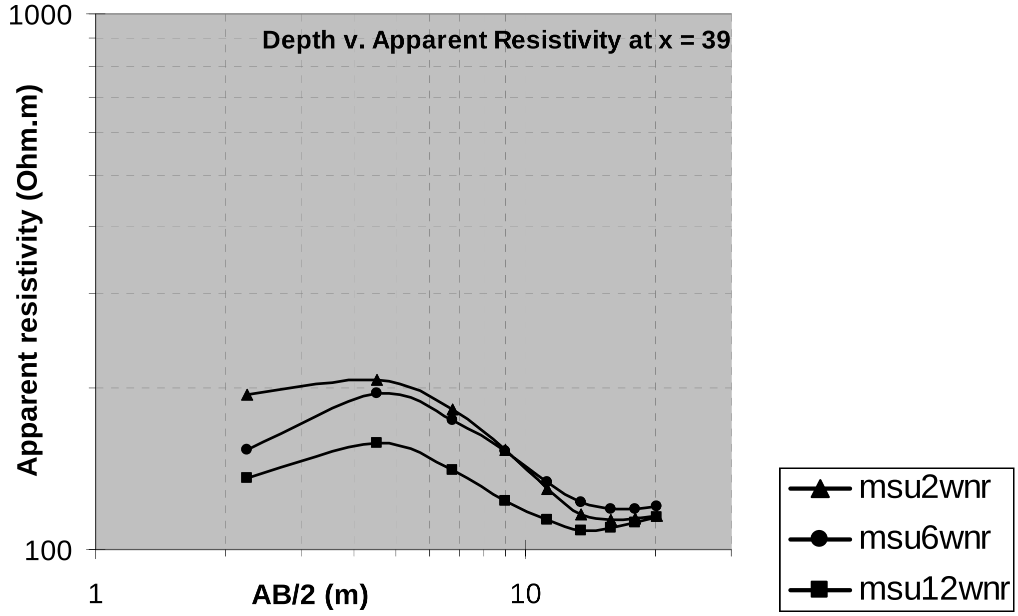
Binley, A., Winship, P., West, L.J., Pokar, M., and Middleton, R., 2002, Seasonal variation of moisture content in unsaturated sandstone inferred from borehole radar and resistivity profiles. Journal of Hydrology 267, pp. 160–172.

Φ:	____________		
θ_{dry}:	____________	ρ_{dry}:	____________
θ_{moist}:	____________	ρ_{moist}:	____________
$\theta_{saturated}$:	____________	$\rho_{saturated}$:	____________

b) Extra: Use RESIST to calculate several sounding curves for a 1m thick wetting front that infiltrates and reaches the 5m deep water table.

Exercise 3: Interpretation of field data:

This is a plot of field data, collected from the Sandhill site. In this plot there are three separate data sets, collected on different days (msu2wnr: oct 25, 2006 – msu6wnr: nov 17, 2006 – msu12wnr: jan 5, 2007), but using the same array.



a) In this plots an increase in the value "AB/2" (to the right on the horizontal axis) means:
   ___________________________________ in electrode separation.

b) For a value of "AB / 2 = 4.5m", and assuming a *Wenner Configuration*, the "a-spacing" is: ____________________________

c) Give as many explanations as possible for the observed differences between the different datasets:

   1. _________________
   2. _________________
   3. _________________
   … _________________

d) Based on visual inspection alone, the minimum number of layers that produced the above datasets is __________, because ________________

WEEK 2:

LABORATORY MEASUREMENTS OF ρ-θ RELATIONSHIP

We will use laboratory measurements to find the ρ-θ relationship and parameters in Archie's equation for different soil types from the study site. Carefully read the Standard Operating Procedure (SOP) 2.01 in the Applied Geophysics lab before conducting these measurements.

The soil types at the site are dominated by distinct units of sand and clay (see well logs in general introduction to the site, above). Each group will measure the ρ-θ relationship for 1 sand and 1 clay sample characteristic for the field area.

This task will take place in Room 6NS. Every group has to sign up for two 3-hour time slots to conduct the measurements. During this week there will be no group lab time.

WEEK 3:

FORWARD MODELING AND DESIGN OF FIELD SOUNDING EXPERIMENT.

During this part of the project you will build stratigraphic models for the field sites using information from the different well logs and calculate (forward model) the expected resistivity response. For this you need to combine knowledge gained in weeks 1 (building resistivity models and interpret the response) and week 2.

This task will be initiated in Room 317NS during regular lab hours. Continue on your own to finish this task if necessary.

a) Build models in RESIST for the 2 wells that have been assigned to you (for each well, 2 teams will build models that will be compared and discussed later). Add resistivity values to your model, for which you need to use values obtained during the lab measurements in week 2.

Well #: ________________	Well #: _________________
Layer 1: texture ________ thickness ________ resistivity _______-_______ comments _________________________	Layer 1: texture ________ thickness ________ resistivity _______-_______ comments _________________________
Layer 2: texture ________ thickness ________ resistivity _______-_______ comments _________________________	Layer 2: texture ________ thickness ________ resistivity _______-_______ comments _________________________
Layer 3: texture ________ thickness ________ resistivity _______-_______ comments _________________________	Layer 3: texture ________ thickness ________ resistivity _______-_______ comments _________________________
Layer 4: texture ________ thickness ________ resistivity _______-_______ comments _________________________	Layer 4: texture ________ thickness ________ resistivity _______-_______ comments _________________________
Layer 5: texture ________ thickness ________ resistivity _______-_______ comments _________________________	Layer 5: texture ________ thickness ________ resistivity _______-_______ comments _________________________

b) At this stage it is impossible to give one correct __________ value for each layer, since we do not know the exact depth of the water table, the soil moisture content, or the resistivity of the pore water. Other complicating factors are that we have to assume (likely incorrect) that all layers are laterally ______.

c) Calculate the resistivity response for both models (using likely resistivity values) using a standard layout of 19 steps and a starting spacing of 1m, and plot the results below. Save the models to your folder or flashdrive (you will use these as a starting point when interpreting the field data; week 5) and give them recognizable names: "res3c_well…" and "res3c_well…".

d) Give a discussion on your results. How much variation can be expected based on uncertainty in layer thickness and resistivity values? Explain whether you think that a layout with 19 steps and a starting spacing of 1m produces the best solution to resolve the expected stratigraphy. If you think it is not, what do you propose?
    - You can use more space and produce extra plots (for different resistivity scenarios and/or layouts) to make your points in the discussion.

Well #: __________	Well #: __________
ρ1: ___________ d1: __________ ρ2: ___________ d2: __________ ρ3: ___________ d3: __________ ρ4: ___________ d4: __________ ρ..: ___________ d..: __________	ρ1: ___________ d1: __________ ρ2: ___________ d2: __________ ρ3: ___________ d3: __________ ρ4: ___________ d4: __________ ρ..: ___________ d..: __________
Discussion:	

WEEK 4:

FIELD DATA COLLECTION.

We will use an AGI supersting R8/IP instrument for our sounding surveys.

Make sure to bring:

- Clothes to brace the weather. There is no shelter.
- Field book and writing material.
- Calculator.

This task will take place obviously in the field (rain or shine), and we will be working with two groups (4 students) at a time. Each group has to sign up for one half-day (4 hour) time slot.

We will meet in Room 317NS, load the equipment after a short introduction, and head out to the site. Provide your own transportation or arrange within your group. During this week there will be no group lab time.

Measurement #	a-spacing (m)	AB/2 (m)	A&B pos (m)	M&N pos (m)	ρ_a (Ωm)

Use the below chart to plot the data in the field (do not forget axis titles, units, and labels):

Title: ______________________________

WEEK 5:

RESISTIVITY INVERSION AND DATA ANALYSIS.

During this almost final part of the project you will analyze the data collected in the field. The models produced in week 3 will serve as the basis for this analysis.

This task will take place in Room 317NS during regular lab hours. Continue on your own to finish this task if necessary.

You will work in your original 2-person group.

WEEK 6:

FINAL REPORT DUE.

Regular lab hour is available to work on results and report and to discuss results.