Exploring the Digital Aquifer

An *Investigation into the groundwater resources in the Baton Rouge area.*

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Description

Where does our drinking water come from? How do we study changes taking place in aquifers hundreds of feet beneath us?

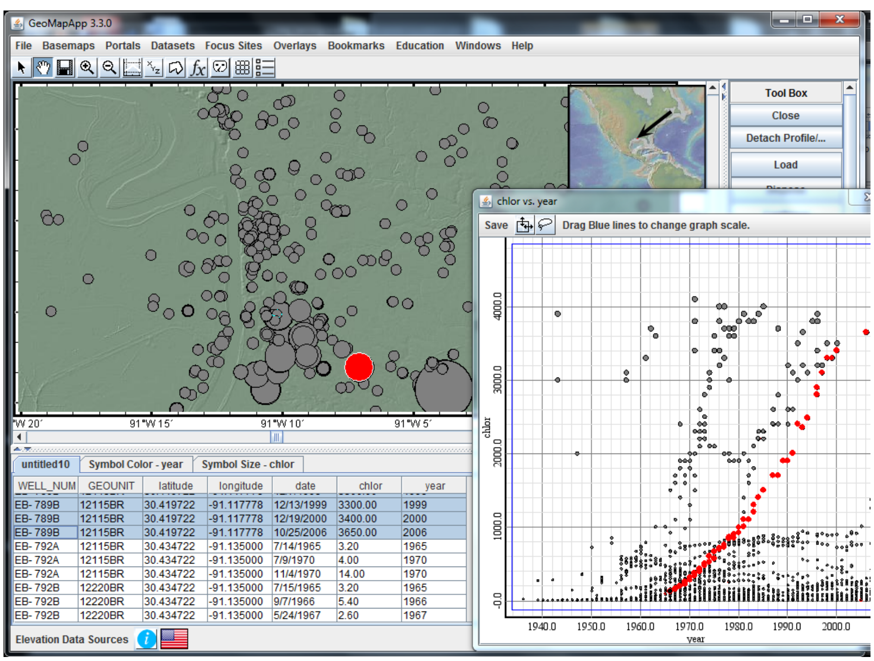
In this activity you will improve the practical skills you need to do science and learn more about how researchers and policy makers track changes in our water resources. You will also refine your technology skills as you use a variety of GIS (geographic information system) tools to solve scientific problems.

In Part 1 you will review a recent scientific paper on local groundwater trends and explore SONRIS, a web-based GIS that includes many valuable layers of information related to Louisiana groundwater.

In Part 2 you will learn to use another GIS tool called GeoMapApp. In this part of the activity you will upload chloride data from USGS into GeoMapApp to create maps of well locations and graphs of changing salinity in area water wells. You will communicate your findings in a report modeled on the paper you read.

Teaching Notes

- **Example Output**
  The graph and accompanying map shown below were created using GeoMapApp software. The graph shows the changing chloride at a well in EBR. The sample map shows icons at the locations of the area water wells with chloride data:



- **Grade Level:**
  This chapter is suitable for students in grades 7-12.

- **Learning Goals:**
  After completion of this chapter students will be able to:
  1. List several groundwater variables scientists study
  2. Download, install and use two GIS tools: SONRIS and GeoMapApp
  3. Construct a variety of geospatial data visualizations
  4. Describe the salinity trend in area groundwater using USGS chloride data
  5. Compare chloride records of different locations
  6. Evaluate the relationship of changing chloride levels the Baton Rouge fault.
- **Tools**:
  - Internet
  - GeoMapApp
  - Microsoft Excell
  - SONRIS
  - Google Earth

- **Rationale**
  There is a growing emphasis on science, technology, engineering and mathematics (STEM) integration in secondary earth and environmental science classrooms. Access to real-time research affords new opportunities for teachers and students to improve their understanding of a range of topics including aquifers, saltwater intrusion and application of GIS tools to understand the physical environment. Teaching with data and using technology prepares students for real world tasks and helps develop critical thinking and evaluation skills central to science.

  Recent research into student inquiry points out that students spend too little time during inquiry connecting to larger concepts and communicating results (Asay, 2011). GeoMapApp is an ideal platform for students to create visualizations that help make sense of multi-modal concepts like groundwater resources and provide them with graphics that can drive discussion and understanding. Interactive visual interfaces like Google Earth and GeoMapApp have been shown to effectively incorporate learning material for students' analysis and reasoning within the contexts of authentic environmental problem-solving tasks (Bodzin, 2011).

- **Background Information**

Most students have likely used geospatial visualizations like Google Earth and will be somewhat familiar with parts of the SONRIS and GeoMapApp toolbars but will need to recognize the different nature of the images shown on the GeoMapApp screen. These data visualizations are much more like other types of maps they may have used than the satellite and aerial photos that make up Google Earth imagery. A basic understanding of latitude and longitude and map projections in needed. Students will be asked to review simple spreadsheets without formulas during the completion of the activities found in this chapter. Students may also need to review the general concepts related to aquifers and groundwater. A great site for students to review can be found at http://ga.water.usgs.gov/edu/earthgw.html.

The USGS Water School features an easy to use table of contents covering all major issues of groundwater and aquifers from the water cycle to well drilling. Also included are fun quizzes to check for understanding.

- **Key words:** groundwater, chloride, aquifer, GIS, saltwater intrusion, mg/l, scatterplot
- **Instructional Strategies**

  To engage students, the teacher may want to begin by holding up a glass of water. Questions to pose could include:
  - "Where does our drinking water come from?"
  - "Are there any threat to our drinking water?"

  Before beginning this chapter, teachers should take time to familiarize themselves with SONRIS and GeoMapApp. Getting to know GeoMapApp can be done by trial and error interactions with the toolbar or by utilizing the tutorials under the education menu.

  Students can be organized into small groups or work independently, but it is important that they have the opportunity to share their findings and imagery. This can be done by hosting a poster session or writing reports at the end of the series of investigations. Students should write captions for the figures they create and include citations where possible. To this end it is valuable to have printed copies of several relevant publications on hand for student review (see resources). Students should also be encouraged to record their results in written form. Answers to prompts throughout the chapter can be kept in a word processing document or in student journals. Encourage students to save images and screenshots as they work. This learning activity presents an excellent opportunity for student inquiry. Students should be encouraged to identify relevant variables and develop an investigation into temporal and spatial patterns of saltwater intrusion. Students should describe a method for collecting data, process the data using graphical techniques, and develop a conclusion and analysis of the results.
- **Pre-Assessment**

The following questions can be used to gauge student understanding prior to completion of this chapter:

- Where does local drinking water come from?
- What is an aquifer?
- Is there evidence of resource depletion in our aquifers?
- What variables are routinely measured in water supplies?
- Why is chloride significant in the study of drinking water?

- **Post-Assessment**

  Upon completion of this chapter students will be assessed on the following:
  Quality of geospatial imagery illustrating location of water wells.
  Ability to communicate data support for inferences about changing chloride levels in groundwater.
  Relate incidence of saltwater intrusion to location of the Baton Rouge fault.

Science Standards

The following National Science Education Standards are supported by this activity.

Science as Inquiry (12ASI)

12ASI1.1 Identify questions and concepts that guide scientific investigations. Students should form a testable hypothesis and demonstrate the logical connections between the scientific concepts guiding a hypothesis and the design of an experiment. They should demonstrate appropriate procedures, a knowledge base, and conceptual understanding of scientific investigations.

12ASI1.3 Use technology and mathematics to improve investigations and communications. A variety of technologies, such as hand tools, measuring instruments, and calculators, should be an integral component of scientific investigations. The use of computers for the collection, analysis, and display of data are also a part of this standard. Mathematics plays an essential role in all aspects of an inquiry. For example, measurement is used for posing questions, formulas are used for developing explanations, and charts and graphs are used for communicating results.

12ASI1.6 Communicate and defend a scientific argument. Students in school science programs should develop the abilities associated with accurate and effective communication. These include writing and following procedures, expressing concepts, reviewing information, summarizing data, using language appropriately, developing diagrams and charts, explaining statistical analysis, speaking clearly and logically, constructing a reasoned argument, and responding appropriately to critical comments.

Common Core English Language Arts Standards for Science and Technical Subjects

RST.11-12.2. Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.

RST.11-12.3. Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.

RST.11-12.7. Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.

RST.11-12.8. Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.

RST.11-12.9. Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible

- **Time Required:**
  2-3 class periods
- **Resources**

Lovelace, J.K., 2007, Chloride concentrations in ground water in East and West Baton Rouge Parishes, Louisiana, 2004–05: U.S. Geological Survey Scientific Investigations Report 2007–5069, 27 p.

Tomaszewski, D,J., 1996. Distribution and Movement of Saltwater in Aquifers in the Baton Rouge Area, Louisiana, 1990-1992. Water Resources Technical Report No.59.

Well locations and chloride concentration data were obtained from the United States Geological Survey (John K. Lovelace, U.S. Geological Survey, written commun., 2012). (attached)

- **Websites**

http://ga.water.usgs.gov/edu/earthgw.html
http://sonris-www.dnr.state.la.us/gis/agsweb/IE/JSViewer/index.html?TemplateID=181
http://www.geomapapp.org/

- **References**

Asay,L. D., Orgill, M. (2011), Analysis of essential features of inquiry found in articles published in THE SCIENCE TEACHER, 1998-2007. J. Res. Sci. Teach., 21: 57-79.

Bodzin, A. M. (2011), The implementation of a geospatial information technology (GIT)-supported land use change curriculum with urban middle school learners to promote spatial thinking. J. Res. Sci. Teach., 48: 281–300. doi: 10.1002/tea.20409

Learning Activities

1. In part 1 you will review a recent scientific paper on local groundwater trends and explore SONRIS, a web-based GIS that includes many valuable layers of information related to Louisiana groundwater.

2. In part 2 you will download, install and use GeoMapApp to Explore a Visualization of the Seafloor

   http://serc.carleton.edu/eet/seafloor/part_1.html

   As soon as you are familiar with the tool you will upload chloride data from USGS into GeoMapApp to create maps of well locations and graphs of changing salinity in area water wells. You will communicate your findings in a report modeled on the paper you read.

Part 1: Getting Started with Goundwater

Step 1: Review Scientific Publication

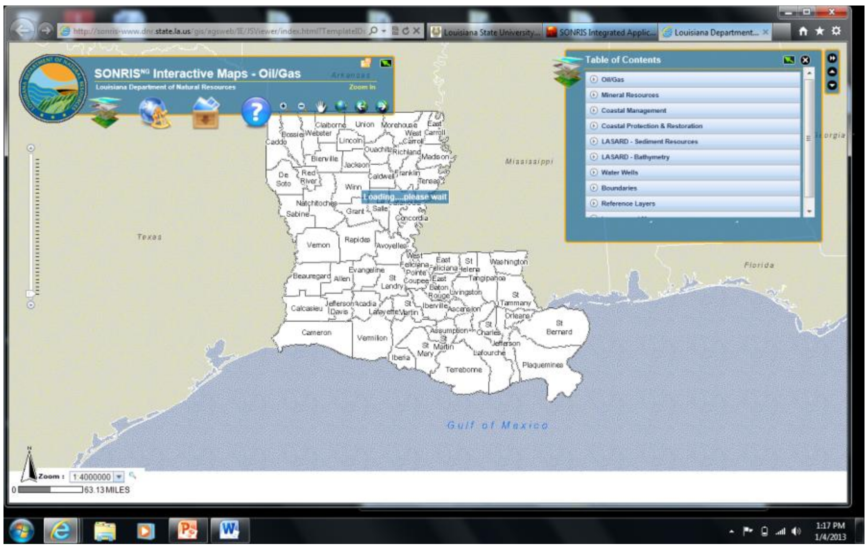
1. Review the paper " Chloride concentrations in ground water in East and West Baton Rouge Parishes, Louisiana, 2004–05" by John Lovelace and answer the following questions:
   a. What is the main threat to fresh ground-water sources in EBR?
   b. What has caused saltwater to migrate north of the Baton Rouge fault?
   c. What is "salt water encroachment?
   d. Look at the map in Figure 1 of the paper. What is the direction of the Baton Rouge fault?
   e. What are the two most common types of figures found in the paper? (figures in scientific publications are illustrations)
2. (Keep this paper handy to use during part 2 as a model for your own paper.)

Step 2: Introduction to GIS

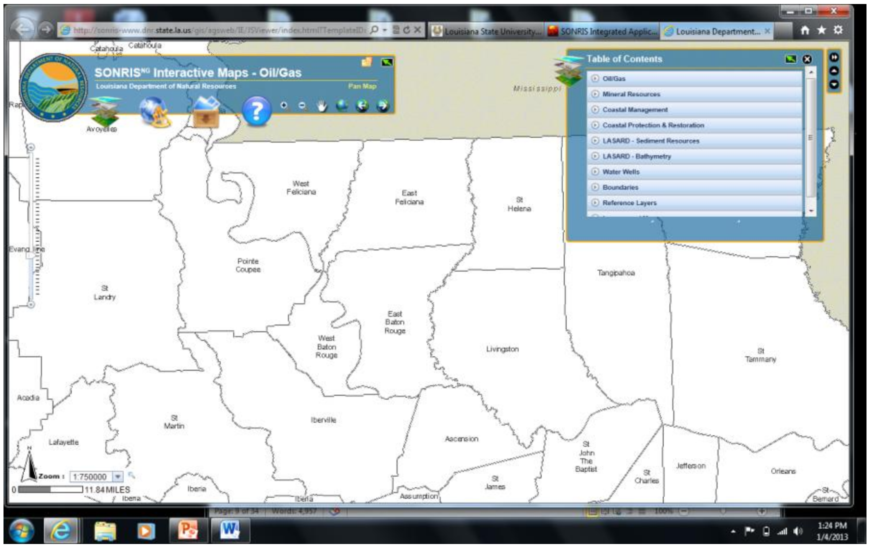
1. GIS is an acronym for "geographic information systems" and refers to digital media that allows users to access layers of information about particular places. You are probably

already familiar with some GIS programs like Google Earth. In this step you will open a program SONRIS that lets you get information about resources here in Louisiana. To begin go to the SONRIS website at: http://sonris.com/

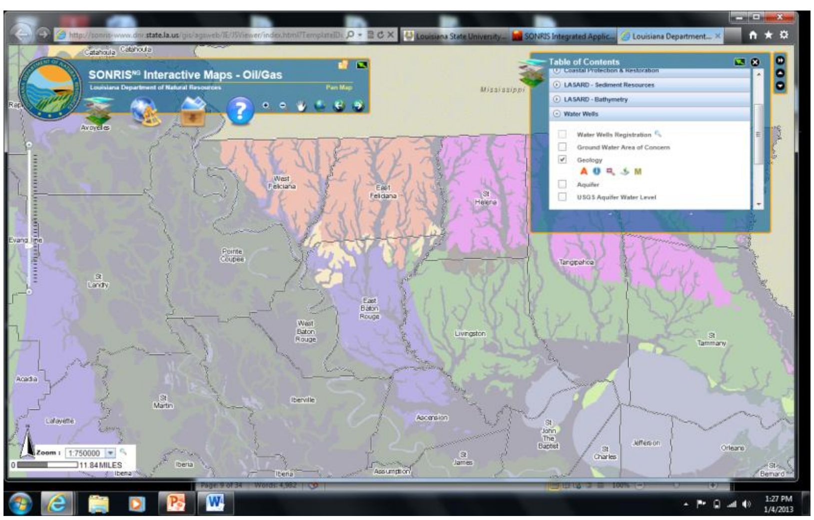
2. On the menu at the left select the third button from the top called GIS.
3. When the page loads you will see a window highlighted in front of the page with user tips and tutorials. Close this page by clicking the **X** on the upper right of the window.
4. Take a moment to look at the page. Notice that in many ways it is similar to Google Earth. At the top you will see a toolbar over the state. At the far left you notice a slider that allows you to zoom in and out. At the top select the magnifying glass with the + sign by clicking on it. Now move your mouse to the slider and click and drag upward to zoom.



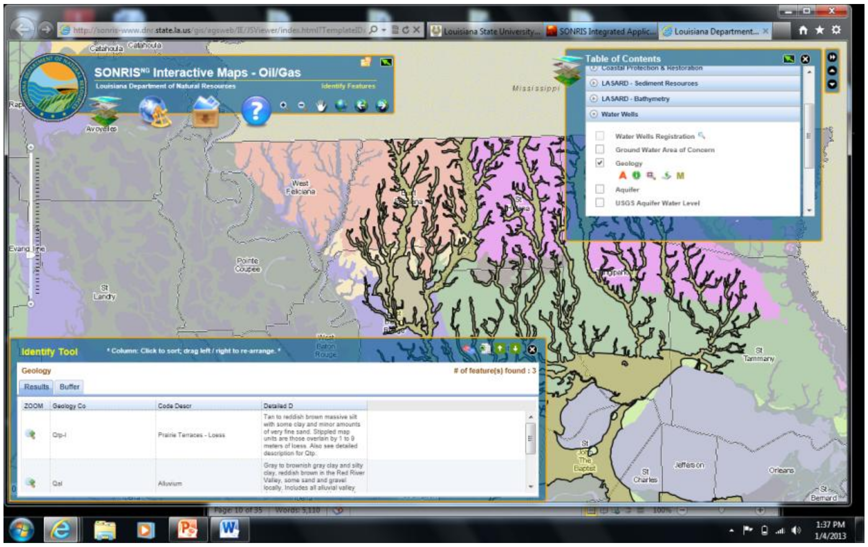
5. Zoom in by moving about 1/3 of the way up along the slider. How many parishes can you see?
6. Select the hand from the top toolbar and use it to click and drag East Baton Rouge parish to the center of the screen.



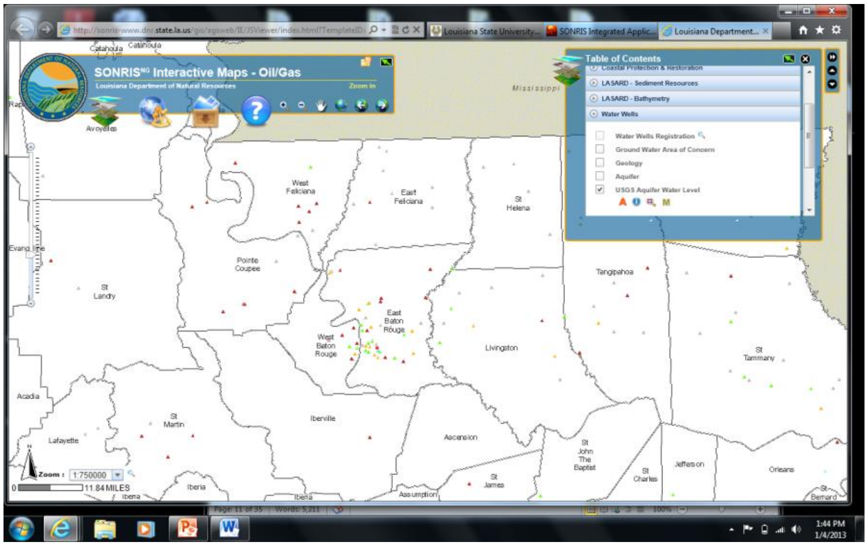
7. From the Table of Contents in the top right corner select the arrow to the right of **Water Wells**. This will open a drop down menu. From the drop down menu select **Geology** (you may need to scroll down the menu using the bar at the right). Wait for the new image to load then answer the following questions:
    a. What two colors dominate the map in EBR parish?
    b. What geographic features do you think the gray color represents?



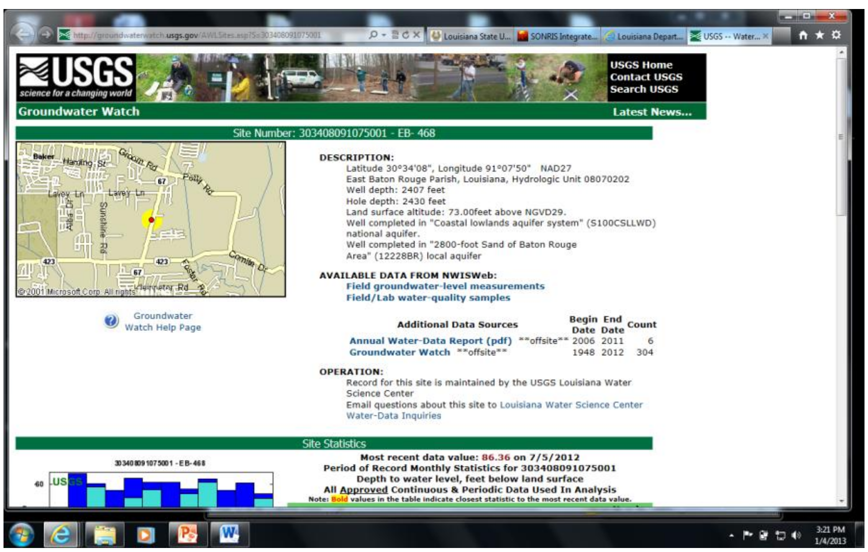
8. Under **Geology** on the Table of Contents click the information icon (it is the round blue I symbol second from the left). Now point and click at the gray area on the map of EBR. What did you notice? Was your answer in 7b correct? How do you know? Notice the box in the lower left gives a description of the surface geology. What type of sediment is found in this area? Close the information box by clicking the X in the upper right corner.



9. Follow the procedure above but select the purple color this time. How are the two soils different? How are they similar?
10. Turn off the **Geology** layer by unchecking the box next to it in the **Table of Contents**. You may also need to put away the information box that appeared by clicking the X in its upper right corner. Now select the **Aquifer** box and wait for it to load. Click the red **A** under **Aquifer** to label the features. What is the name of the main aquifer in EBR? Turn off the Aquifer layer.
11. Turn on the USGS Water Level layer as you did before with Geology. What do you notice appearing on the map? Each of these colored triangles represents a well that is monitored by the USGS. Each well has data including its location, depth, and water level underground. Use the information icon as you did above to select one of the red triangles on the map. You'll notice that as before an information box appears on your screen. Scroll from left to right in this screen to find the column labeled "**Depth to water**". What is the depth for the well you have selected? Look three columns to the right to find out if that is above or below normal. This can be found in the "**s**" column.

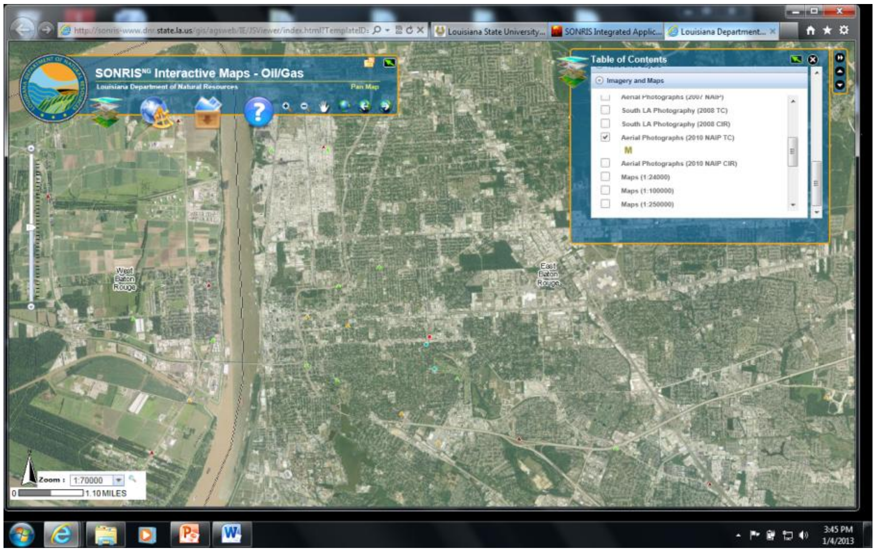


12. At the extreme right of this data table you will find a box labeled “**Hyperlink**”. Click the link to review more information about the well. This will open a link to USGS Groundwater Watch. Notice a map appears on the web page showing your well’s location alongside a description. Scroll to the bottom of the page and look at the graph of water depth vs. time for your well. Is there a trend? How would you describe it?



13. Zoom in and select a few wells near your school to study. Do they all show similar trends? What factors can account for the patterns of water depth you see?
14. Close the USGS page and the information box on your map. Use the scrollbar to the right of the table of contents and scroll down to **Imagery and Maps**. Open the layer by clicking the arrow. You will need to scroll down to see all choices. (Note that there are now two scroll bars to manipulate.)

15. Scroll down and select **Aerial Photographs (2010 NAIP TC)** to view a true color image of your study area. Notice that you can still see your well locations. Turn off the layer.



16. Under **Imagery and Maps** select **Map (1:24000)**. Zoom in a bit to read your map and look for your well locations on the street map.
17. Now that you know how to obtain GIS information to study groundwater consider creating a project such as a PowerPoint to share your findings. Any images you create with SONRIS can either be printed outright or you can get a screenshot (FN+F11) to paste into your project. Good Luck!

Part 2:Using GeoMapApp to Investigate Groundwater

Step 1: Introduction to GeoMapApp

1. If you are new to GeoMapApp complete this Earth Exploration Toolbook activity. In this activity you will learn to manipulate the toolbars and create visualizations using the data:

   http://serc.carleton.edu/eet/seafloor/part_1.html

   If you are already familiar with the tool, skip ahead to **Part 2 Step 2** to begin working with local groundwater data.

Step 2: Understanding scientific investigations.

During this investigation you will create a report modeled on the scientific paper you read earlier. Take time now to list the main parts of that paper:

a. ____________________________
b. ____________________________
c. ____________________________
d. ____________________________
e. ____________________________

For this assignment you will use a new GIS tool called GeoMapApp to create products similar to those you accessed using SONRIS. You will then use these products to write your own scientific paper. As you may have noticed, data about saltwater intrusion was not found in your SONRIS explorations. This will by your job! You will use USGS data to create the maps and graphs of changing chloride levels in EBR.

Take a minute to review the Scientific Practices listed below:

1. **Asking questions and defining problems.**
2. **Developing and using models.**
3. **Planning and carrying out investigations**
4. **Analyzing and interpreting data.**
5. **Using mathematics and computational thinking.**
6. **Constructing explanations and designing solutions.**
7. **Engaging in argument from evidence.**
8. **Obtaining, evaluating and communicating information.**

**Although your project can take many forms (report, poster, presentation) these practices are at the core of scientific investigations. Keep these practices in mind as you move forward.

Step 3- Review Data

Chloride Levels in EBR Area Wells

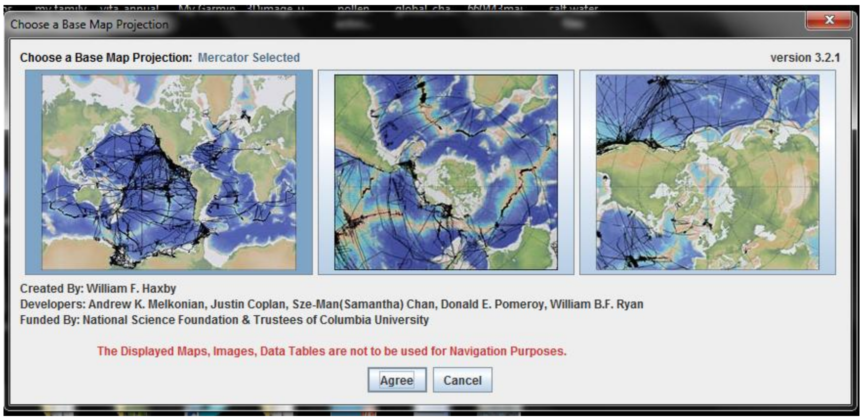
WELL_NUM	GEOUNIT	latitude	longitude	date	chlor	year
An- 16	12112BR	30.335556	-90.904444	1/7/1955	440.00	1955
An- 16	12112BR	30.335556	-90.904444	8/24/1956	430.00	1956
An- 16	12112BR	30.335556	-90.904444	10/11/1956	420.00	1956
An- 16	12112BR	30.335556	-90.904444	4/9/1957	510.00	1957
An- 16	12112BR	30.335556	-90.904444	8/2/1957	420.00	1957
An- 16	12112BR	30.335556	-90.904444	4/21/1958	450.00	1958
An- 16	12112BR	30.335556	-90.904444	5/3/1960	450.00	1960
An- 16	12112BR	30.335556	-90.904444	12/7/1960	460.00	1960
An- 16	12112BR	30.335556	-90.904444	12/7/1961	470.00	1961
An- 16	12112BR	30.335556	-90.904444	12/5/1963	460.00	1963
An- 16	12112BR	30.335556	-90.904444	3/5/1964	450.00	1964
An- 16	12112BR	30.335556	-90.904444	6/18/1964	450.00	1964
An- 16	12112BR	30.335556	-90.904444	10/14/1964	460.00	1964
An- 16	12112BR	30.335556	-90.904444	12/11/1964	450.00	1964
An- 16	12112BR	30.335556	-90.904444	3/5/1965	460.00	1965
An- 16	12112BR	30.335556	-90.904444	10/24/1973	460.00	1973
An- 16	12112BR	30.335556	-90.904444	11/9/1978	470.00	1978
An- 16	12112BR	30.335556	-90.904444	12/18/1978	450.00	1978
An- 16	12112BR	30.335556	-90.904444	12/23/1983	510.00	1983
An- 16	12112BR	30.335556	-90.904444	6/25/1985	510.00	1985

Table adapted from John K. Lovelace, U.S. Geological Survey, written commun., 2012). The data shown were collected as part of ongoing research by USGS. Chloride levels shown in mg/l are used to gauge salinity over time.

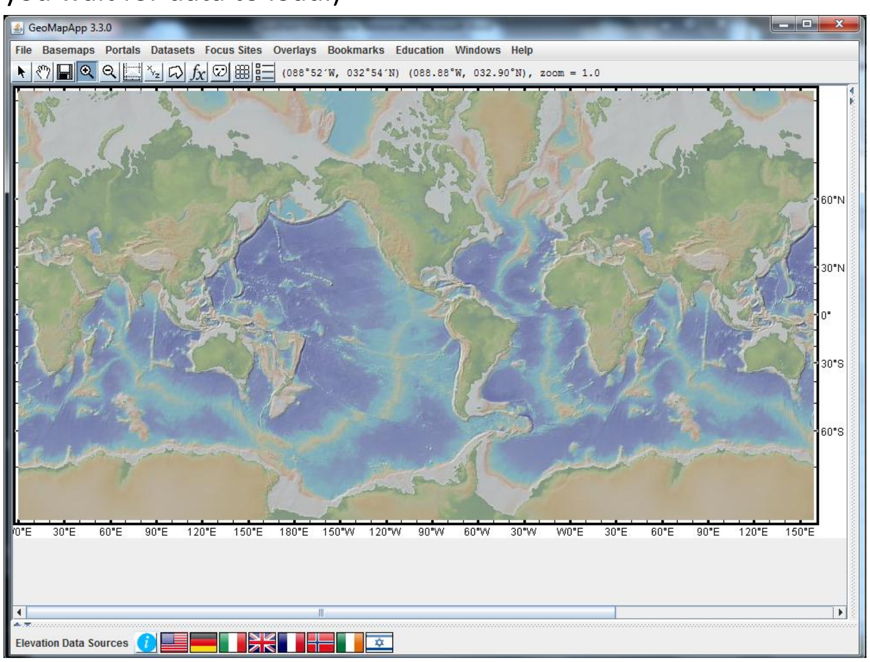
Notice how all the data for well An-16 has latitude and longitude coordinates. With any GIS work these location coordinates are the key that allows data to be “geo-reference”. This is the same type data collected by phones or other “smart” devices to help you shop or get directions. All the chloride data is given in milligrams per liter (mg/l). The table reproduced above is a short selection of data for well AN-16 but to complete this activity you will use the entire data set found in the file called “***BRsand_chlor09***”.

Step 4- Open GeoMapApp and Import Data.

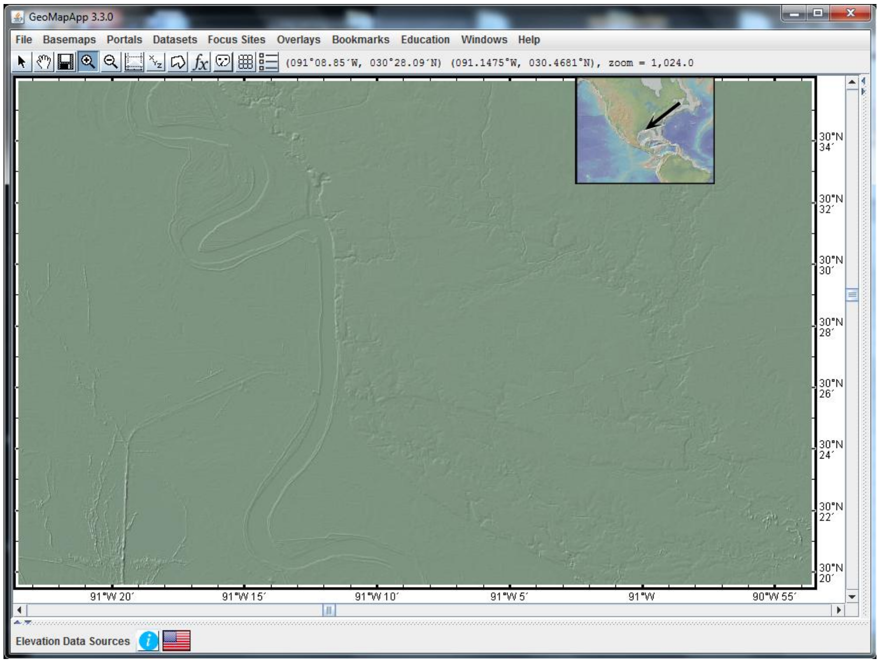
In this step you will learn to upload EBR chloride level data into GeoMapApp. Once you have uploaded the data you will use GeoMapApp to identify well locations that exhibit steep increase rates of chloride. You will then compare these locations to the Baton Rouge fault.



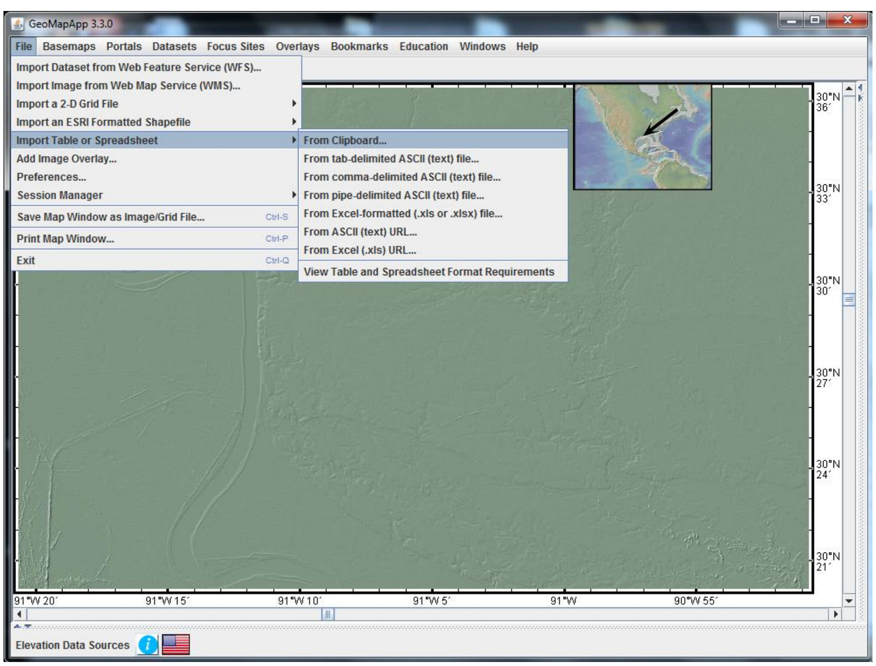
1. Take a moment to examine the start screen. For this investigation we will use the Mercator projection on the left.
2. To select Mercator click on the left map and click **Agree**.
3. Use the zoom tool (magnifying glass with a + sign) from the toolbar at the top to zoom in to Baton Rouge area you looked at with SONRIS. (This may take a bit of patience as you wait for data to load.)



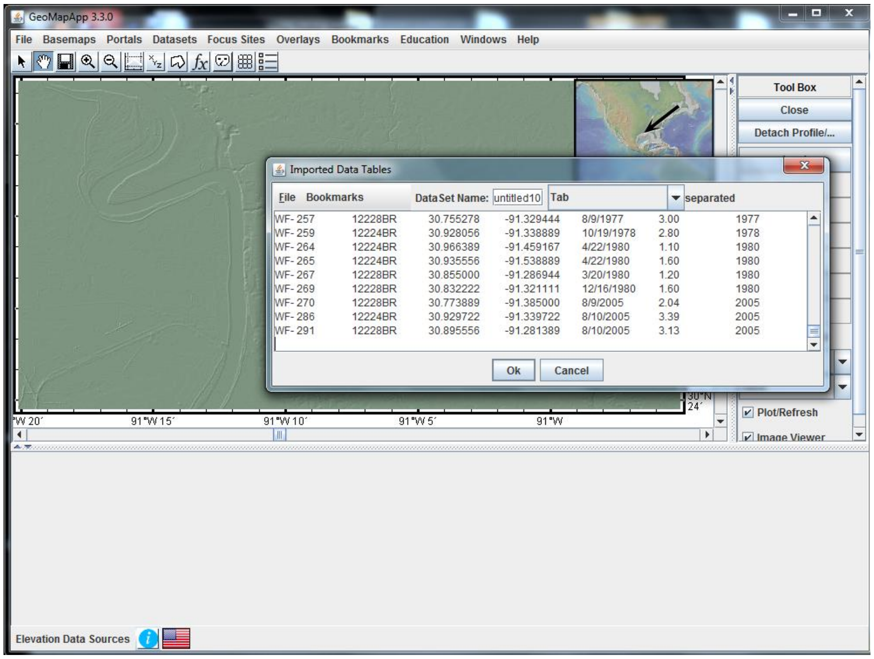
Tip: it will take about 10 clicks on the magnifying tool to get you zoomed in. If you get lost you can use the hand to drag the map center to (091.1470W, 030.467N)



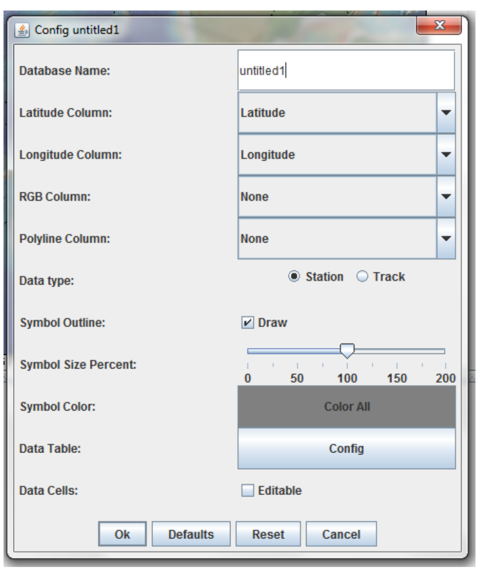
4. Open the file called “BRsand_chlor09”. Highlight and copy the entire table to your clipboard. Make sure you copy the column headers as they will be used in GeoMapApp.
5. At the top left of your GeoMapApp screen select **File**>**Import Table or Spreadsheet > From Clipboard…**



(If you have a saved Excel file you can select **From Excel-formatted file…** in this same window.) The Excel file you copied on your clipboard should now be pasted directly into the highlighted box:

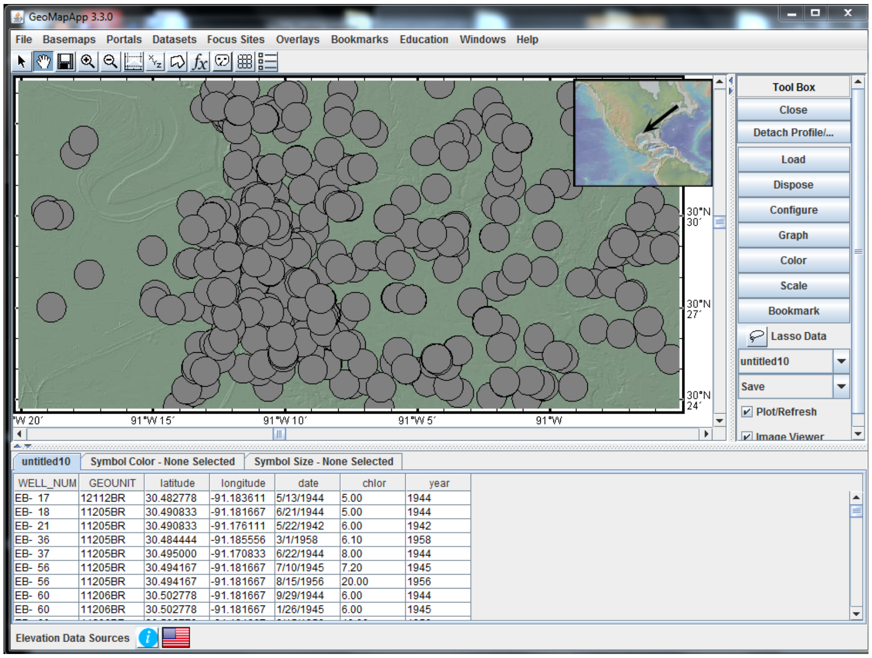


6. After clicking **Ok** you will see the following new window appear:



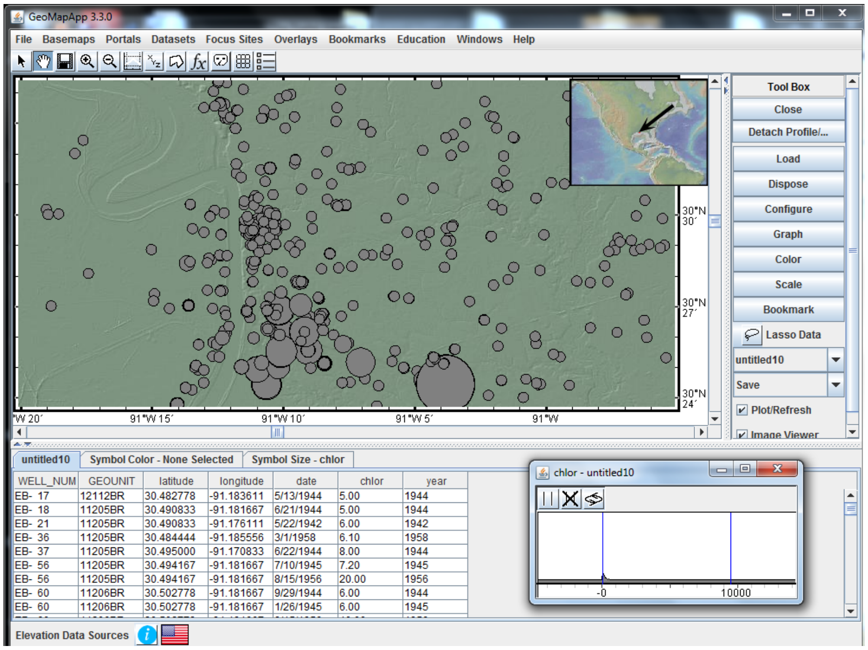
Notice that the latitude and longitude columns you loaded will automatically be used as the GeoMapApp latitude and longitude values. Any future tables you want to load must have columns of latitude and longitude for location reference. These coordinates must be in decimal form. (Note: If you are working with sexagesimal (degrees, minutes, seconds) you can convert the data using the online calculator found at: http://www.overspoor.nl/convert/sexagesimal2decimal.asp North latitudes should be entered with positive decimal values and south with negative values. West longitudes should be entered with negative values and east with positive values.)

7. Click **Ok** to load the data.



Step 5- Manipulating Symbol Size and Color

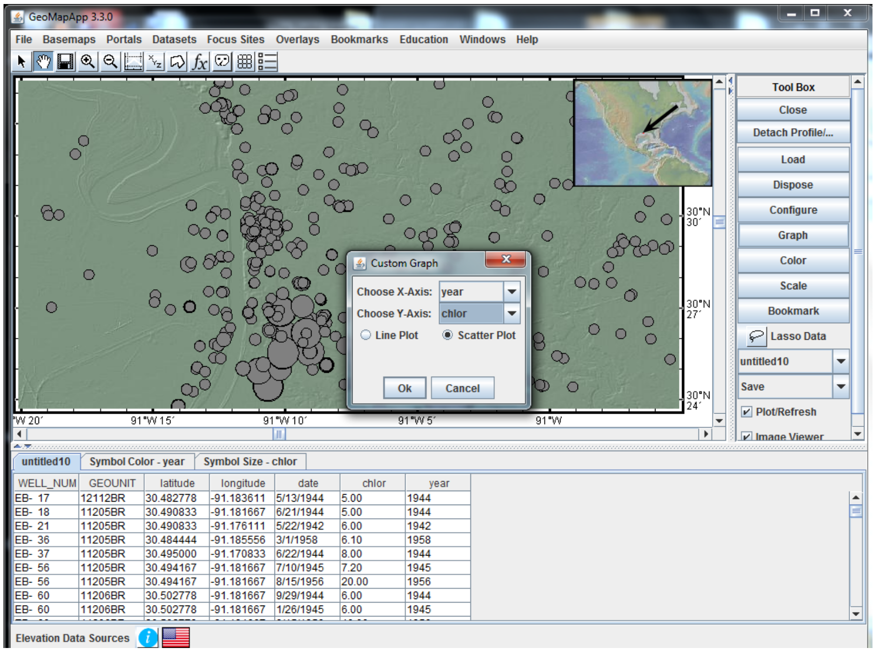
1. Notice that the uploaded table now appears on the GeoMapApp dock at the bottom of the screen and that the well coordinates have been loaded into the map as round icons. (Many of the icons overlap even though the wells do not. You will solve this problem later.) If needed, you can continue by zooming into the area where the well icons are located using your zoom tool as you did in Part 1.
2. Put away the zoom tool and select the arrow pointer from the left side of the toolbar. Click one of the round well icons with the arrow pointer tool. What did you notice? Each symbol you select causes the corresponding row in the data table to be highlighted. Now you will manipulate the symbols to enhance image
3. To change the well icon sizes and show the amount of chloride found in the well, use the pointer tool to select the **Scale** button on the **Tool Box** to the right. Click the arrow to the right on the **Select Column** box to open the dropdown menu. Select ***chloride*** > **Ok**.



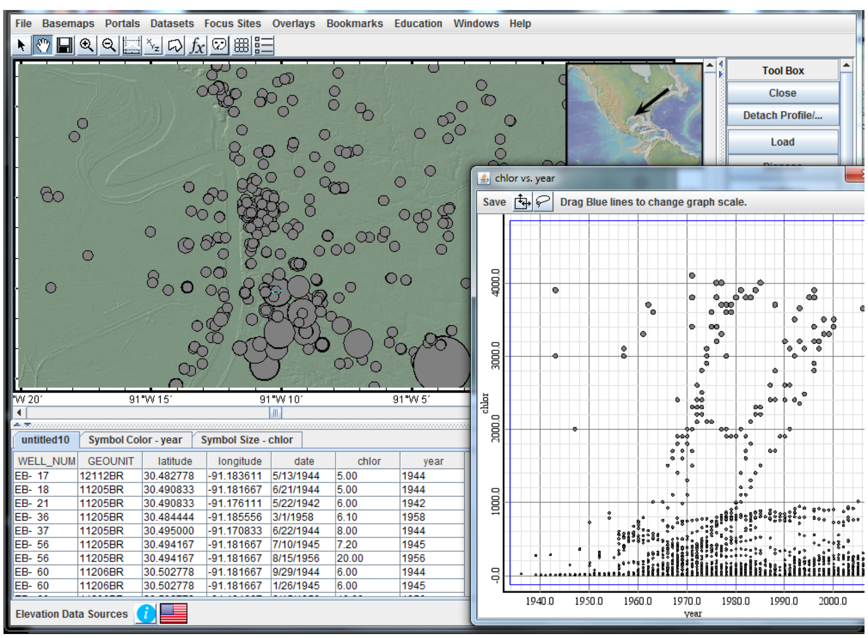
Now the size of your well icons corresponds to the chloride levels in the wells. How could this be useful? What is the name of the well with the highest reported chloride?

Step 6- Creating Graphs with GeoMapApp

1. Although you can see the relationships between location and chloride level with your map, you can also create graphs using the data you uploaded. Use your pointer tool to select the **Graph** button from the **Tool Box** at the right. Follow the prompts to select **year** as your x-axis and ***chloride*** as your y-axis.
2. Select the **Scatterplot** function.

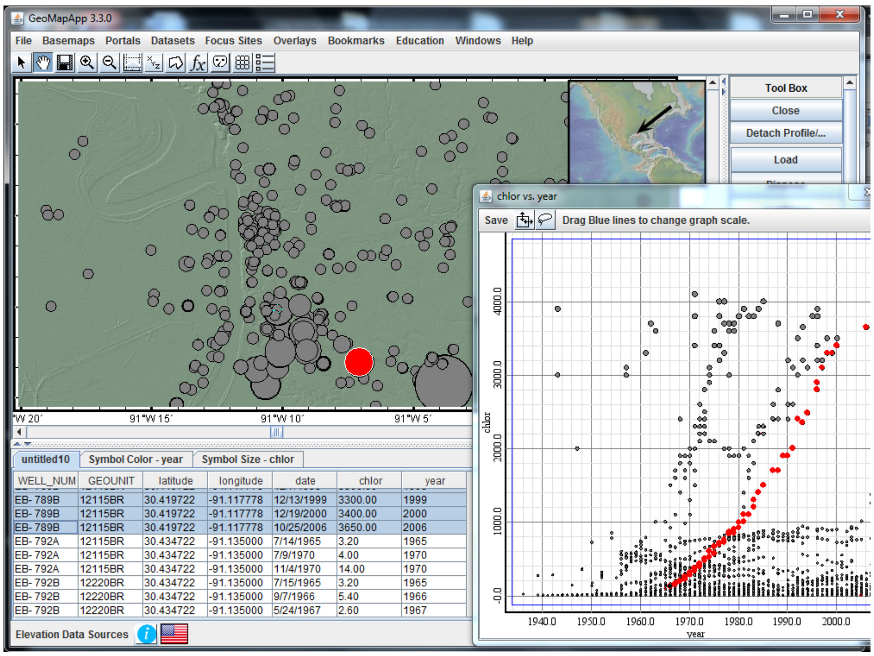


Take a few minutes to review the graph you have created. Do you notice any trends? Keep in mind that this graph shows all chloride data for all wells in our study area. We are most interested in identifying the wells with strong positive chloride trends as they can help us find which wells are experiencing saltwater intrusion.

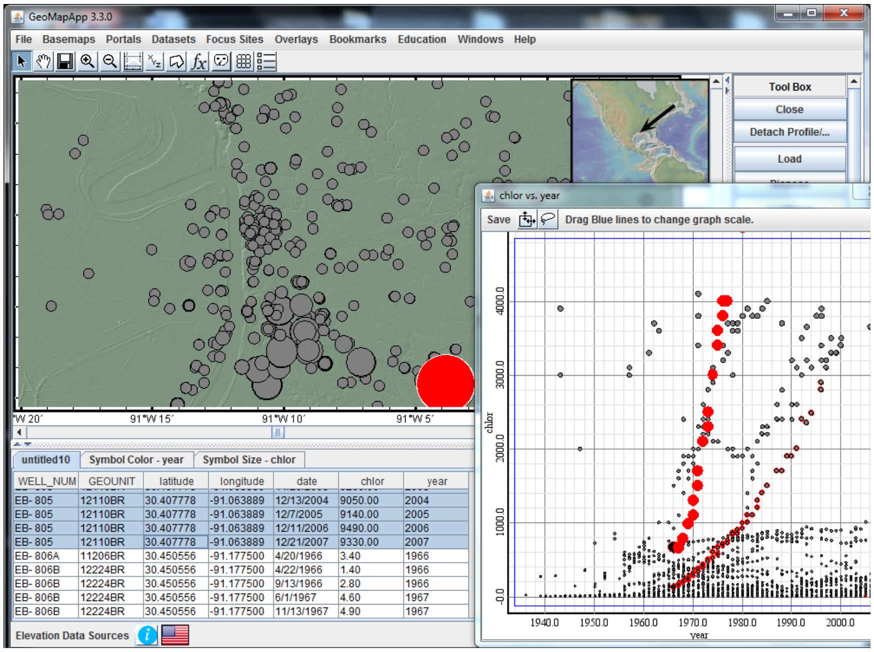


3. To look at the chloride trend for one of your wells, select the pointer tool from the top toolbar and use it to click on one of the well icons shown in the map. Notice that the

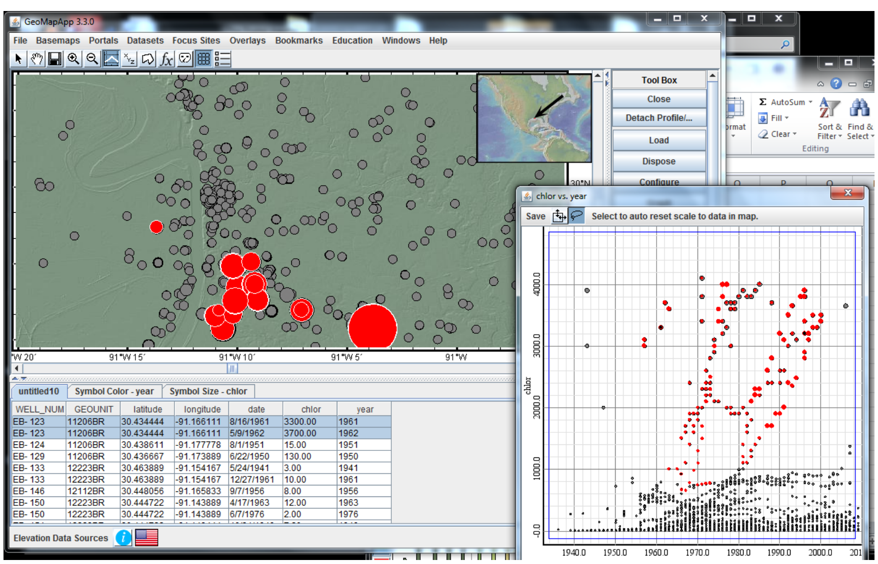
icon is now red. When you selected this well feature you also highlighted the rows of data in your table that correspond to that well. Simultaneously, you have highlighted the data points on the graph which show that well's chloride levels. You can use this function to identify wells of interest by name and coordinates in your report. (Remember you can always capture screen shots of you work for your report or follow the prompts to save the graphs you create during your investigation.)



Go ahead and select a different well and compare the trends between the two:



4. Since you are interested in locating all of the wells with a spike in chloride levels you can use another tool on the graph you created. At the top left of the graph select the "lasso" tool with your mouse. Now click and drag on the graph to circle the data points where the trend is strongest.

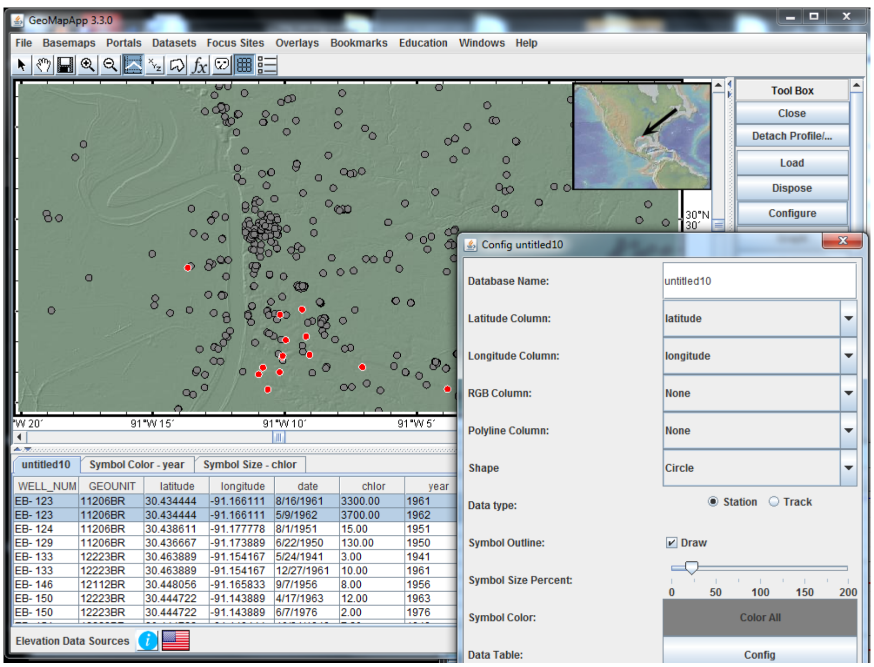


This will highlight all well locations in your table and on your map that show sharply increasing chloride levels. These are the areas where saltwater intrusion is taking place. As before you can now copy the well names and coordinates into your report.

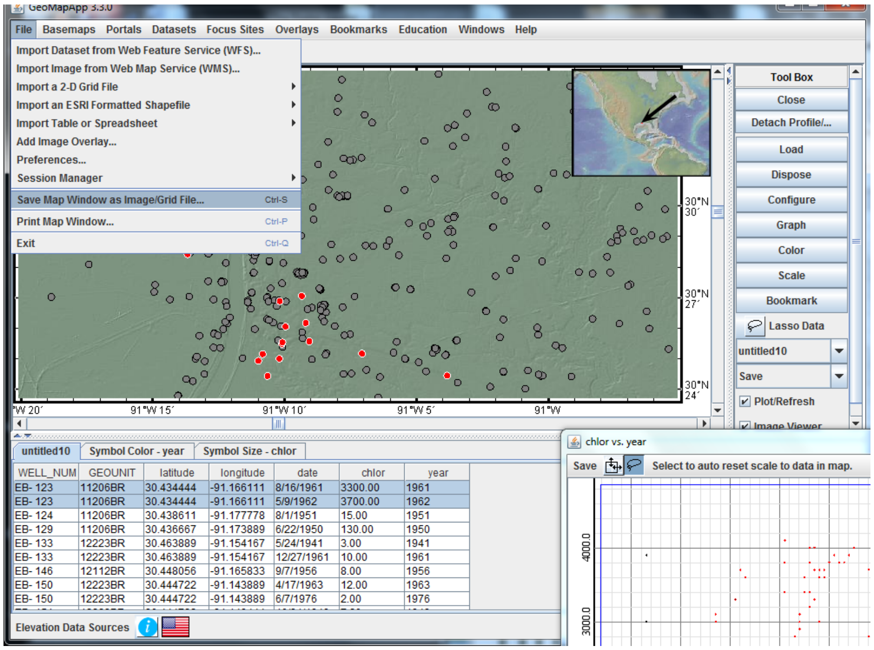
Step 7- Resizing data points and opening GeoMapApp products in Google Earth.

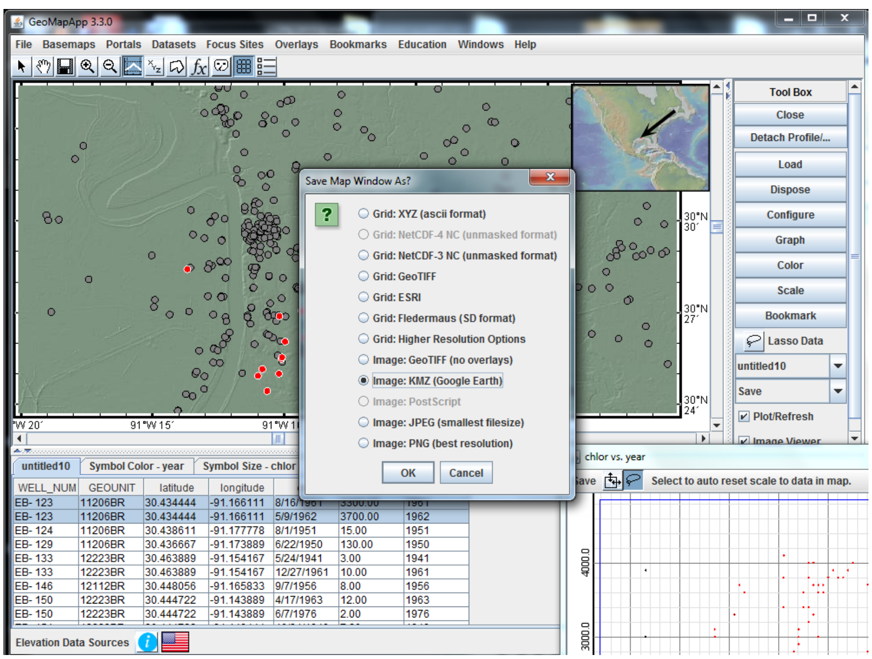
Your map products are powerful visualizations that help you understand changes in groundwater but unlike SORIS products they lack links to satellite images that show the connection to the city you live in. In this part of the investigation you will save you maps as files that can be opened in Google Earth.

1. Begin by cleaning up the clutter caused by the oversized well icons. To do this select **Configure** from the **Tool Box** at the right of the screen. In the pop-up window that appears you will see a slider labeled **Symbol Size Percent**. Slide the arrow to 25% and click **OK**.

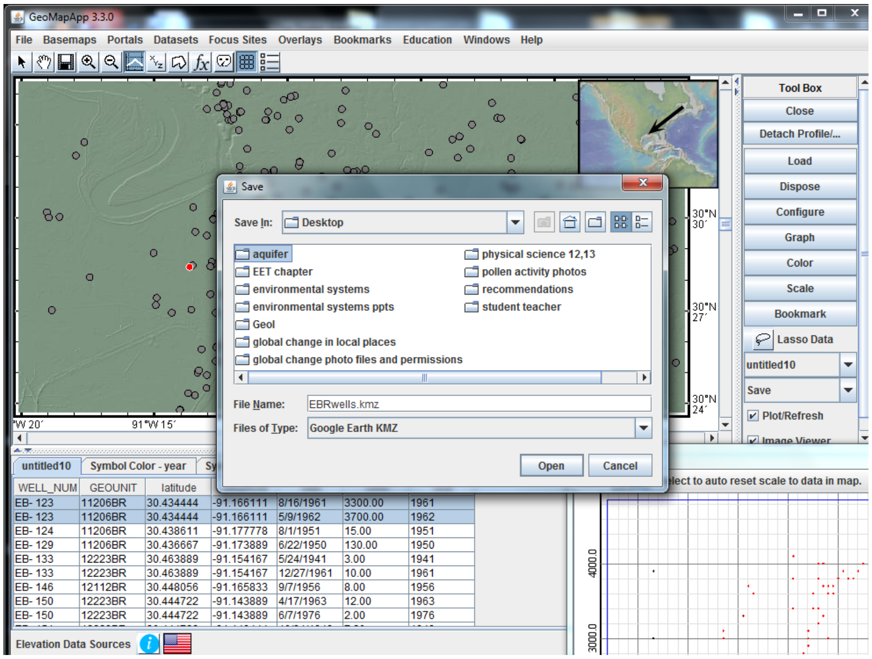


2. To save your image, select **File** at the upper left. From the drop down menu select **Save Map Window as Image/Grid file**. In the pop-up box select **Image KMX (Google Earth)** and click **OK**.s

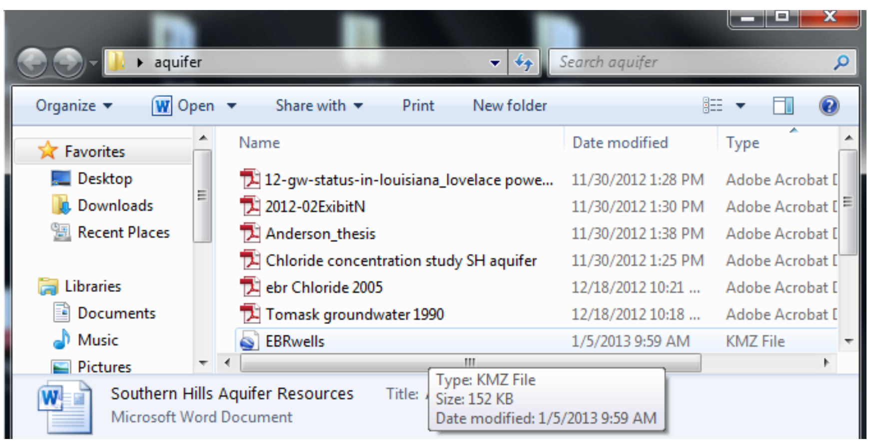


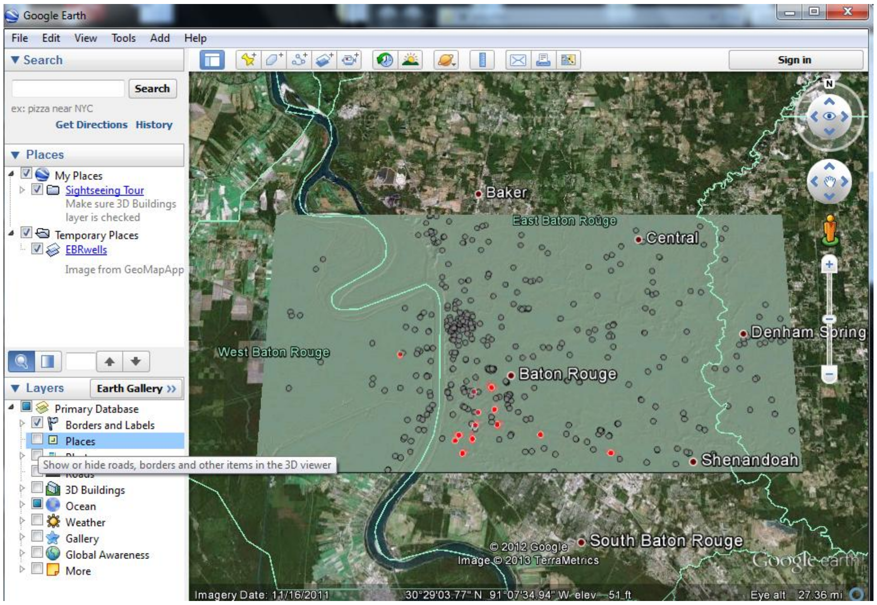


3. Follow the prompts to give your file a name and choose a destination folder. Minimize all GeoMapApp windows.



4. Navigate to the file you just created. Select and open the file. (If you do not have Google Earth already loaded on your computer you can obtain the free download at: www.google.com/earth/download-earth





When you zoom in with Google Earth you will notice that your image overlay may become too blurry to use. If this is the case, go back to GeoMapApp and zoom in closer to your area of interest before saving the KMZ file. Opening this new image in Google Earth will solve the blurring problem.

Step 8- Completing your report

Follow your teacher's guidelines for communicating your results.