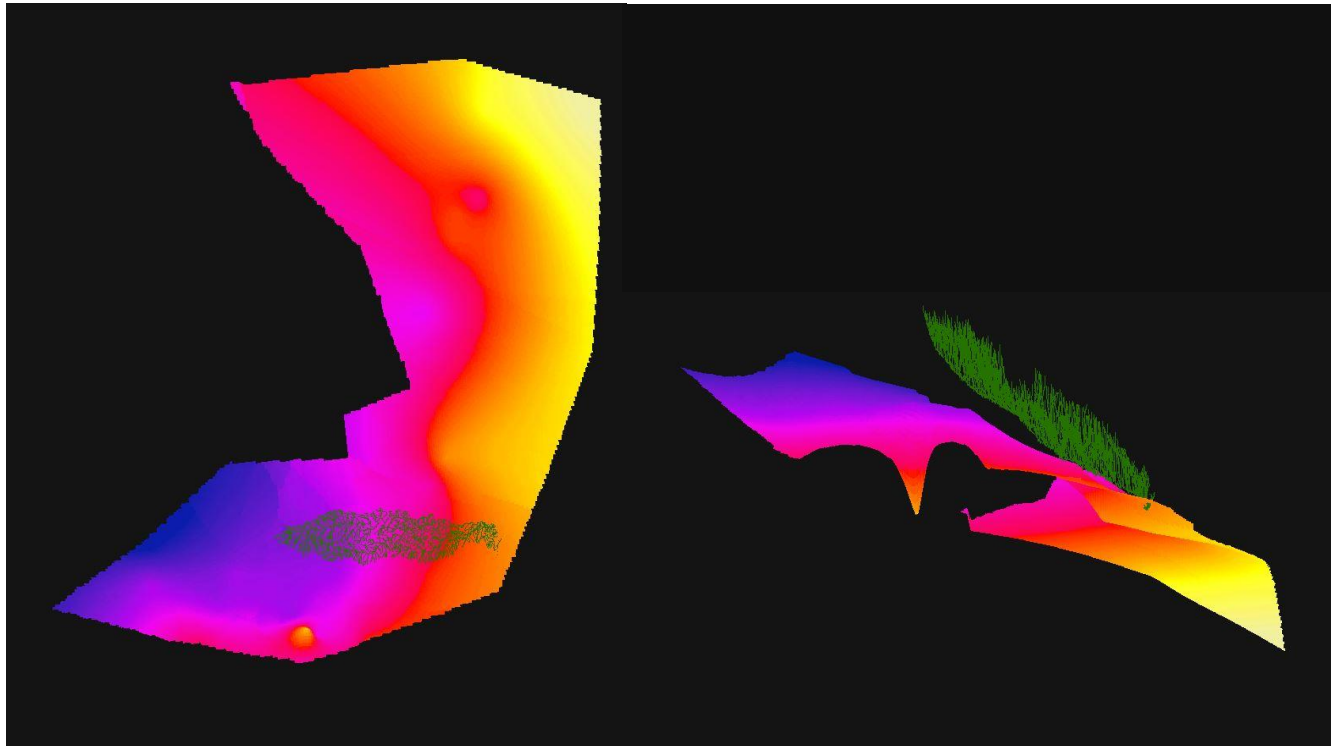# QUANTIFYING LOSS FROM THE MIDDLE TRINITY AQUIFER (2008 TO 2013) AND UNDERSTANDING GAIN-LOSS ALONG THE BLANCO RIVER

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GEO327G: GIS & GPS Applications in Earth Sciences

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INTRODUCTION

The Blanco River serves as in important link between the Trinity and Edwards Aquifer systems. Flow from the Blanco River comes from precipitation in the watershed and from the Trinity Aquifer. In the downstream reaches of the Blanco River, flow may also come from the Edwards Aquifer, but it is generally thought that the Blanco River loses flow to the Edwards Aquifer in this area. During drought conditions, it is thought that the Blanco River supplies the majority of the discharge to Barton Springs. This suggests that the Trinity Aquifer, which controls baseflow in the Blanco River, may also control flow in the Edwards Aquifer. Furthermore, the Edwards and Trinity Aquifers supply hundreds of millions of gallons of water per day to the public. Therefore, it is crucial to understand how water is lost from the Trinity and exchanged into the Edwards.

In recent years, there have been systemic water level declines in the Trinity Aquifer, particularly surrounding the Blanco River. It remains unclear whether these declines come from pumping, reduced recharge, or another factor. In an attempt to understand how this decline in water levels may affect discharge from the Blanco River, the amount of water lost from the Trinity Aquifer must be quantified-both across the spatial extent of available data and beneath the Blanco River Watershed. The simplest, most accurate way of estimating this loss is to process water level data within the ArcGIS software suite.

Additionally, it is important to understand how water is exchanged from the Trinity Aquifer into the Edwards Aquifer via the Blanco River. To do this, a time-series animation of gain and loss along the reaches of the Blanco River between Wimberley, Halifax Ranch, and Kyle is a useful tool for visualization of the temporal and spatial changes that occur along the Blanco River. It is unclear through time how gains and losses are distributed and if there is a seasonal effect on gains and losses.

Questions to be answered by this project are:

1. What is the volume of water lost from the Trinity Aquifer within the spatial extent of available data in recent years?
2. How are gains and losses temporally and spatially distributed along the Blanco River?

LIST OF FIGURES

MAPS

ANIMATIONS

DATA COLLECTION

The data used for this project came from a variety of sources. The digital elevation model (DEM) for the project, the Shuttle Radar Topography Mission (SRTM) 1 arc second DEM, came from the USGS Earth Explorer. Daily water level data for wells in the Middle Trinity Aquifer were downloaded from the Texas Water Development Board. Discharge measurements from the three gages (and their locations) along the river were downloaded from the USGS National Water Information System. Present discharge measurements along the Blanco River were taken for my thesis project in November 2013 in conjunction with the Edwards Aquifer Authority and the Barton Springs/Edwards Aquifer Conservation District. Streamlines were downloaded from the National Hydrography Dataset (NHD). Edwards Aquifer Zone GIS files were published for use from the Texas Commission on Environmental Quality (TCEQ) (http://www.tceq.texas.gov/gis/boundary.html). The Trinity outcrop and subcrop GIS files were published for use through ESRI (http://www.arcgis.com/home/item.html?id=581fcec116b1462695dc3909ea814487). County shapefiles were downloaded from the class lab folder. The metadata of final files was updated to contain name of collection site, location of site (URL), month accessed, a brief description of the file contents, coordinate system, and resolution of the data.

PART I. MIDDLE TRINITY AQUIFER LOSS

I. Data Preprocessing

Data should be downloaded from the TWDB website as a tab-separated fixed-width separated text file. The text files are imported into excel each in a different sheet (**Data> From Text File**). The data is then sorted to display the measurement from the first hour of the first day of each month at the top (**SORT BY COLUMN 2, THEN BY COLUMN 3, etc.**). The elevation of each well is looked up on the TWDB Well Query, and the water levels are subtracted from this value to get height above sea level instead of depth below the land surface. *This is an important step for later creating the raster in ArcGIS.* The first hour of the first day data is copied to another excel file where the data is transposed **(Paste Special > Transpose)** and reversed **(Fill neighboring cells automatically with 1,2,3,4, then SORT high to low)** such that the water level data becomes a row with each month in a different column, starting with November of 2013 and going back to October of 2007. This row is then copied to a new excel sheet and appended to the appropriate well number, and this process is repeated for each well in the Middle Trinity from the TWDB Daily Water Level Monitoring Wells. The final spreadsheet for the well data is shown in Figure 1.

Figure 1: Final well data spreadsheet

After this time-consuming step is completed, months which corresponded to peaks and troughs in water levels in well 5674705 (a well with close proximity to the Blanco River) are copied to a new sheet along with the well number, latitude, and longitude as shown in Figure 2. Wells for which there was no data during the month are deleted from the spreadsheet as shown in Figure 3. The spreadsheet with a single month and corresponding wells is then exported to a CSV (comma delineated) text file. The months that were used for this project were June-2013, October-2011, September-2011, May-2010, September-2009, and June-2008, and the corresponding CSV text files were saved in the same folder.

Figure 2. Wells including no data

Figure 3. Wells with no data removed

II. ArcGIS Processing

After processing in excel, an ArcMap document is created. Streamlines, county lines, HUC outline are all added to the new ArcMap document as shapefiles. These shapefiles contained the coordinate system that I want to use for all files in this project (NAD 1983 UTM Zone 14N). By uploading these files into the map first, the data frame of the map is set to be NAD 1983 UTM Zone 14N.

Point Shapefile Creation

Then, the CSV files that were exported from excel are added to the map (**ADD DATA** button). For each separate table that was created through the add data process the XY data was displayed (**RIGHT CLICK TABLE > DISPLAY XY DATA > ACCEPT DEFULT LAT AND LONG SELECTIONS, SET COORDINATE SYSTEM TO GCS_NAD_1983 ONLY > FINISH**). *It is important to note that in displaying the XY data you must NOT accept the default coordinate system (the data frame) and you must change it to a non-projected coordinate system, otherwise the points end up somewhere completely wrong.* **(After finished is clicked, a dialog box appears that asks if you would like to add the data to the current map. Click Yes).**

The points that appear on the map are projected on the fly to the data frame. After ensuring the wells are plotting in the proper location, export the file to a shapefile with the coordinate system as NAD_1983_UTM_Zone_14N (**RIGHT CLICK FILE > DATA > EXPORT> SELECT "the data frame" AS THE EXPORTING COORDINATE SYSTEM).** Add the exported point shapefile to the map, it should resemble something like Figure 4. Repeat this step for each CSV file imported from excel. It would be prudent to export the point shapefiles to a single folder or geodatabase.
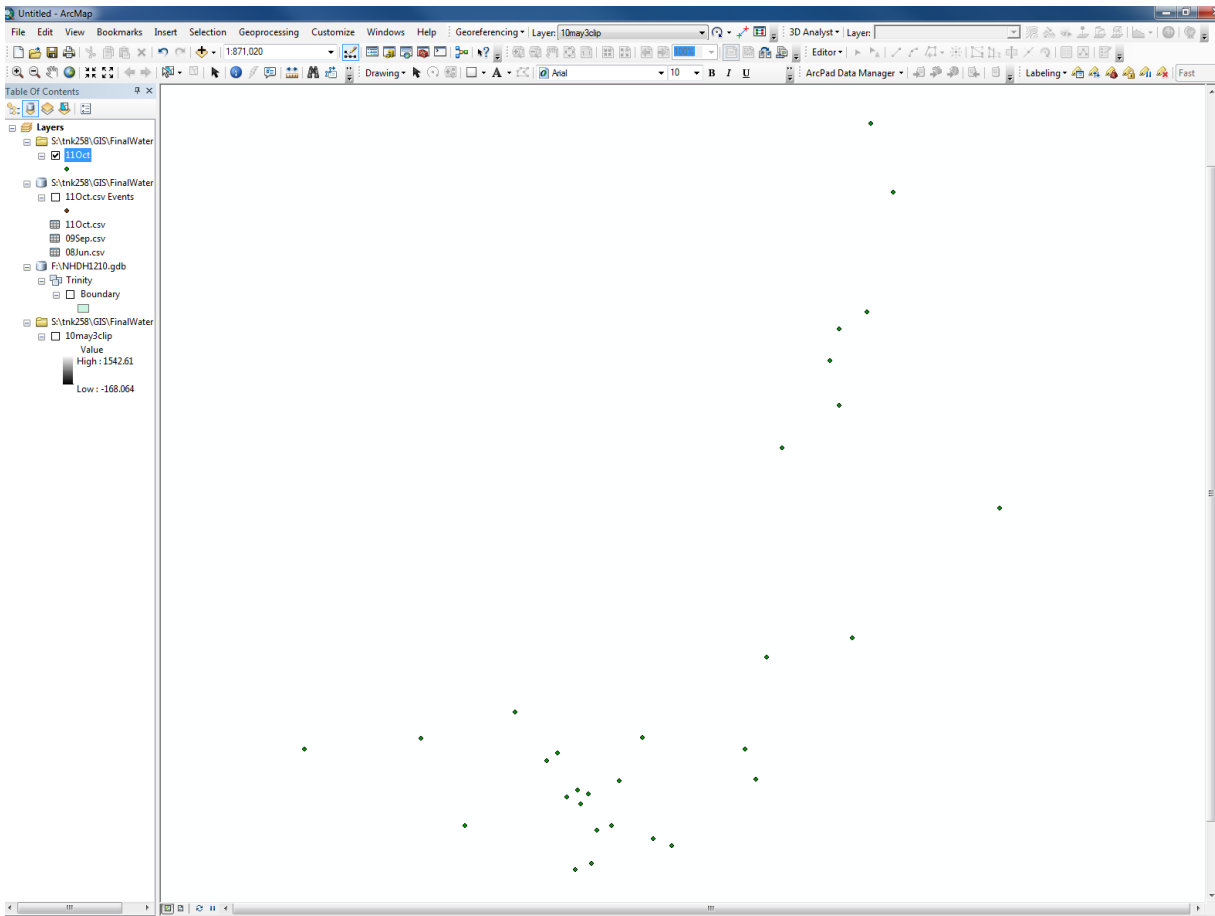
Figure 4. Point Shapefile has been created and added to the map.

Boundary Creation

For interpolation purposes, a boundary polygon should be created. Interpolation methods in ArcGIS, by default, interpolate across a square. However, the data may not be well constrained in many areas of the square. Therefore, it is important to have an extent for the interpolation and a polygon to clip the interpolation to.

To create this "boundary," load the Trinity Aquifer outcrop and subcrop layers, and move them below the displayed well points (Figure 5). There are two important ways the data should be constrained: the boundary extent should not exceed (roughly) the extent of the aquifer outcrop and subcrop and the boundary extent should not exceed the outside data points where the interpolation in not constrained.
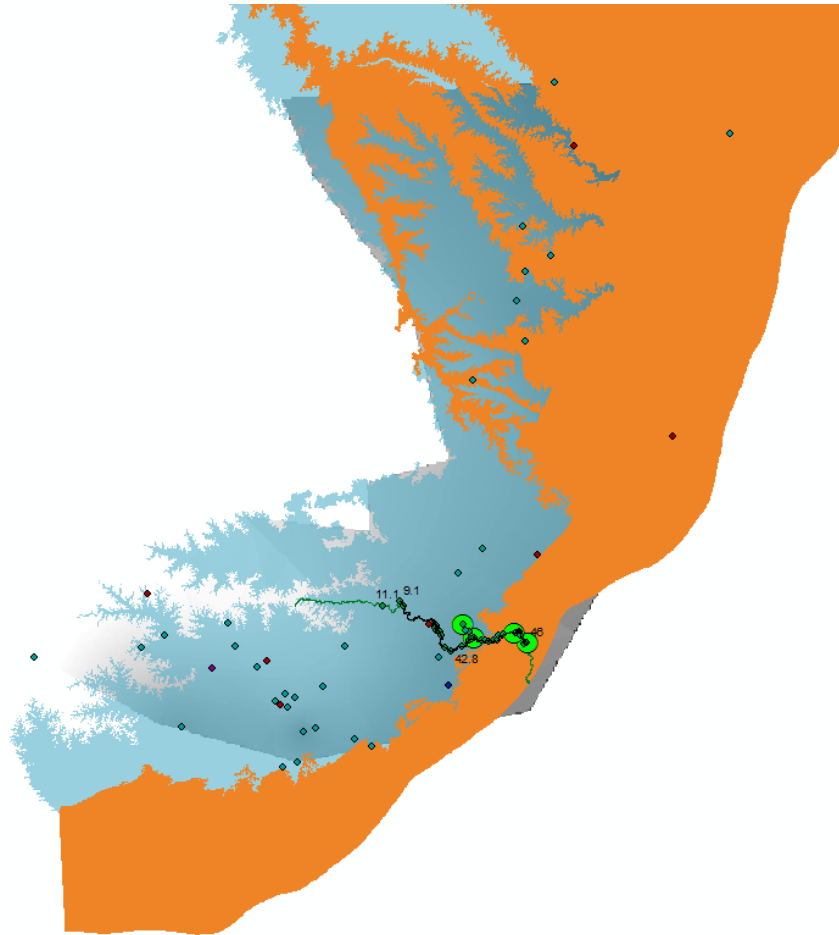
Figure 5. Trinity Aquifer Outcrop, Subcrop, and Middle Trinity Wells

In ArcCatalog, add a new feature dataset to the geodatabase. In this project, I worked out of the NHD geodatabase. Add a new polygon feature class to the geodatabase, and then add this polygon feature class to the map. Turn on editing for the new polygon feature class. Create a new polygon via the editing toolbar. The outline of this polygon should follow the data points and/or the outcrop/subcrop (Figure 6). Save edits.
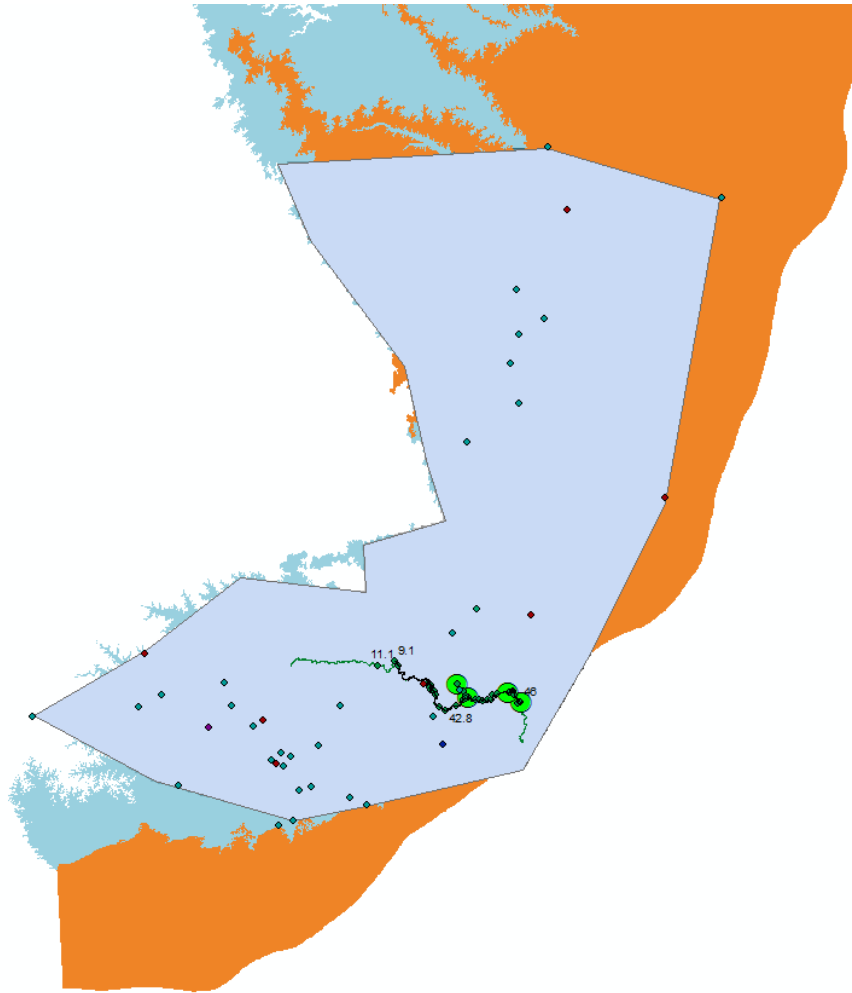
Figure 6. Boundary Polygon

Interpolation

After all CSV files have become point shapefiles with a projected coordinate system of NAD_1983_UTM_Zone_14N, and the boundary has been created, the interpolation process can began. Ensure that the Spatial Analyst extension is turned on (CUSTOMIZE>EXTENSIONS> CHECK 3D ANALYST). Open ArcToolbox and navigate to the Kriging tool under Spatial Analyst (SEARCH > KRIGING).

There are actually a several different interpolation tools that are available, such as IDW and Spline, however raster surfaces created from the well points using these interpolation methods either:

A) *Looked exactly like the linear Kriging interpolation – which takes less time to run*
B) *Looked wildly erratic – something a water table is not*

As a result, only the linear Kriging method was used in the final raster interpolations of the well data.

To see the shape of the surfaces, the interpolated surfaces were added into ArcScene (IN ARCSCENE, RIGHT CLICK RASTER > PROPERTIES> BASE HEIGHTS> DISPLAY BASE HEIGHTS> SELECT THE RASTER >OKAY).

Now that the Kriging tool is open (Figure7):

1. select the point shapefile for input
2. set the z value field to the water level column (in this case Oct_11),
3. Again, it would be prudent to set the output to an organized location
4. Select "ordinary" and "linear" from the drop down menu
5. Accept the default cell size
6. Click "Environments", and set the processing extent to the "Boundary Layer" (Figure 8)
7. Click "OK"
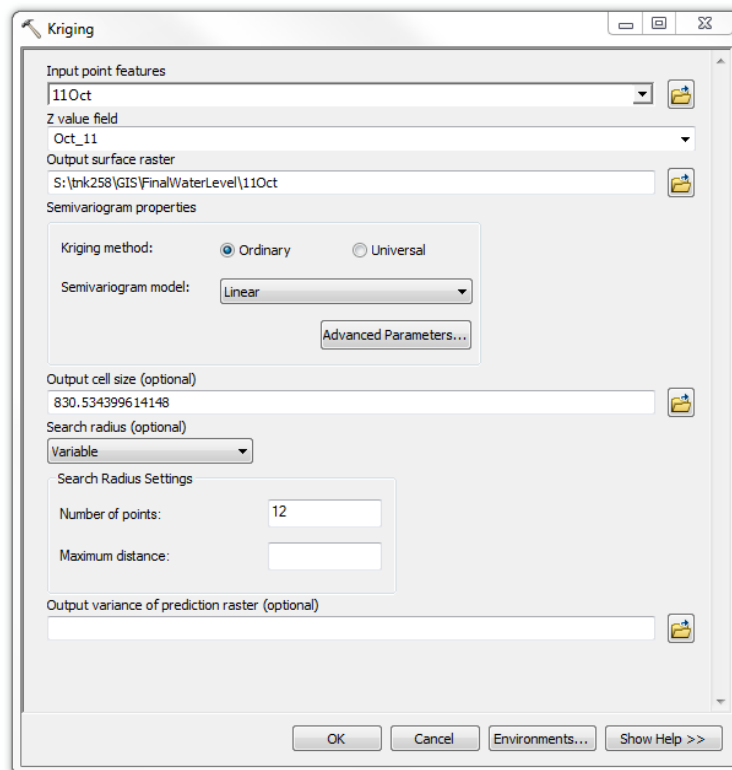
Figure7. Kriging tool set up
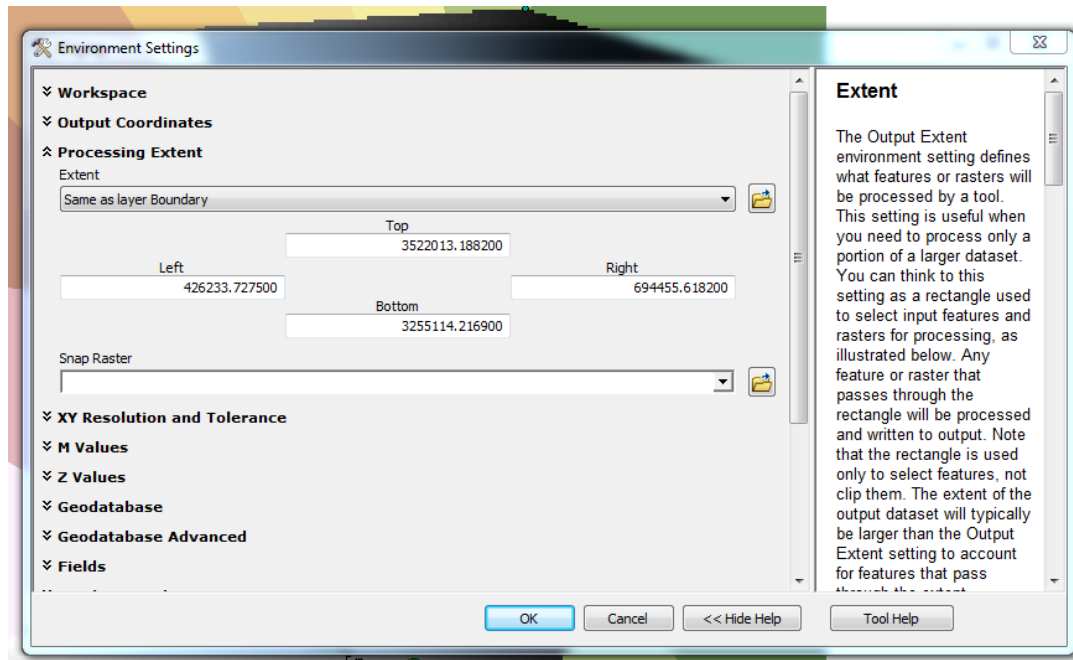
Figure 8. Environment Settings, Same as layer "Boundary"

If the Kriging fails, try saving the output surface raster in an alternate folder or on the Desktop. For whatever reason, this seems to pacify the software.

Use the linear Kriging interpolation tool for each of the point shapefiles. After each raster is created, it will be added to the map (Figure 9).
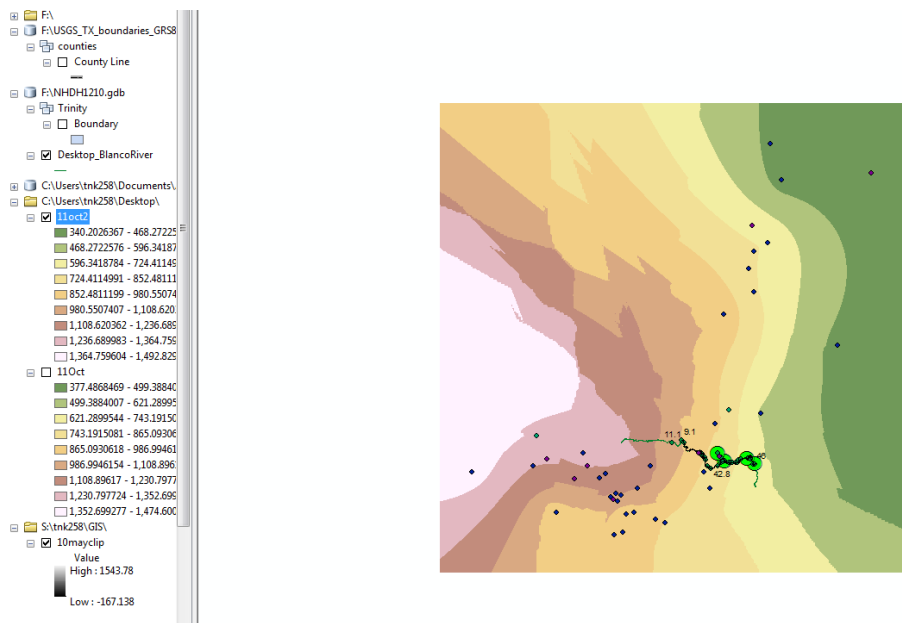
Figure 9: Output from Kriging tool

After the six rasters have been created, they will be clipped to the Boundary layer to avoid using interpolation outside the spatial extent of the data where the interpolation is not well constrained. To do this, navigate to the "Extract By Mask" tool (**SEARCH> "EXTRACT BY MASK"**). This tool works in much the same way as the "Clip" tool, but it is functional on raster datasets. For the input raster, select the Kriged surface; for the feature mask data, select the "Boundary" layer (Figure 10). Save the output raster in an organized location, click "OK", and add the clipped raster to the map (Figure 11). Repeat this step for all six water level surfaces.
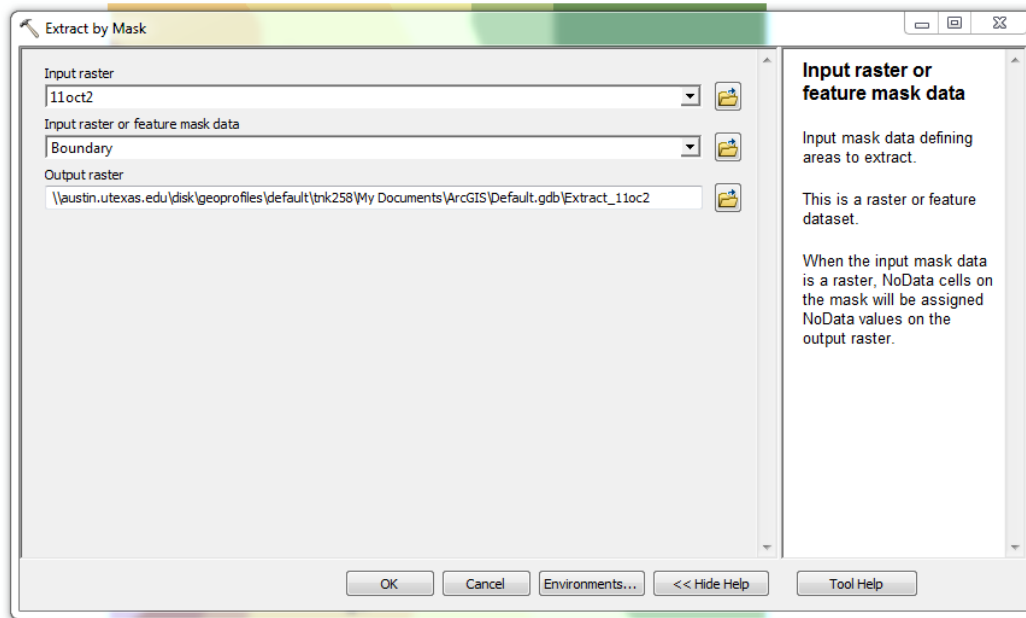
Figure 10. Extract by Mask tool
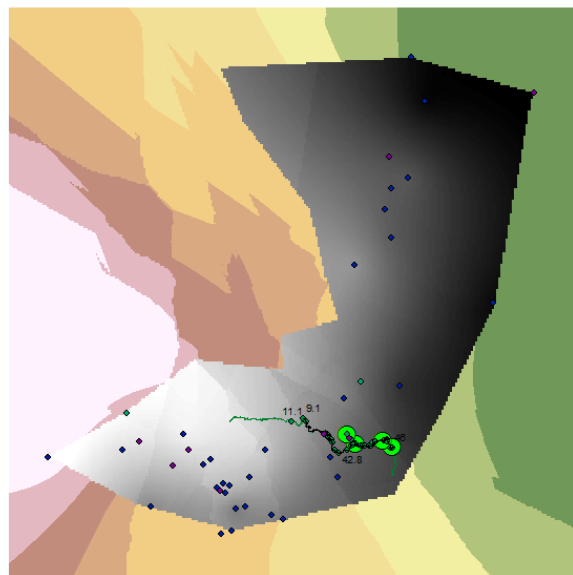
Figure 11. The clipped raster

Volume Calculation

In order to determine the volumetric difference between the water level surfaces, the volume beneath a single water level surface must be calculated. To do this, navigate to the "Surface Volume" tool within "3D Analyst" (Make sure the 3D analyst extension is enabled). This tool exports the calculated volume as a text file. To use this tool, a base level must be set to calculate the volume from. This base level should be set at a value lower than the lowest water level elevation in the rasters. In this case, the base level was set to -210ft for each volume. It is important to have a consistent base level between all the water level surfaces.

Open the "Surface Volume" tool (Figure 12). For the input surface, choose the clipped water level surface. Save the output text file in an organized location. Set Reference Plane to ABOVE; doing this will calculate the volume above the baseline and below the raster surface. Set the plane height to the chosen base level. Leave Z factor at 1. Click "OK". Repeat this step for all six clipped water level surfaces.
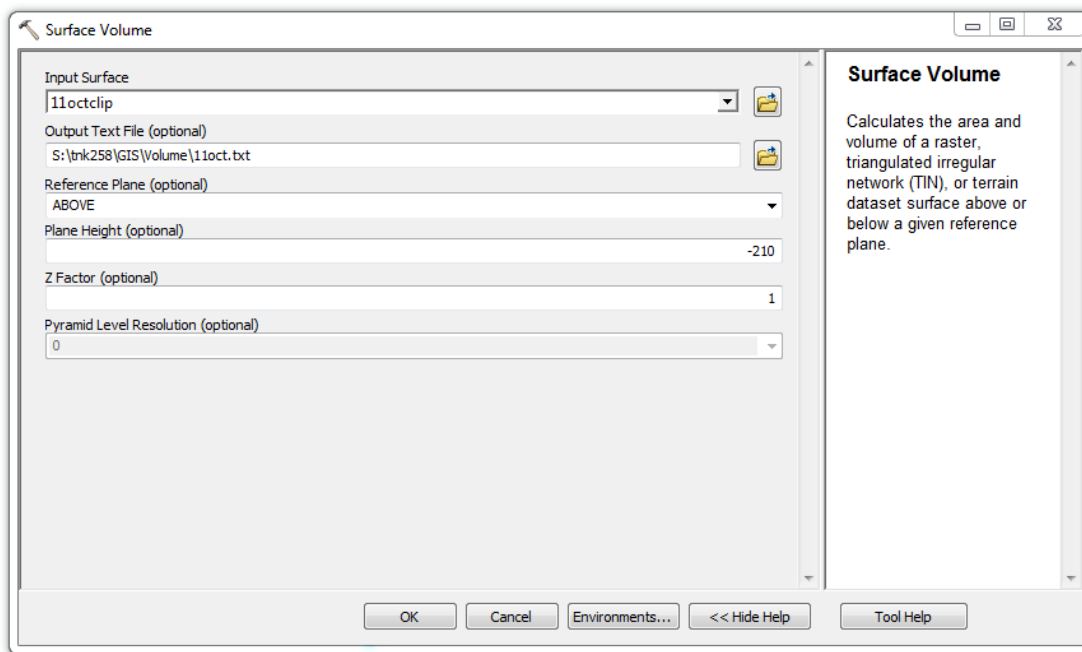
Figure 12. Surface Volume Tool.

III. Data Postprocessing

The "Surface Volume" tool exports as a CSV file containing a column for Dataset, Plane_Height, Reference, Z_Factor, Area_2D, Area_3D, Volume. Import the six CSV files into excel (as discussed previously). Delete repetitive headings, and the useless file location under "Dataset" (Figure 13). The volumes are contained under the column "Volume."

It is INCREDIBLY IMPORTANT to note the units under which the raster and volume were created. In this project, water level elevations were in feet, but the XY data were in meters. This means that the units of the volume column is not cubic meters. The units are actually ft*m^2! The volume was then converted to cubic meters by multiplying by the appropriate conversion from ft to m.

	A	B	C	D	E	F	G	H	I	J	K	L	M
	Dataset	Plane_Height	Reference	Z_Factor	Area_2D	Area_3D	Volume (ft*m2)	VT (m3)	Differences	Total Difference	Vw,d (m3)	Vw,d (gal)	Vw,d (acre-ft)
2	08Junclip	-210	ABOVE	1	23969586600	23970397889	2.46606E+13	7.51656E+12					
3	09sepclip	-210	ABOVE	1	23969575595	23970655348	2.39841E+13	7.31037E+12	-2.0619E+11		-536093418.2	-1.4E+11	-434617.92
4	10may3clip	-210	ABOVE	1	23932606137	23934727927	2.42341E+13	7.38656E+12	76195635848		198108653.2	5.2E+10	160609.27
5	11sepclip	-210	ABOVE	1	23969076528	23970793934	2.49659E+13	7.60961E+12	2.23047E+11		579922799.1	1.5E+11	470150.97
6	11octclip	-210	ABOVE	1	23831262207	23832172326	2.40758E+13	7.3383E+12	-2.71305E+11		-705393528.5	-1.9E+11	-571871.73
7	13junclip	-210	ABOVE	1	23939078713	23941561622	2.39906E+13	7.31234E+12	-25961424217		-67499702.97	-1.8E+10	-54722.89
8	Total									-2.04214E+11	-530955197.4	-1.4E+11	-430452.30

Figure 13. Final Spreadsheet Quantifying Loss

Now, subtract the volume from one month/year from the previous month/year. This corresponds to the volume of saturated aquifer lost during this time period. Using an estimated Storativity value, calculate the volume of water lost (drained) using the following equation (only applies for unconfined systems).

$$V_{w,d} = S * V_T$$

For the Middle Trinity Aquifer a minimum Storativity value was estimated at 2.6 x 10^{-3} (Weight and Sonderegger, 2001). From this, the volume of water drained or gained was calculated in cubic meters then converted into gallons and acre-ft. The results of this calculation suggest that from June-2008 to June 2013, roughly 140 billion gallons (430,000 acre-ft) have been lost from the Middle Trinity Aquifer. The complete results of this calculation is shown in Table 1. The area of the boundary was 9,413 sq mi.

Date	Vw,d (gal)	Vw,d (acre-ft)
Jun/2008 - Sep/2009	-1.4E+11	-434617.92
Sep/2009 - May/2010	5.2E+10	160609.27
May/2010 - Sep/2011	1.5E+11	470150.97
Sep/2011 - Oct/2011	-1.9E+11	-571871.73
Oct/2011 - Jun/2013	-1.8E+10	-54722.89
Jun/2008 - Jun/2013	-1.4E+11	-430452.30

Table 1. Volume of Water Lost in Gallons and Acre-Ft

While some periods of time show a gain, from the highest peak in June of 2008 to the highest peak in June of 2013, there is a net loss of water. Periods of gain may be associated with years of greater recharge. However, it is important to note that after periods of gain, the peak in water levels is never as high as the proceeding peak.

IV. Data Presentation

For animations of the water level surfaces in ArcScene, see the attached files. The frayed lines are the tributaries and the Blanco River within the Blanco River watershed projected onto a DEM using the base heights of the DEM in the streamlines shapefile. A cone of depressions is visible appearing and disappearing through time. The surfaces in ArcScene are 50x vertically exaggerated. The final animation shows the water level in June of 2008 (green-purple) and the water level in June of 2013 (purple-orange). It is clear in the animation that the water level in 2008 is generally higher than in 2013.

Creating Surfaces in ArcScene

To create a surface in ArcScene, add the clipped water level raster into ArcScene. Navigate to the raster properties and float the elevation on the raster. As seen in Figure 15, be sure to set the raster resolution of the base surface to the original surface (RIGHT CLICK>PROPERTIES>BASE HEIGTS> FLOATING ON A CUSTOM SURFACE>SELECT CLIPPED RAS TER>RASTER RESOLUTION>OK>OK).
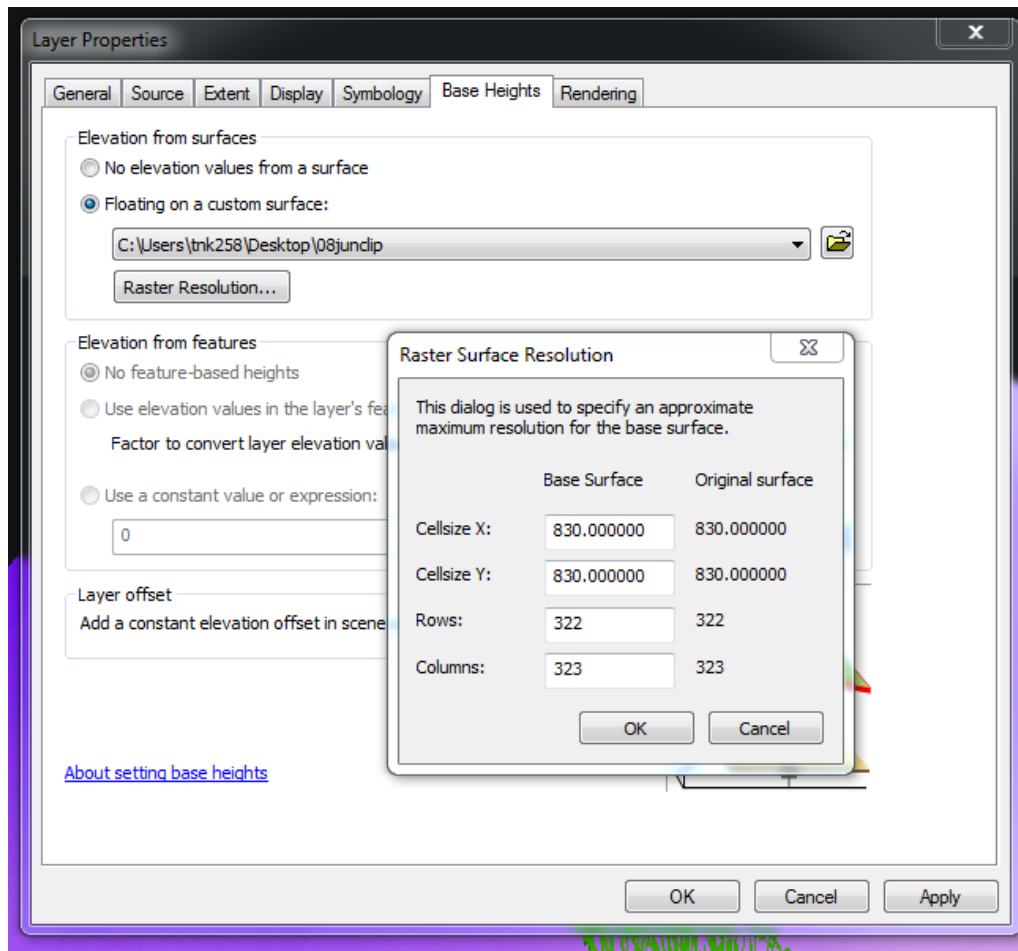
Figure 15. Base Heights and Raster Surface Resolution Properties

To add the Blanco River watershed, add the Tributaries layer that has been clipped to the HUC boundary. Then, add the DEM to ArcScene as well. Make the DEM display in 3-D as discussed above. To project the streams on the DEM, navigate to the Base Heights tab of the stream layer, select floating on a custom surface, and this time choose the DEM as the surface. For orientation purposes, it is helpful to add a directional arrow (**VIEW> VIEW SETTINGS >CHECK DIRECTIONAL ARROW>OK**) (Figure 16).
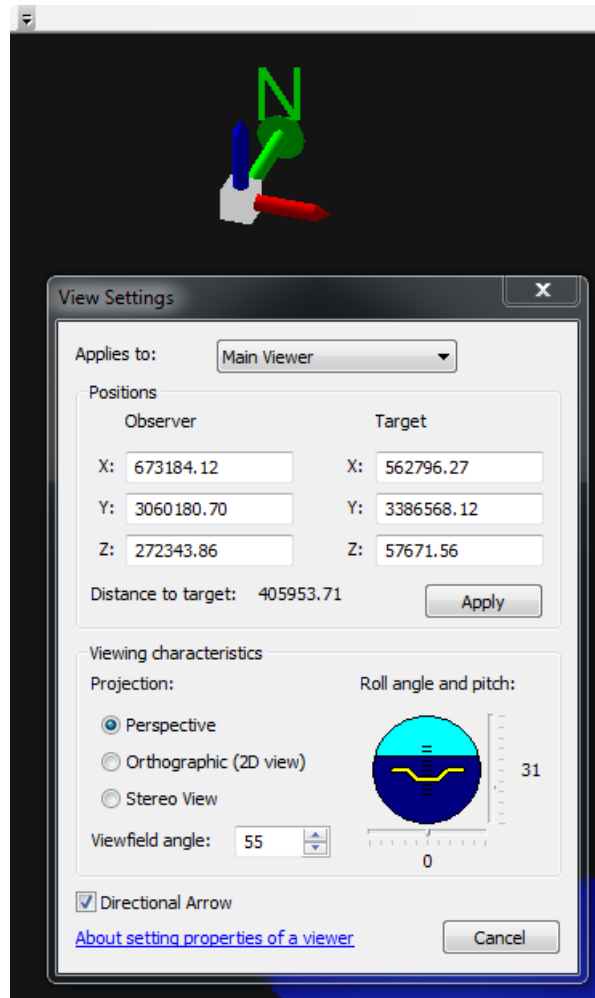
Figure 16. Adding a Directional Arrow

Creating Animations in ArcScene

Open or add the animation tool bar in ArcScene (**CUSTOMIZE>TOOLBARS>ANIMATION**) (Figure 18).
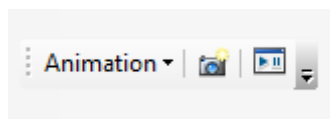
Figure 18. Animation Toolbar

Animations can be created by bookmarking keyframes; after these frames are bookmarked, ArcScene will automatically, smoothly move between them. Creating a keyframe can be done with the small camera tool seen on the Animation Toolbar (Figure 18). Clicking the camera button will bookmark a keyframe. *The camera tool will not become your mouse, it will only work when clicked directly.* Drag the clipped water level surface in ArcScene to the animation starting position. Click the camera button. Drag the surface to the next position, and again click the button. Repeat this, circling around the water level surface, and finish by setting the surface in map view. Now, click the play/pause button in the Animation

Toolbar (Figure 18). This will open up a dialog box containing video controls. Click the triangle to play the animation. If a keyframe needs to be edited in the animation, navigate to the animation manager, locate the appropriate scene (Can be viewed by clicking "view"), and delete or add scenes as necessary **(ANIMATION>ANIMATION MANAGER)** (Figure 19).
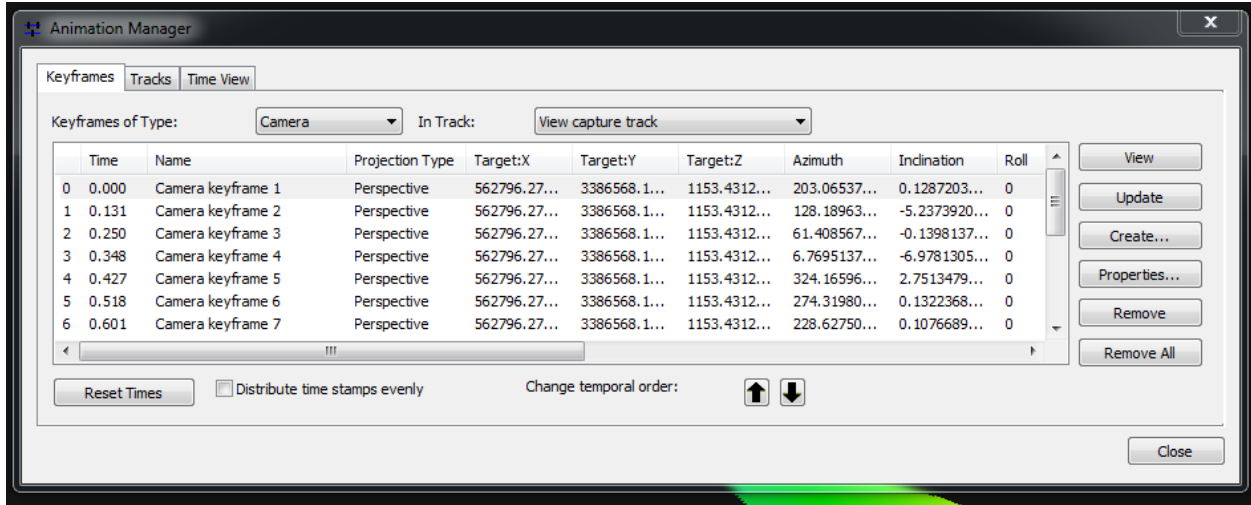
Figure 19. Animation Manager

When the animation is complete, export the animation, save in an organized location and accept all defaults in the subsequent prompts (**ANIMATION>EXPORT ANIMATION).** Repeat these steps for each month-year, and add the DEM to the Jun-2013 for comparison of the water level surface to the land surface.

The selected keyframes will remain saved in the Animation Manager, even after layers have been turned on and off.

Do not attempt to zoom or move the surface as the animation is exporting. This will appear in your final exported video.

PART II. GAIN LOSS ON THE BLANCO RIVER AND CYPRESS CREEK, TX

I. Data Preprocessing

Download monthly discharge data from the USGS website in tab-separated format. Download the data from the gages on the Blanco River at Wimberley (W), Halifax Ranch (HR), and Kyle (K). Then download the data from the gage at Jacob's Well (JW) on Cypress Creek. Import these data into separate sheets on excel. Create a new sheet. On this sheet, create columns for, "Date", "JWW","WHR", and "HRK". In this case, the gage at Halifax Ranch is the temporally limiting gage. Therefore, the months and years for which data is available at Halifax Ranch will be used to create the final spreadsheet.

The new sheet with the four empty columns will be imported into ArcGIS. The Time property of a layer in ArcGIS will only accept certain date formats. Because there are only months and years, the format that will be necessary is YYYYMM. To create this format in excel, open the format cells dialog box, make sure that the original format was a date format, and then click "custom". In the text box, type "yyymm", and the dates should convert to that format. Unfortunately, this date is still stored as a string date, and this is not understood by ArcGIS. The quickest way to get around this problem is to copy and paste the date column into notepad, save it as a text file, and import it back into excel. This process should retain the date as a text formatted cell.

Next, subtract the appropriate cells from each sheet on the final sheet. For example, in the JWW column, subtract the discharge from Wimberley from the discharge from Jacob's Well. Drag to copy the formula in all succeeding cells. Do this for each pair. The resulting gain-loss table should look something Figure 20.

200012			13.0
200901	-1	-12.8	-13.8
200902	-0.8	-12.5	-13.3
200903	-1.6	-14.5	-16.1
200904	-3.2	-14.5	-17.7
200905	-6.2	-10.3	-16.5
200906	-4.02	-5.25	-9.27
200907	-2.96	-3.21	-6.17
200908	-2.77	-2.78	-5.55
200909	-2.4	-30.9	-33.3
200910	39	-56.8	-17.8
200911	39.2	-53.3	-14.1
200912	43.8	-55.3	-11.5
201001	60.8	-45.5	15.3
201002	95.1	-23.4	71.7
201003	48.2	-51.6	-3.4
201004	18.2	-4.7	13.5
201005	30.7	5.5	36.2
201006	26.6	-19.4	7.2
201007	21	-30.3	-9.3
201008	0.6	-27.3	-26.7
201009	42.6	82.7	125.3
201010	0.3	-17.8	-17.5
201011	-9.3	-17.1	-26.4
201012	-7.9	-15.1	-23
201101	-4.6	-17.3	-21.9
201102	-5.3	-19	-24.3
201103	-5.1	-20.1	-25.2
201104	-3.9	-18.56	-22.46
201105	-2.5	-17.197	-19.697
201106	-1.9	-11.3	-13.2
201107	-1.93	-8.77	-10.7
201108	-1.97	-6.97	-8.94
201109	-1.68	-7.44	-9.12
201110			12.7

Figure 20. Preliminary Gain-Loss Table

Unfortunately, the next part of this process is incredibly tedious. Copy the data, open a new sheet, right click a cell and click "Paste Special." Click transpose when the dialog box opens. The result should look like Figure 21.

A	B	C	D	E	F	G	H	I
200901	200902	200903	200904	200905	200906	200907	200908	200
-1	-0.8	-1.6	-3.2	-6.2	-4.02	-2.96	-2.77	-
-12.8	-12.5	-14.5	-14.5	-10.3	-5.25	-3.21	-2.78	-3
-13.8	-13.3	-16.1	-17.7	-16.5	-9.27	-6.17	-5.55	-3

Figure 21: Transposed Gain loss table

Create a new sheet, with a columns labeled "Name", "Discharge", "Display", and "YYYYMM." Under the column name, type the three codes from before, JWW, WHR, and HRK. Select these three cells and drag down to repeat and copy. Then, copy each corresponding date and drag it to repeat the date three times before. Then copy and paste the appropriate gain-loss values to correspond with each date. Finally, select the first cell in the display column and type in the following expression: =IF(*gain/loss value cell* >0,1,0). This will display a 1 for a gain value (positive) and a 0 for a loss value (negative). The final table should look like Figure 22.

Do not use "key" and "true" as headings as seen in the figure. In ArcGIS, these are special words and attempting to use them as headers will anger the software.

Key	Discharge	TRUE	YYYYMM
WHR	-1	0	200901
HRK	-12.8	0	200901
JWW	12.76	1	200901
WHR	-0.8	0	200902
HRK	-12.5	0	200902
JWW	12.23	1	200902
WHR	-1.6	0	200903
HRK	-14.5	0	200903
JWW	15.558	1	200903
WHR	-3.2	0	200904
HRK	-14.5	0	200904
JWW	16.927	1	200904
WHR	-6.2	0	200905
HRK	-10.3	0	200905
JWW	16.126	1	200905

Figure 22. Final Gain Loss Table

II. ArcGIS Processing

Gage Station Point Shapefile

The gage station point station shapefile was created by making an excel table containing the gage names, and their respective latitudes and longitudes. This table was imported into ArcMap, the XY data was displayed, and the file was exported as a shapefile.

Stream Segment Creation

Add the NHD Flowline, the HUC outline, and the Gaging Station Points to the map. Clip the flowline shapefile to the HUC outline of the Blanco River watershed. Then select the entire Blanco River. Export this selection as a shapefile FOUR TIMES, name one file "Blanco River" and the others "JWW," WHR", "HRK". Exporting the same shapefile makes it easy to retain original NHD attributes and new database classes don't have to be created.

Add all exported shapefiles to the map. Edit the JWW layer with all layers visible. Use the trace features tool to trace a polyline of the segment of Cypress Creek and Blanco River between the Jacob's Well Station and the Wimberley Station. Do the same for WHR and HRK, tracing each of the respective segments. Make sure to delete any other lines in each shapefile. Open the attribute table for each and rename the GNIS_NAME field to the three letter code for each segment.

There are now three shapefiles corresponding to each coded name that must be merged into a single file. Use the merge tool to achieve this (**ARCTOOLBOX>DATA MANAGEMENT>MERGE**) by inputting the three coded polyline shapefiles. The output should result in a single shape file with three records corresponding to each segment.

Creating a Query Table

The next hurdle is to connect the excel table and the merged polyline shapefile. This will be a Many to One Join, which ArcGIS likes to call "relate." While relating a table to a polygon shapefile seems to work, relating a table to a polyline shapefile does not. The best way to connect the two is to use a Query Layer (actually, no other way will work).

A query table allows both spatial and nonspatial information stored in a database to be joined in any fashion (i.e. many-to-many, one-to-many, many-to-one, etc.).

IMPORTANT: The key phrase here is "stored in a database." If the shapefile and the table to be related in a query table are not stored in a database (the SAME database), making a query table will not work! If you try to input two things not in a database, it will return an error message.

To export the excel file to a geodatabase, right click>data>export. In the dialog box that appears (Figure 23), save as type "file and personal geodatabase table" and navigate to the database. To export the shapefile to a geodatabase feature class, do the same thing.
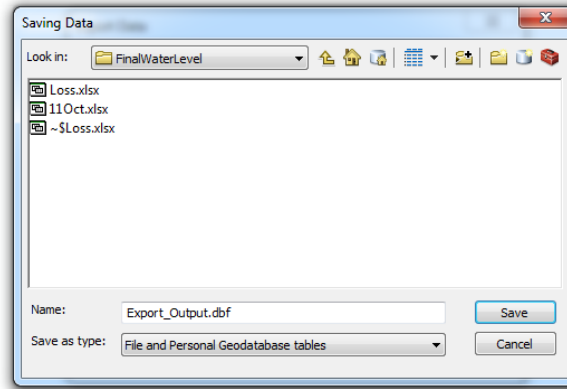
Figure 23. Exporting a Table or Shapefile to a Geodatabase

To use the make query table tool (Figure 24), input the excel table from the geodatabase and the merged shapefile from the geodatabase. In the "Fields" box, select all. This will retain all fields from both the table and the shapefile in the same file.

In the "Expression" text box, enter the following SQL statement:

reachesmerge.GNIS_NAME = codeddischarge.NAME

This is what the tool will use to relate the two tables. In the "Key Fields Options" dropdown menu, select "USE_KEY_FIELDS." Finally, select all key fields. The tool will use all the key fields to generate a unique ID for each record. Realistically, you could pick just a couple fields from BOTH inputs, but clicking "select all" saves some time.
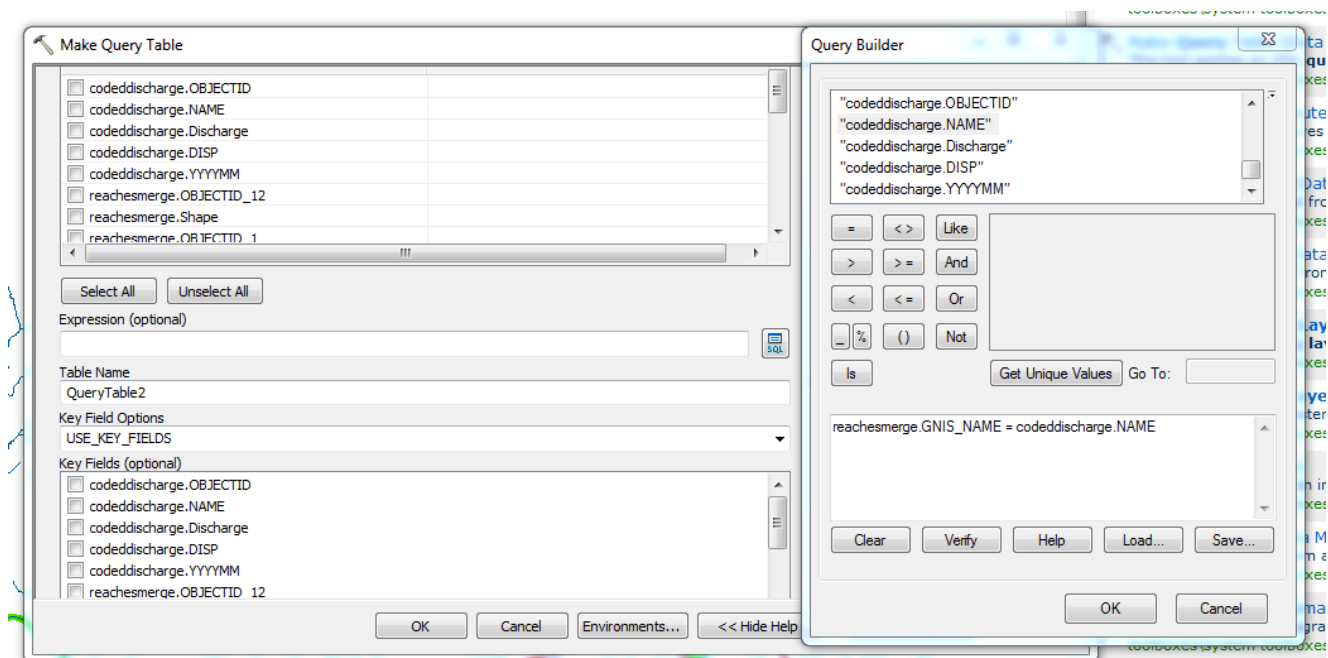
Figure 24. Make Query Tool

When the table is created, it should appear in the map as a polyline shapefile layer. Navigate to the layer properties, and click on the time tab (Figure 25). Enable time on the layer; each feature should have a single time field named "YYYYMM." The field format should match the field name. Set the Time Step Interval to 1 month, and click apply.
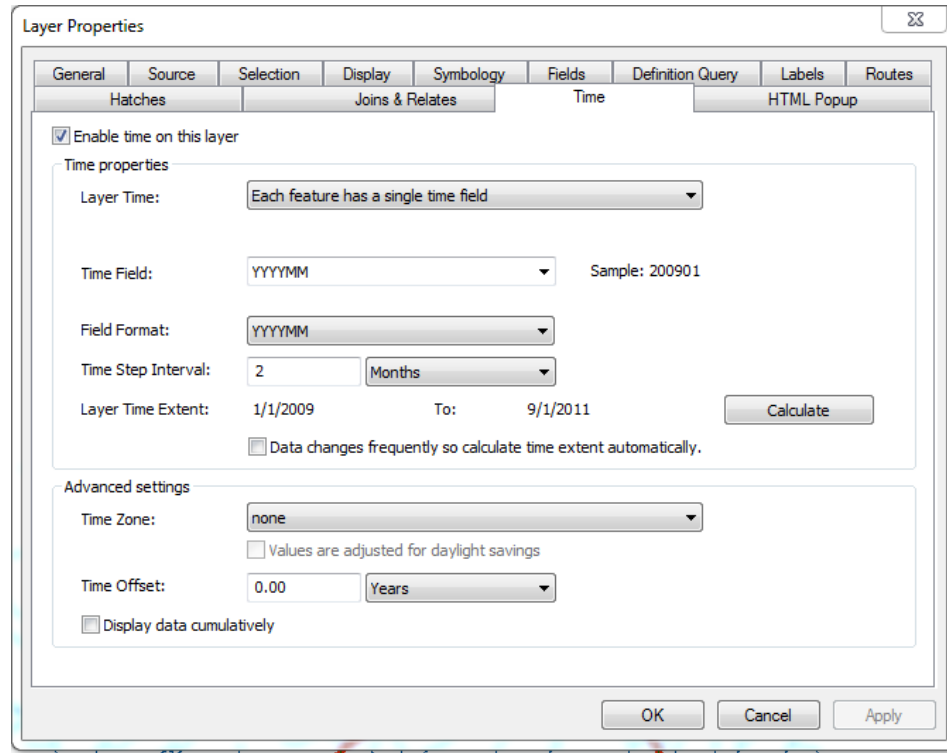
Figure 25. Enabling Time on a Layer

Now, to display gaining or losing, navigate to the symbology tab of the Query Table (shapefile). Show Categories and select "Display" for the Value Field. Click "Add all values." The two values that should appear are "0" and "1"; color the zero red for losing and the one green for gaining (Figure 26). Uncheck the box next to <all other values>. Click OK.
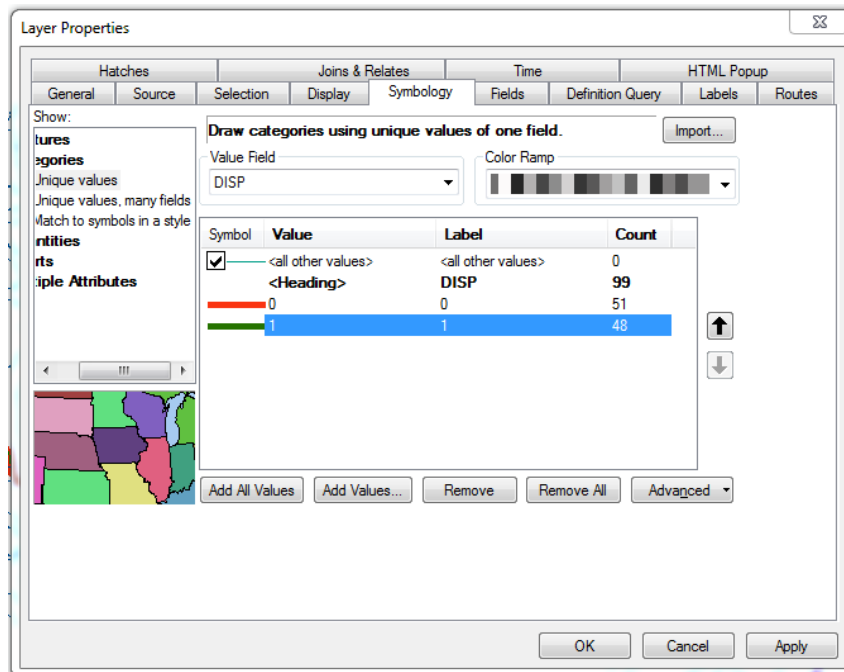
Figure 26. Displaying Gain-Loss Colors

To animate the map, click the small box with the clock on it on the toolbar (⌚⊕) which will open the time slider. Then click the options button (▦). Click the Time Extent tab in the dialog box, and select <all visible time enabled data> (Figure 27). Click the Playback tab to adjust the playback speed (Figure 28). Exit the dialong box and click the play button on the time slider to play the animation. Under time display check the box to display time on the map.
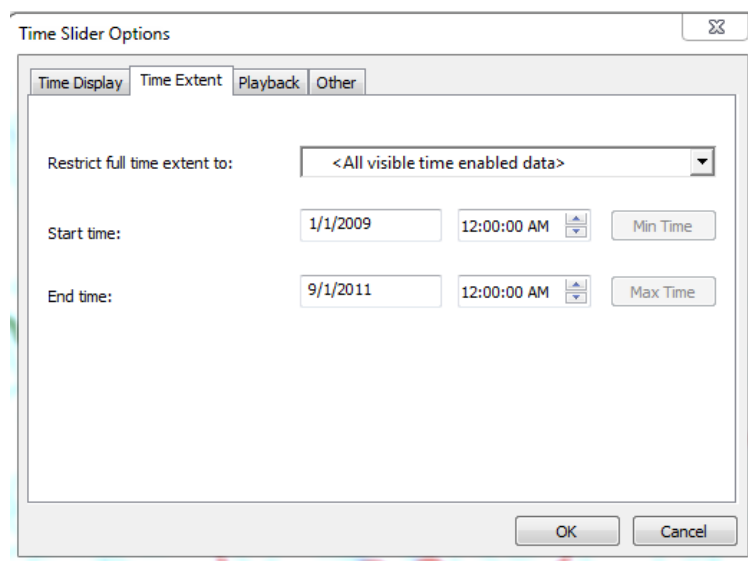
Figure 27. Time Extent, Time Slider Options
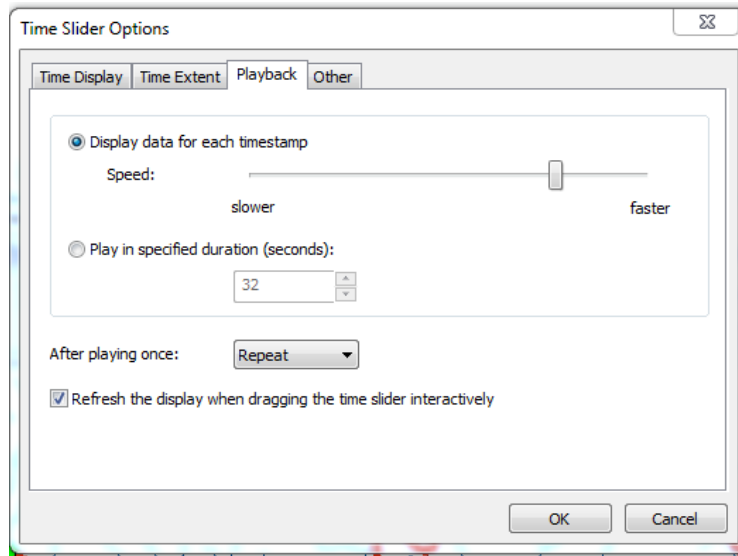
Figure 28. Playback options

The animation can then be exported in map view with any other additions via the "Export Animation" button ().

Current Field Data

The excel file containing discharge measurements was used to calculate gain loss measurements by subtracting between measurement locations. This was then imported into ArcMap where the XY data was displayed and exported to a shapefile. These points were used along with the Blanco River shapefile extraction from the previous section to trace out small segments between points (trace features button) along the Blanco River and Cypress Creek. The attribute table of the segmented shape file was edited to include a field (via ArcCatalog) to contain a gain/loss measurement along with a field for display purposes with a 0 or 1. A similar method of assigning 0's and 1's to a gain or loss value was used to display the gains and losses of the current synoptic field study. *See associated map.*

IV. Data Presentation

This animation was overlayed on top of Edwards Aquifer Zone maps from the TCEQ and a DEM, and runs with a one month time interval. The present field data was overlayed on top of Edwards Aquifer Zone maps, but covers a greater extent to the West of the animation. I-35 was selected and exported out of a shapefile containing roads.

CONCLUSIONS & FUTURE WORK

Part I.

Based on previous analysis, there are systemic water losses in the Middle Trinity Aquifer. While some time periods show gain, the peaks in water level never return to the previous high. Analysis of the declining water levels in the Middle trinity Aquifer, particularly near the Blanco River, suggest that over the past five years 140 billion gallons (430,000 acre-ft) have been lost from the Middle Trinity Aquifer over an area of 9,413 sq. mi. Assuming an average pumping rate of 200 million gallons per day from the Trinity Aquifer (USGS, 2009) this is a total loss of nearly two years worth of water. This is a huge amount of loss. Decreasing the storativity value by an order of magnitude suggests that the total loss over five years is about 14 billion gallons, or about half a year of water over a period of 5 years.

To expand on this study, I would like to quantify the amount of water lost specifically beneath the Blanco River watershed in order to see how this might correlate to discharge from the Blanco River and recharge into the Edwards Aquifer.

Part II.

As evidenced by the present synoptic study and the historical gain-loss animation, gains and losses on the Blanco River are not spatially or temporally cosnsitent. The Blanco River should be losing throughout the recharge zone. However, in the map, the river is actually gaining through a signifcant portion of the recharge zone, and losing in the contributing zone. Therefore, it is clear from the comparison with the official Edwards Aquifer Recharge Zone map that our current understanding of recharge and discharge zones is not detailed enough to explain the gains and losses along the Blanco River.

However, the animation is supported by the current synoptic study of the Blanco River. Reach 1 of the Blanco River is always gaining, Reach 2 is gaining or losing, and Reach 3 is nearly always losing. In the present synoptic study, Reach 1 is gaining, Reach 2 consists of both gaining and losing segments, and Reach 3 is losing. The dynamism of Reach 2 may be controlled by different, smaller segments of the reach through time as seen in the synoptic study.

To expand on this study, I would like to digitize a detailed geologic map of the Blanco River Watershed that is currently in print in the Walter Geology Library. I would then like to compare this to the current synoptic study to see if a more detailed geologic map can better define the recharge zone of the Edwards Aquifer within the Blanco River Watershed.

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<http://pubs.usgs.gov/ha/ha730/ch_e/E-text8.html>.

Weight, W.D, Sonderegger, J.L, 2001, Manual of applied field hydrogeology: McGraw-Hill, 608p.

FURTHER READING FOR THIS STUDY AREA

Wierman, Douglas A., Broun, Alex S., Hunt, Brian B., 2010, Hydrogeologic atlas of the Hill Country
Trinity Aquifer, Blanco, Hays and Travis counties, central Texas: Hays-Trinity, Barton
Springs/Edwards Aquifer, and Blanco Pedernales Groundwater Conservation Districts, p. 2-11.

Gain-Loss on the Blanco River, TX, November 2013

Cypress Creek at Jacob's Well

Blanco Rv at Halifax Rch nr Kyle

Blanco Rv at Wimberly TX

Blanco Rv nr Kyle TX

1:200,000
NAD 1983 UTM Zone 14N

0   1.5   3   6 Miles

Explanation

● Gage Station

● Discharge Measuring Site

— · — County Line

—— Blanco River Watershed

══ I-35

Gain-Loss

—— Loss

—— Gain

—— No Change

—— Tributaries

N
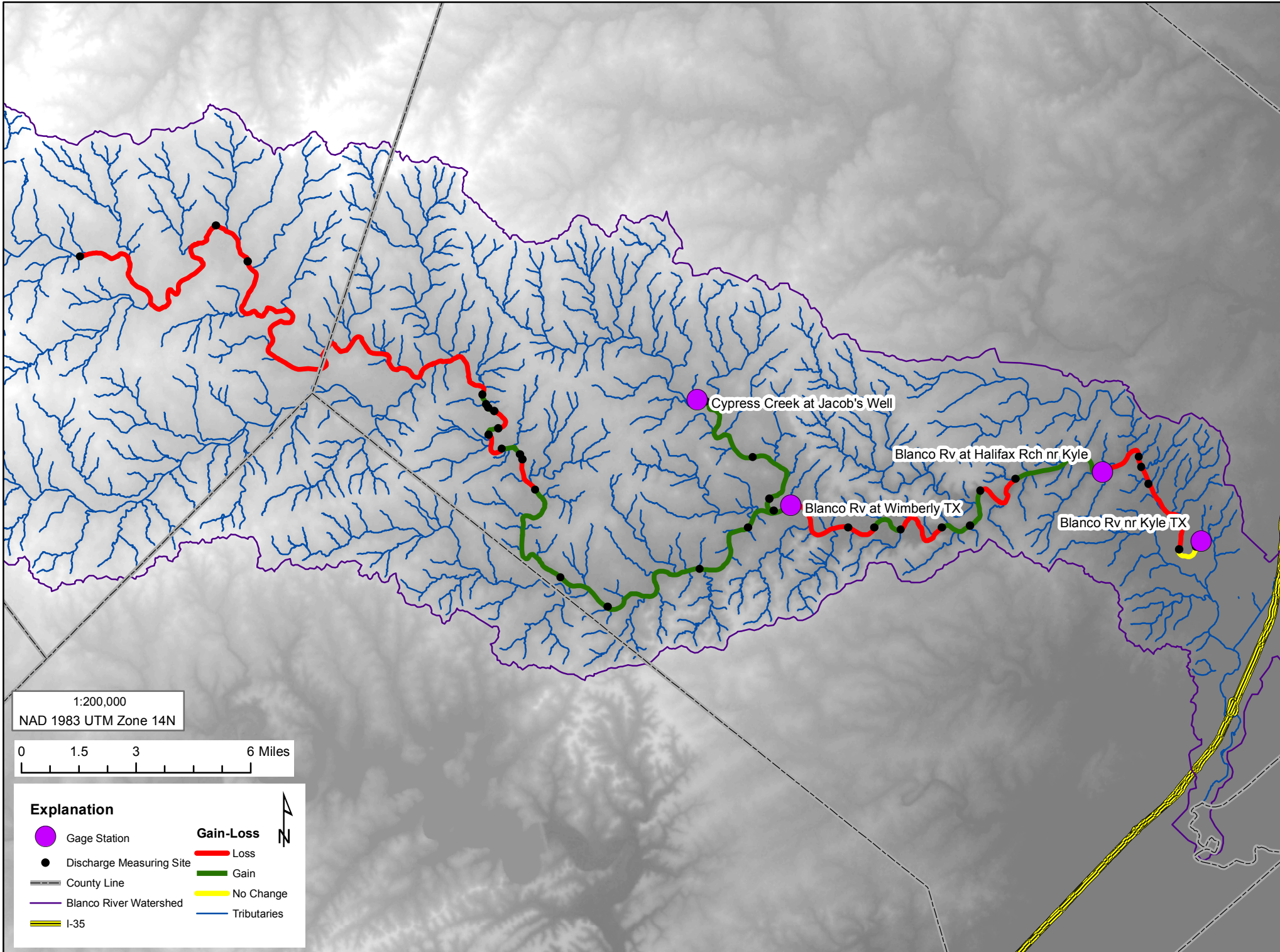
Gain-Loss on the Blanco River, TX, November 2013 and Edwards Aquifer Zones

Tiffany Kocis 12/4/2013

Cypress Creek at Jacob's Well

Blanco Rv at Halifax Rch nr Kyle

Blanco Rv at Wimberly TX

Blanco Rv nr Kyle TX

1:200,000
NAD 1983 UTM Zone 14N

0   1.5   3   6 Miles

Explanation

Gage Station

Discharge Measuring Site

County Line

Blanco River Watershed

I-35

Gain-Loss
- Loss
- Gain
- No Change
- Tributaries

Zone
- Edwards Aquifer Contributing Zone
- Edwards Aquifer Recharge Zone
- Edwards Aquifer Contributing Zone within the Transition Zone
- Edwards Aquifer Transition Zone

N