# *Sulfate and Chloride Analysis of Matagorda County, Texas*

## I. Goal

The goal of this project is analyze the concentrations of sulfate and chloride in the Chicot aquifer, underlying Matagorda County, Texas, and compare data over time. Determination of a relationship between the changes in concentrations and saltwater intrusion within the aquifer will be another focus.

## II. Problem

With talks of freshwater becoming as valuable as oil in terms of a natural resource in the near future, the responsibility of knowing the quality and how that quality changes overtime becomes a necessary study when providing clean, healthy drinking water to an ever growing population. This project focuses on one potential contaminant to freshwater resources, salt water intrusion. The area of interest for this analysis is the Chicot aquifer within Matagorda County, Texas. Two time periods (1960-1965 and 1997-2006) will be compared with one another to determine changes in constituent concentrations. Sulfate and chloride were chosen as the analytes, due to their substantial presence in salt water. What changes in sulfate concentration occur between these two periods of time? How have chloride concentrations changed? Do both constituents show the same trend over time? Can these changes attributed to fluctuations in salt water intrusion?

## III. Data

The data utilized in this project come from two sources:

1. The Texas General Land Office website: Provided a county boundary shapefile for the entire state of Texas. Data was provided to the Texas General Land Office by the Texas Commission on Environmental Quality (TCEQ).

2. The Texas Water Development Board: Provided water quality information and well location data for Matagorda county (data was downloaded as text delimited files).

## IV. Procedure

Summary of steps needed to create comparable data:

A. Conversion of county data to a new geographic coordinate system.
B. Limiting Matagorda as county of interest.
C. Conversion/manipulation of well data for Matagorda County.
D. Importing well data into ArcGIS and creating a shapefile.
E. Binding geo-statistical data within the county boundary.
F. Interpolate well shapefile data to create raster data models.
G. Create analysis masks for analyte concentrations.
H. Perform raster calculations to analyze changes in sulfate and chloride concentrations over time.

### A. Conversion of county data to a new geographic coordinate system:

After downloading the county shapefile, an exploration of the metadata in ArcCatalog showed that the predefined coordinate system was GCS_North_American_1927 (Fig. 1A). A search through the Texas water development board website showed that well location data was taken in GCS_North_American_1983. These two coordinate systems differ by about 10 meters, which could potentially create problems when analyzing and creating calculations on spatial data.

To avoid this problem, the County shapefile was converted to NAD83 (Fig. 2A) under the shapefile properties in ArcCatalog. Doing this in ArcCatalog permanently converts this data to the newly selected Geographic Coordinate System.

### B. Limiting Matagorda as county of interest:

After converting the county shapefile to the same coordinate system as the well location data, Matagorda County needed to be selected from the other counties in Texas, and exported to create a new shapefile of that county.

After adding the County shapefile to ArcMap, Matagorda County was selected by the attributes option (Fig. 1B), and then exported to create a shapefile only showing Matagorda County (Fig. 2B).

### C. Conversion/manipulation of well data for Matagorda County:

Data from the Texas Water Development Board was downloaded as two files, water quality data and well location data, in the form of text files spaced by commas (Fig. 1C). The files contained considerably more data than what was needed, came in a format that is unable to be manipulated easily or accurately, and was separated into two when only one "master file" was needed.

To combat this problem, the two texts files were converted into Microsoft Excel, so that manipulation of the data was performed without fault or with too much difficulty. Once converted into an Excel file, well data was limited and combined to form six columns: State well number, latitude, longitude, year sampled, SO4 concentration, and Cl concentration (Fig. 2C). Excel data was further limited by the removal of years and wells that were not within the scope of the project. This became the "master file" of well information.

Four additional Excel files were created to decrease the amount of time selecting data to interpolate at a later point in the project. These excel files split well data/locations into sulfate and chloride concentrations into the two time spans (i.e. SO4 60-65, Cl 60-65, SO4 97-06, and Cl 97-06).

**D. Importing well data into ArcGIS and creating a shapefile:**

After the data was manipulated into separate files, it was then imported into ArcMap via the Add X,Y Data tool, making sure to set the Coordinate System as NAD83 (Fig. 1D). After importing the Excel well data, a check of the attribute tables showed that all information carried over correctly, however, the file present in ArcMap was not a shapefile, but merely an "event". To create an actual shapefile, the data points needed to be exported and saved, similarly to the exportation of the Matagorda County shapefile.

Once exported out, four shapefiles were created representing the different constituents over different time spans (Fig. 2D).

**E. Binding geo-statistical data within the county boundary:**

The next step was to make sure that all raster data models would be contained within the county boundary. This step was easily accomplished by setting Matagorda County as the boundary to be clipped to within the Data Frame properties (Fig. 1E).

**F. Interpolate well shapefile data to create raster data models:**

The next step in this project was to convert the newly created shapefile data into a raster data model that could easily show concentrations and to create calculations to show changes in concentrations of the constituents.

These raster data sets were created using the Spatial Analysis tool within Arc Toolbox. After selecting Interpolate, a multitude of options were available for the type of interpolation that would occur. Kriging was selected because it allowed for an interpretation of data between well points, and lowered the overall error associated with the interpolation process. Another important decision was selecting a Semivariogram model for the interpolation of the data. The Gaussian model was used in this case so that the interpolation would be weighted to a greater degree upon the higher density area of my wells (Fig. 1F). The areas that had a higher density of wells created an area that was much more likely to decrease the error, however, points farther from the density circle would have much more error, and were least likely to fit "real world conditions".

Kriging for the four datasets created four different raster models that showed a certain concentration of a constituent at a certain time (Fig. 2F).

**G. Create analysis masks for analyte concentrations:**

Analysis of the two raster models created for both sulfate and chloride showed that they were not the same size, which makes since because each well data shapefile used different wells from one another. These well distances shaped part of the boundaries for the raster images. To accurately create calculations based upon these rasters, two contour analysis masks were created, one for sulfate and once for chloride.

Masks were created from the creation of contours of each time period, for each constituent under the Geo-statistical Analyst tool, and then clipping (from Arc Toolbox) two time periods to one another for each constituent to make an analysis mask (Fig. 1G). (i.e. S04 60-65 & 97-06 contours were clipped to one another to create a mask shape that best fit both rasters)

**H. Perform raster calculations to analyze changes in sulfate and chloride concentrations over time:**

After creation of the masks, calculations based upon the sulfate and chloride raster models were ready to be created.

The first step was to set the proper analysis mask for each calculation, which was selected under the options tab under the spatial analyst tools. Under this same toolset, the Raster Calculator was then used to subtract the 1960-1965 data from the 1997-2006 data for each constituent (Fig. H1). The resulting calculations showed the change in concentration of Sulfate from 1960-1965 to 1997-2006 (Fig. 2H) and Chloride from 1960-1965 to 1997-2006 (Fig. 3H).

## V. Conclusion

### Changes in Sulfate concentration:

A purely graphical view of the sulfate concentration from the 60's when compared to the 90's/2000's shows a decrease near the middle of the county with higher concentrations towards the coastline of the Gulf of Mexico. With this data, one might believe that salt water has intruded farther into the county, however, analysis of the numbers associated with the raster data shows something else.

Min. = -19.00 mg/l
Max. = 30.75 mg/l
Mean = -1.15 mg/l
STD = 7.73 mg/l

The changes in sulfate concentrations are slight, so an interpretation on such a small order cannot be made. The mean concentration actual shows a loss in sulfate concentration, however, this statistics is worthless because the standard deviation (or error) is greater than the mean, which again means that an interpretation would be difficult at best to make.

Another factor to consider is that the accuracy of the interpolation is weighted near the higher density areas, so the edges of the interpolation have the greatest error. These just happen to be areas that show an influx of sulfate concentration.

### Changes in Chloride concentration:

Again, looking at the map in a purely graphical since, the same seen in the Sulfate concentrations, can be seen with the Chloride concentrations. There is a decrease in the concentration of chloride in the central and northern areas of Matagorda, but there is a sharp increase in concentration near the coast. This would seem to indicate that an influx of chloride occurred from the 60's to the 90's/2000's. Analysis of the actual data representing the rasters is needed.

Min. = -374.51 mg/l
Max. = 1065.20 mg/l
Mean = 114.38 mg/l
STD = 218.40 mg/l

In this analyte, the difference in the minimum and maximum concentrations are drastic, and seem to indicate that concentrations of chloride seem to have increased overtime. The mean change in concentration, though, again is smaller than the standard deviation, which could mean that the concentrations have stayed the same over time.

As with the sulfate concentrations, the chloride concentrations between the data points were weighted more heavily upon higher density data, which leaves a greater error seen near the edges of the raster model. This again, is where the greatest differences in concentrations are seen.

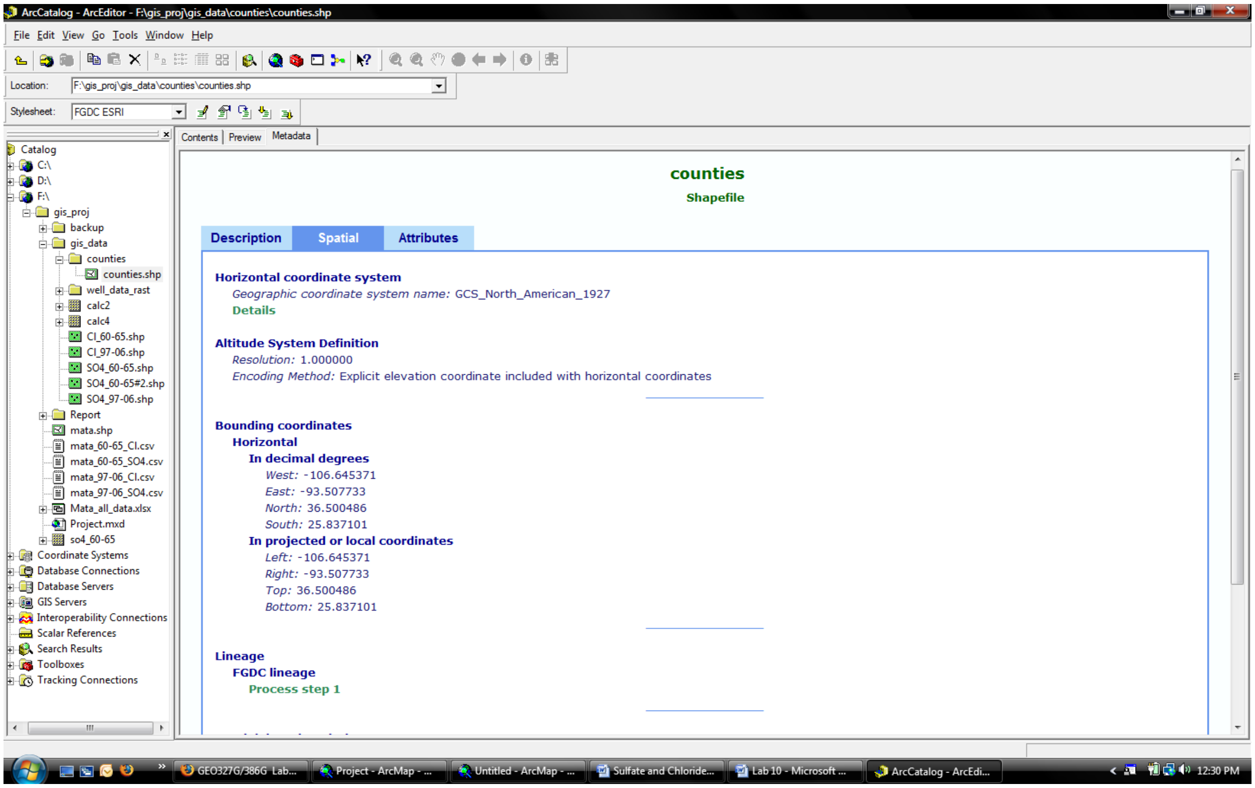
**Overall Picture:**

It is hard to accurately say whether or not salt water has intruded farther in to the county or has regressed towards the coastline. Graphically, a similar correlation between the sulfate and chloride concentrations is seen, with an influx of concentration in both near the coastline and a loss of concentration near the central and northern areas. Analysis of the numerical data shows that the error is too great to say either way what is actually going on.

What can be said though, is that there is a correlation between the two constituents. My hypothesis is that there has been a slight influx of salt water into the Chicot over time, the cause of which is beyond the scope of this paper.

The accuracy of this project and of the GIS data created would be further enhanced by the following factors:

1. A greater amount of wells (especially near the coastline and other missing areas seen in the raster calculations) within Matagorda County, that also have a relatively standard distance from the next well.
2. Greater amount of sample data (i.e. sampling events from every well within the same six month span or at least the same year).
3. Interpolation of other constituents to analyze any further correlations
4. Considering other aquifers within the Gulf Coast Aquifer system
5. Correlation of data with other counties along the Gulf of Mexico



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calc2
calc4
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mata_97-06_CI.csv
mata_97-06_SO4.csv
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Project.mxd
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Database Connections
Database Servers
GIS Servers
Interoperability Connections
Scalar References
Search Results
Toolboxes
Tracking Connections
counties
Shapefile
Description Spatial Attributes
Horizontal coordinate system
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Details
Altitude System Definition
Resolution: 1.000000
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Bounding coordinates
Horizontal
In decimal degrees
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In projected or local coordinates
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Lineage
FGDC lineage
Process step 1
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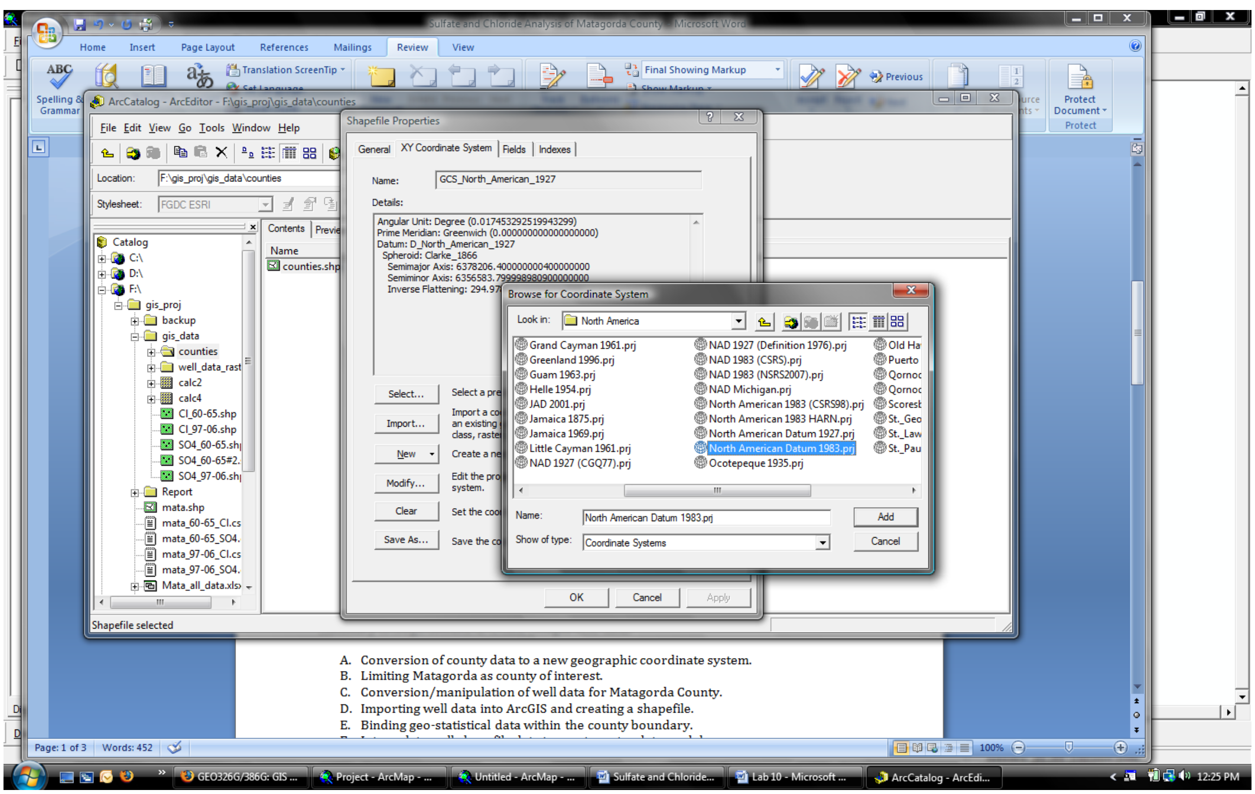
*Fig. 1A*



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Details:
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Datum: D_North_American_1927
Spheroid: Clarke_1866
Semimajor Axis: 6378206.400000000400000000
Semiminor Axis: 6356583.799998980900000000
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Browse for Coordinate System
Look in: North America
Grand Cayman 1961.prj
Greenland 1996.prj
Guam 1963.prj
Helle 1954.prj
JAD 2001.prj
Jamaica 1875.prj
Jamaica 1969.prj
Little Cayman 1961.prj
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NAD 1927 (Definition 1976).prj
NAD 1983 (CSRS).prj
NAD 1983 (NSRS2007).prj
NAD Michigan.prj
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North American Datum 1927.prj
North American Datum 1983.prj
Ocotepeque 1935.prj
Name: North American Datum 1983.prj
Show of type: Coordinate Systems
Add Cancel
Shapefile selected
A. Conversion of county data to a new geographic coordinate system.
B. Limiting Matagorda as county of interest.
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E. Binding geo-statistical data within the county boundary.
Page: 1 of 3 Words: 452
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*Fig. 2A*

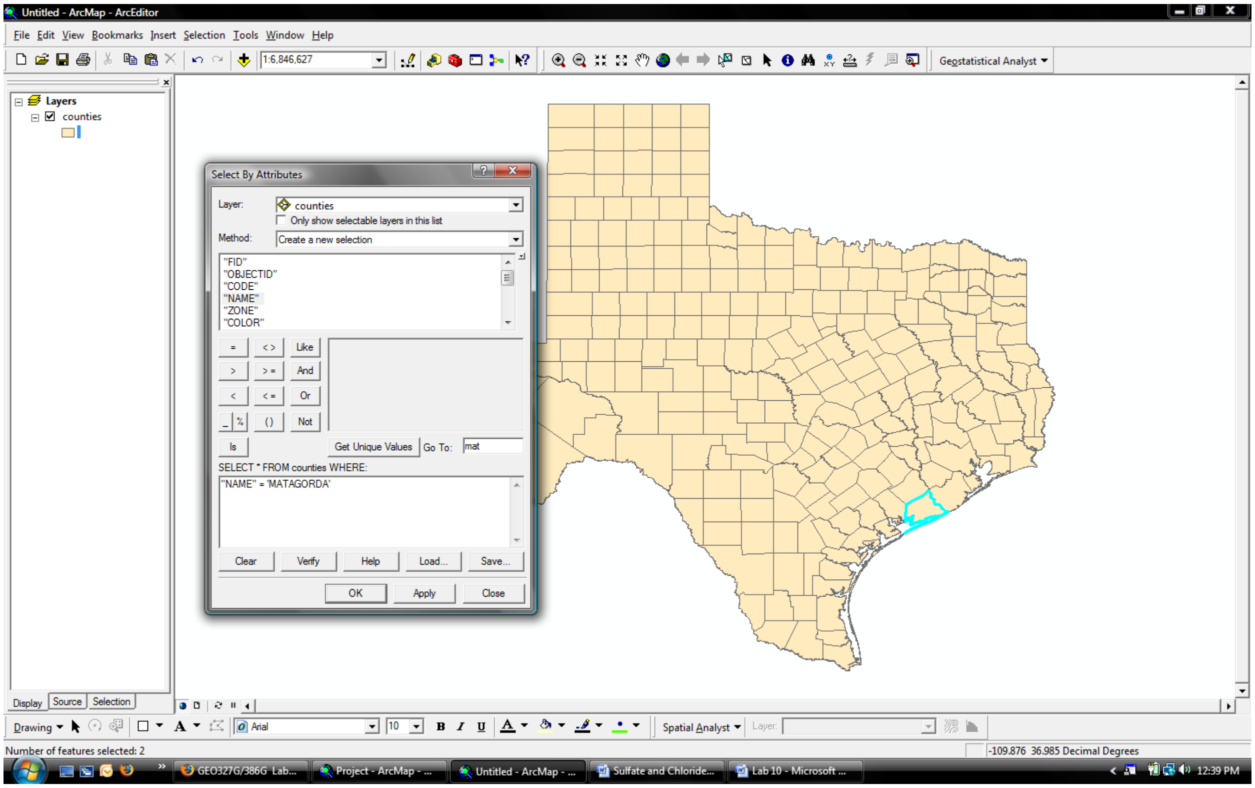
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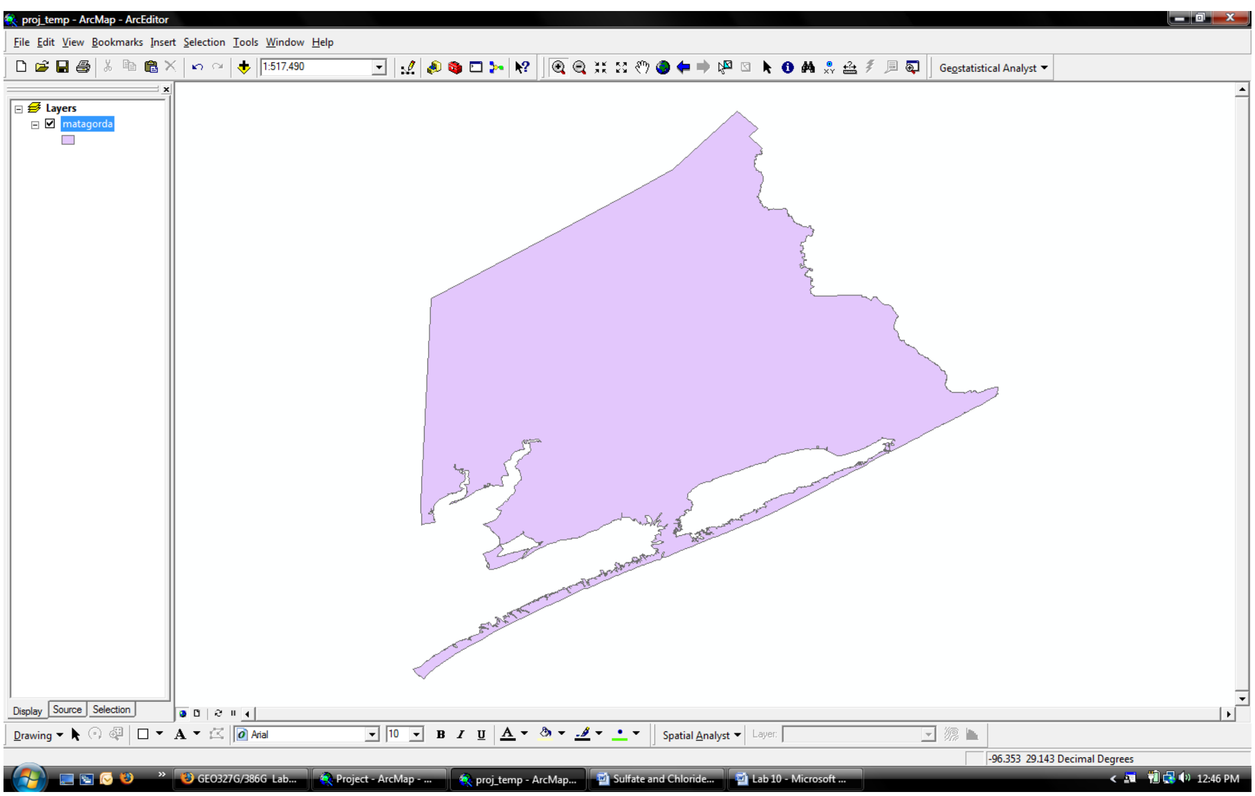
*Fig. 1B*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matagorda

*Fig. 2B*

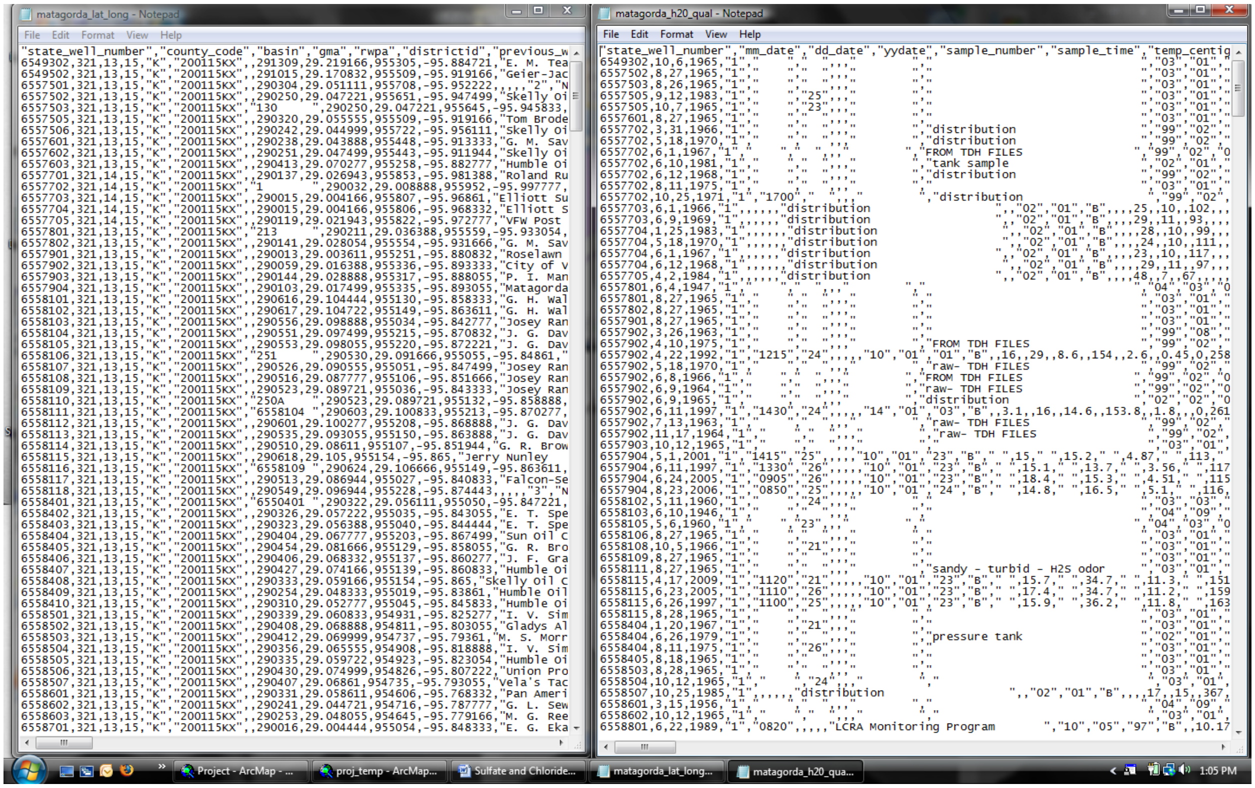
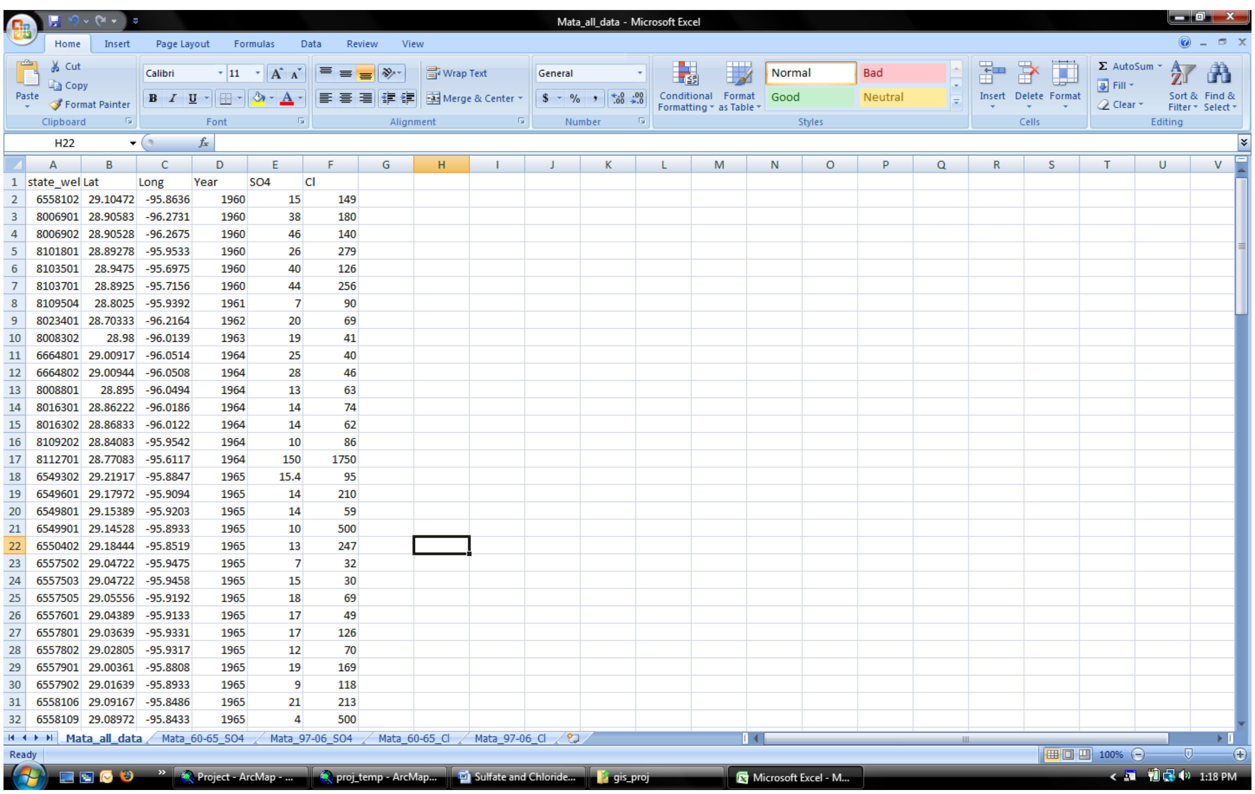



*Fig. 1C*




| state_wel | Lat | Long | Year | SO4 | Cl |
|---|---|---|---|---|---|
| 6558102 | 29.10472 | -95.8636 | 1960 | 15 | 149 |
| 8006901 | 28.90583 | -96.2731 | 1960 | 38 | 180 |
| 8006902 | 28.90528 | -96.2675 | 1960 | 46 | 140 |
| 8101801 | 28.89278 | -95.9533 | 1960 | 26 | 279 |
| 8103501 | 28.9475 | -95.6975 | 1960 | 40 | 126 |
| 8103701 | 28.8925 | -95.7156 | 1960 | 44 | 256 |
| 8109504 | 28.8025 | -95.9392 | 1961 | 7 | 90 |
| 8023401 | 28.70333 | -96.2164 | 1962 | 20 | 69 |
| 8008302 | 28.98 | -96.0139 | 1963 | 19 | 41 |
| 6664801 | 29.00917 | -96.0514 | 1964 | 25 | 40 |
| 6664802 | 29.00944 | -96.0508 | 1964 | 28 | 46 |
| 8008801 | 28.895 | -96.0494 | 1964 | 13 | 63 |
| 8016301 | 28.86222 | -96.0186 | 1964 | 14 | 74 |
| 8016302 | 28.86833 | -96.0122 | 1964 | 14 | 62 |
| 8109202 | 28.84083 | -95.9542 | 1964 | 10 | 86 |
| 8112701 | 28.77083 | -95.6117 | 1964 | 150 | 1750 |
| 6549302 | 29.21917 | -95.8847 | 1965 | 15.4 | 95 |
| 6549601 | 29.17972 | -95.9094 | 1965 | 14 | 210 |
| 6549801 | 29.15389 | -95.9203 | 1965 | 14 | 59 |
| 6549901 | 29.14528 | -95.8933 | 1965 | 10 | 500 |
| 6550402 | 29.18444 | -95.8519 | 1965 | 13 | 247 |
| 6557502 | 29.04722 | -95.9475 | 1965 | 7 | 32 |
| 6557503 | 29.04722 | -95.9458 | 1965 | 15 | 30 |
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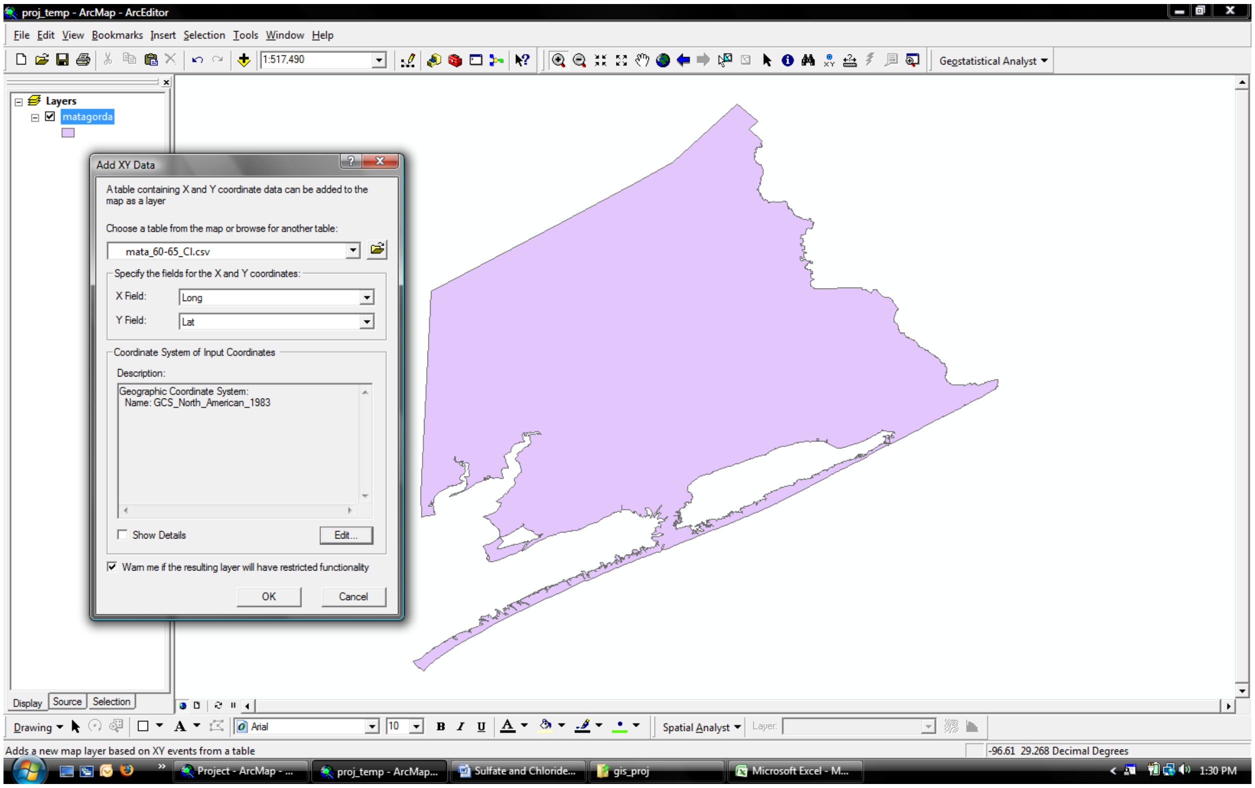
| 6557801 | 29.03639 | -95.9331 | 1965 | 17 | 126 |
| 6557802 | 29.02805 | -95.9317 | 1965 | 12 | 70 |
| 6557901 | 29.00361 | -95.8808 | 1965 | 19 | 169 |
| 6557902 | 29.01639 | -95.8933 | 1965 | 9 | 118 |
| 6558106 | 29.09167 | -95.8486 | 1965 | 21 | 213 |
| 6558109 | 29.08972 | -95.8433 | 1965 | 4 | 500 |

*Fig. 2C*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matagorda
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Choose a table from the map or browse for another table:
mata_60-65_Cl.csv
Specify the fields for the X and Y coordinates:
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Y Field: Lat
Coordinate System of Input Coordinates
Description:
Geographic Coordinate System:
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*Fig. 1D*

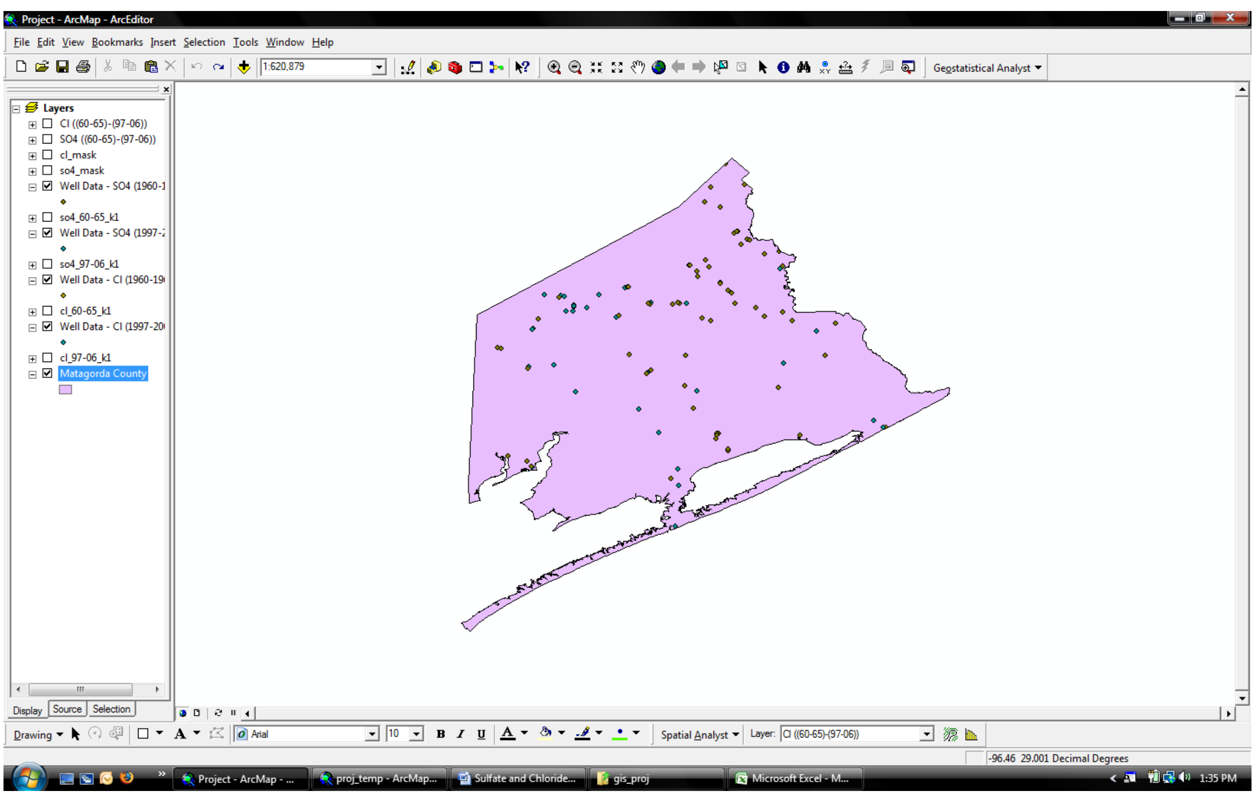
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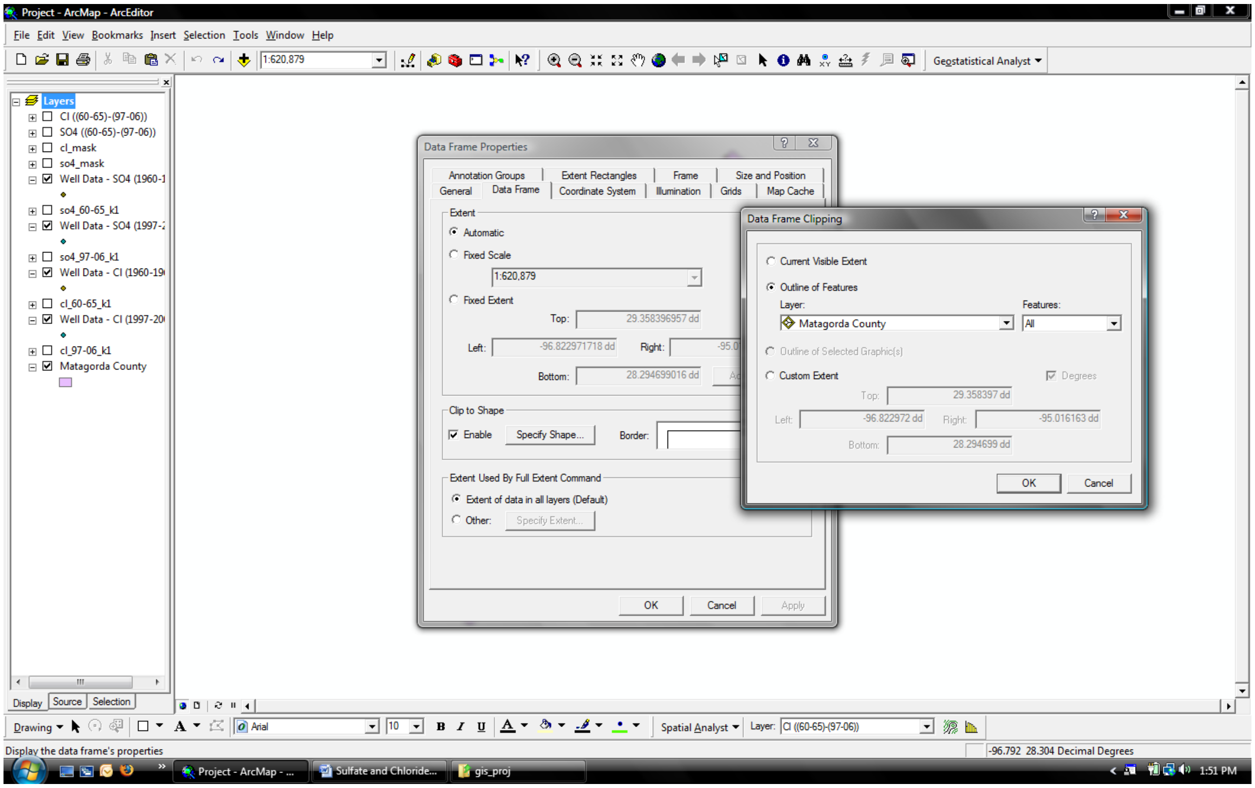
*Fig. 2D*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Frame
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General
Data Frame
Coordinate System
Illumination
Grids
Map Cache
Extent
Automatic
Fixed Scale
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Fixed Extent
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Left: -96.822971718 dd
Right:
Bottom: 28.294699016 dd
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Enable
Specify Shape...
Border:
Extent Used By Full Extent Command
Extent of data in all layers (Default)
Other:
Specify Extent...
OK
Cancel
Apply
Data Frame Clipping
Current Visible Extent
Outline of Features
Layer:
Features:
Matagorda County
All
Outline of Selected Graphic(s)
Custom Extent
Degrees
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Bottom: 28.294699 dd
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Cancel
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Arial
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Sulfate and Chloride...
gis_proj
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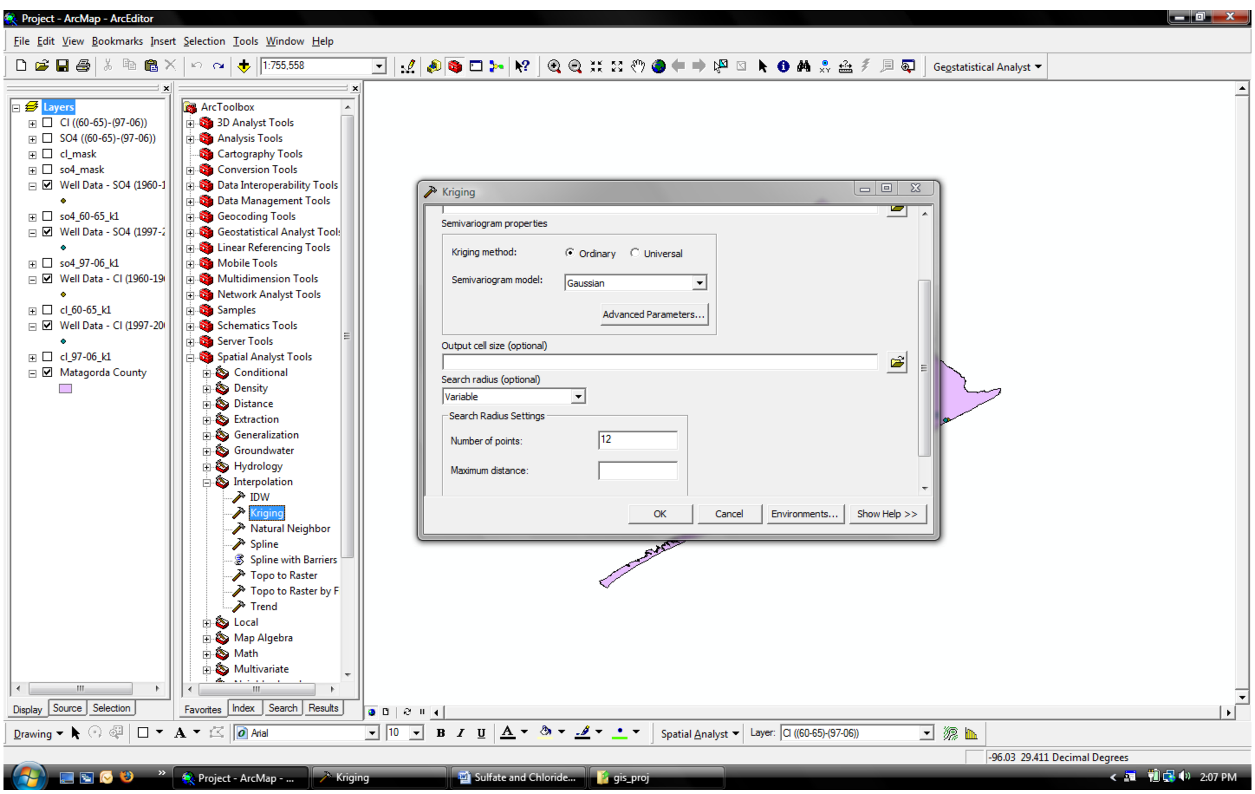
*Fig. 1E*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3D Analyst Tools
Analysis Tools
Cartography Tools
Conversion Tools
Data Interoperability Tools
Data Management Tools
Geocoding Tools
Linear Referencing Tools
Mobile Tools
Multidimension Tools
Network Analyst Tools
Samples
Schematics Tools
Server Tools
Spatial Analyst Tools
Conditional
Density
Distance
Extraction
Generalization
Groundwater
Hydrology
Interpolation
IDW
Kriging
Natural Neighbor
Spline
Spline with Barriers
Topo to Raster
Trend
Local
Map Algebra
Math
Multivariate
Kriging
Semivariogram properties
Kriging method:
Ordinary
Universal
Semivariogram model:
Gaussian
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Search radius (optional)
Variable
Search Radius Settings
Number of points:
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Maximum distance:
OK
Cancel
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Sulfate and Chloride...
gis_proj
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*Fig. 1F*

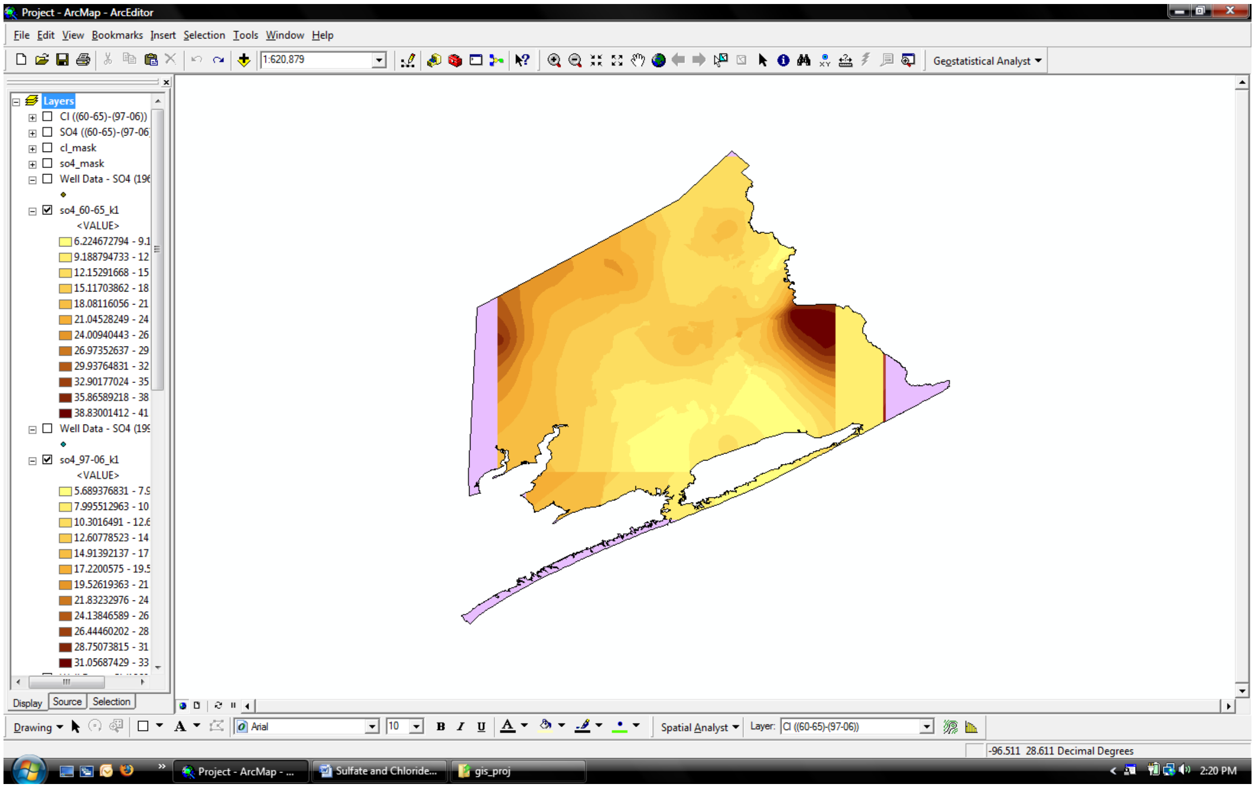


*Fig. 2F*

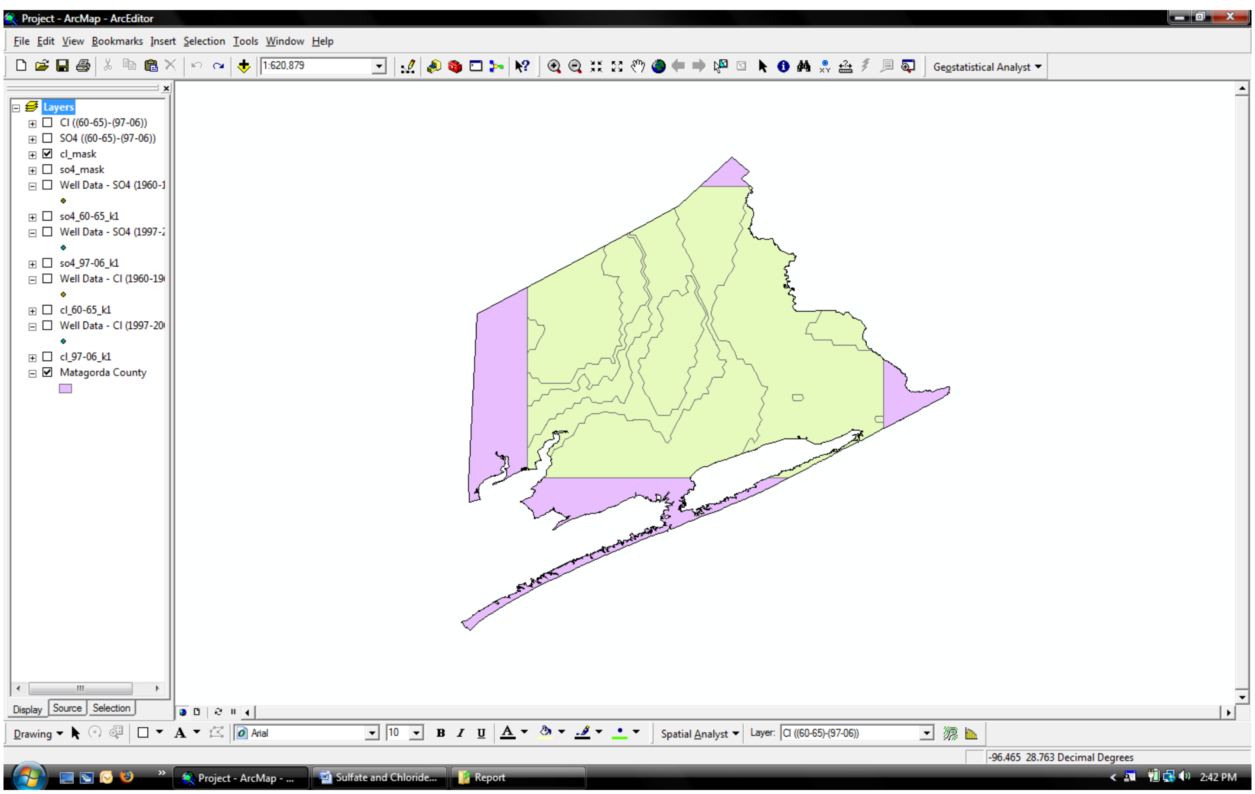
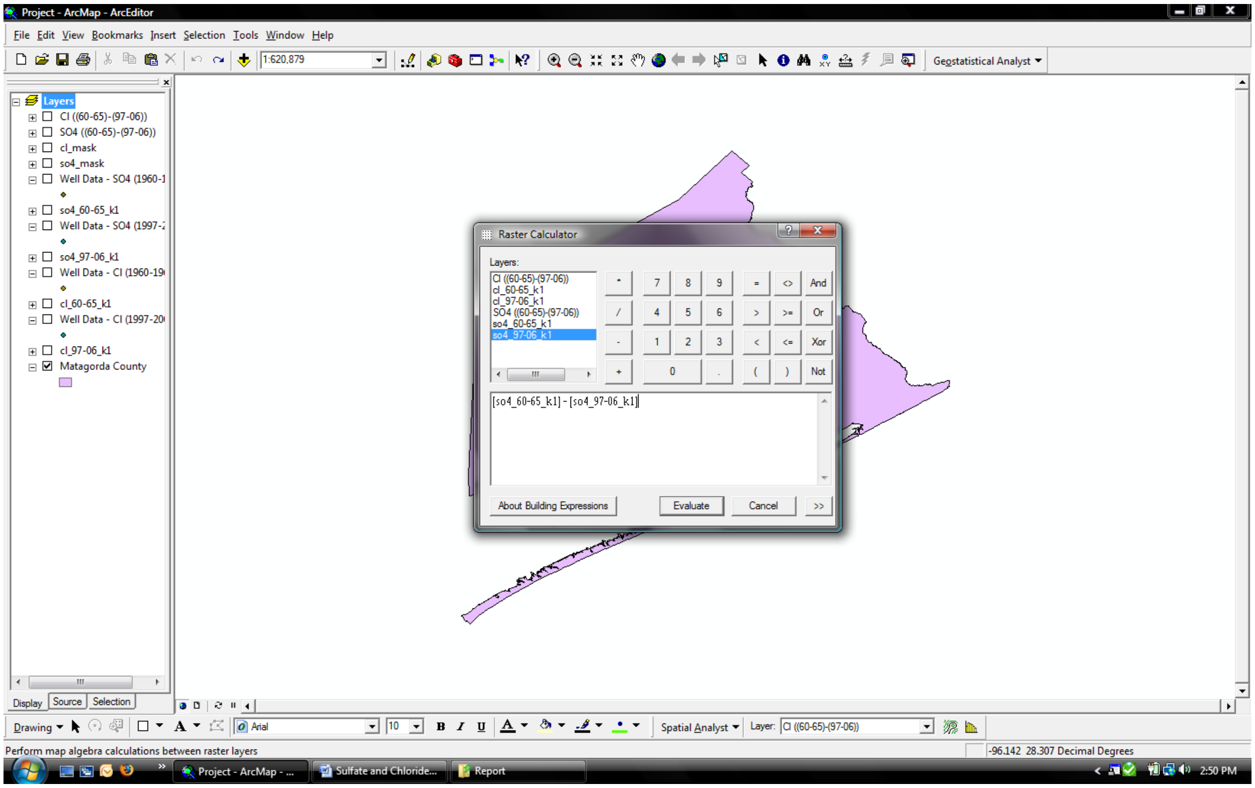


*Fig. 1G*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Matagorda County
Raster Calculator
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*Fig. H1*

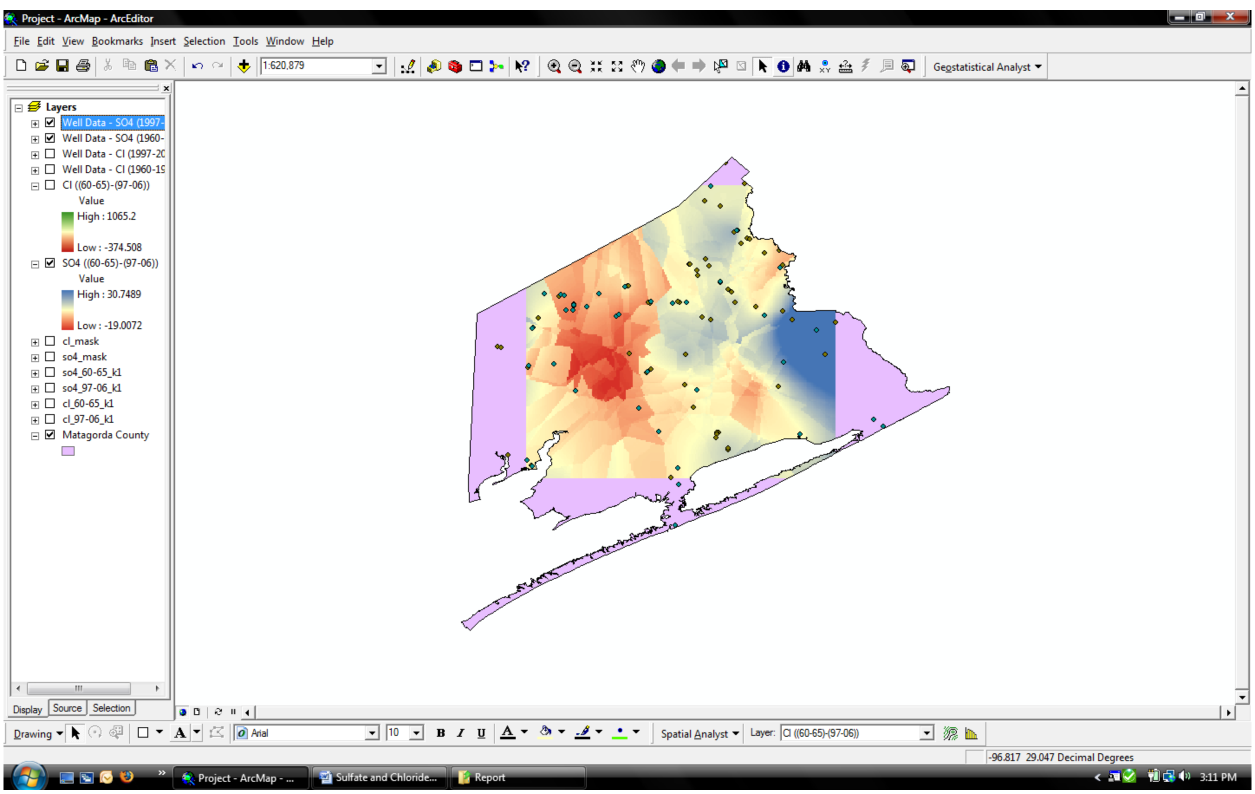
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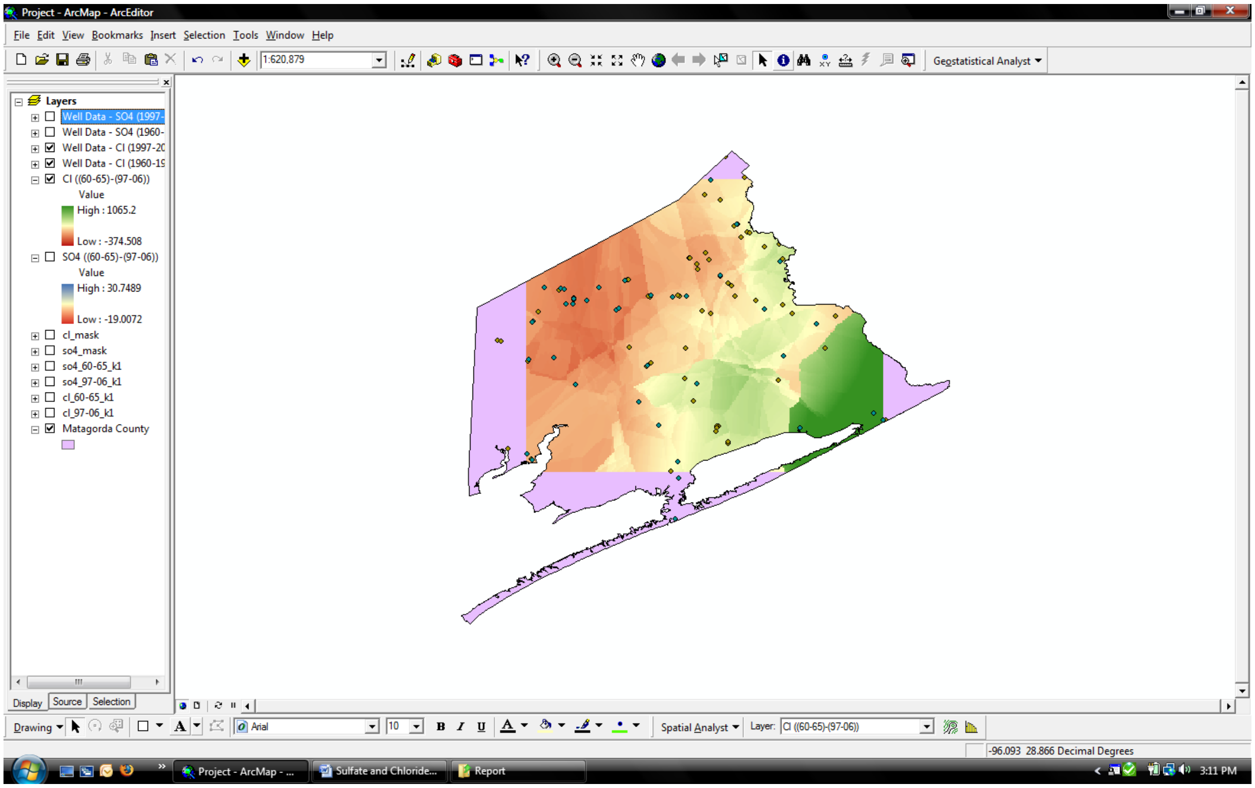
*Fig. 2H*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Geostatistical Analyst
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Well Data - SO4 (1960-
Well Data - Cl (1997-20
Well Data - Cl (1960-19
Cl ((60-65)-(97-06))
Value
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Low : -374.508
SO4 ((60-65)-(97-06))
Value
High : 30.7489
Low : -19.0072
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so4_97-06_k1
cl_60-65_k1
cl_97-06_k1
Matagorda County
Display Source Selection
Drawing
Arial
10
Spatial Analyst
Layer: Cl ((60-65)-(97-06))
-96.093 28.866 Decimal Degrees
Project - ArcMap - ...
Sulfate and Chloride...
Report
3:11 PM
*Fig. 3H*