Abigail Tomasek
GIS in Water Resources
Fall 2011

Water Quality and Flow of Barton Springs Pool

Introduction

Barton Springs Pool is a valuable resource in the Austin area, both in terms of recreational and ecological value. The unique hydrology of Barton Springs results in its possible sensitivity to land use change and developmental pressure. Understanding the hydrology and changing water quality of Barton Springs can aid in preserving this unique resource as the Austin area continues to expand.

The Edwards aquifer is composed of limestone that has been dissolved and fractured, causing a karstic system. The aquifer is divided into three portions due to its complex faulting, the nNorthern, San Antonio, and Barton Springs portions. The Barton Springs portion is about 155 square miles and comprises about four percent of the total area of the Edwards aquifer. The Barton Springs system is the main discharge point of the Barton Springs portion of the Edwards aquifer. It consists of four natural springs, the largest of which is the Barton Springs pool (shown in figure 1 as the pink dot). It has been estimated that about 85 percent of the Barton Springs portion of the Edwards aquifer's recharge comes from six streams (Barton Creek, Bear Creek, Little Bear Creek, Onion Creek, Slaughter Creek, and Williamson Creek) that cross the recharge zone (Mahler and others, 2011), labeled in figure 1. These streams flow over the contributing zone into the recharge zone, where the aquifer is near the surface and freely allows water to flow into the karstic limestone pores and channels, and discharges at Barton Springs. Figure 2 shows the hydrogeology behind this process.

Barton Springs is filled by groundwater flow from fissures in the aquifer matrix. A dam on the upstream side of the pool keeps surface water from Barton Creek from flowing into the pool, and another dam at the downstream end keeps the pool filled with groundwater. One reason for particular concern on the water quality of Barton Springs, besides being a popular swimming location, is the presence of the Barton Springs salamander. The salamander is federally endangered and is only found in Barton Springs. It is only aquatic, so it is susceptible to changing water quality, and it relies on a clean, continuous flow of water. As Austin continues to grow at a rapid rate, questions arise on the effect this growth is having on water quality, especially due to its unique hydrology**.** After storms, surface runoff recharges quickly into the aquifer and delivers storm-associated contaminants to Barton Springs with little time for dilution (Mahler and others, 2006). Severe storm events can also cause Barton Creek to flood enough to overtop the upstream dam, delivering contaminants directly to Barton Spring, such as in 2010 when tropical storm Hermine hit Austin. Mahler and others (2011) also found that during dry periods, stream recharge comprised about 0-8 percent of Barton Springs discharge, but during wet periods, stream recharge comprised about 80 percent of the discharge.

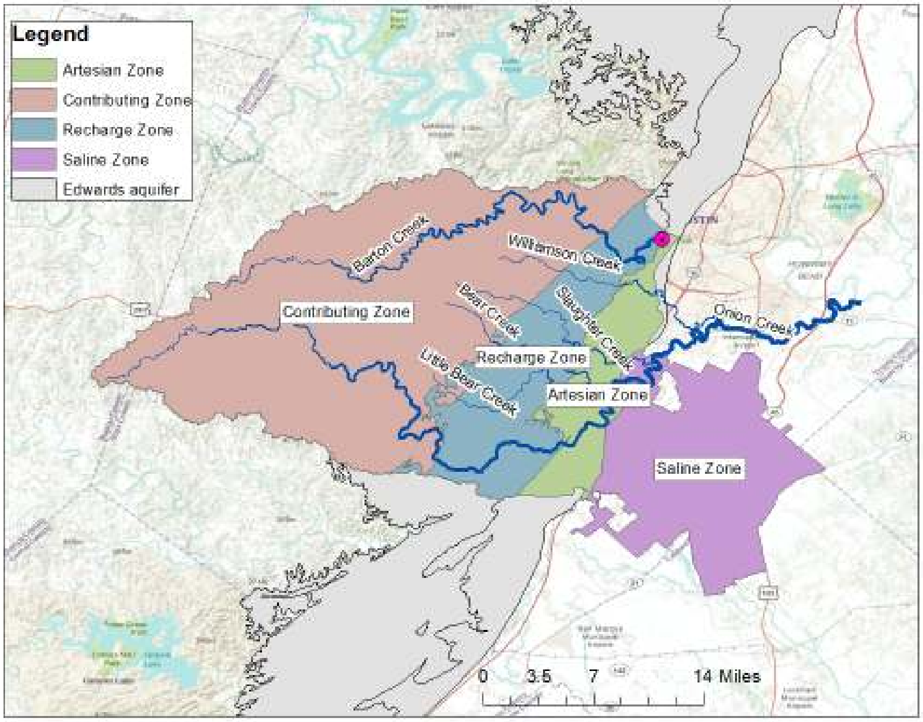

Figure 1. Edwards aquifer and the hydrozones of the Barton Springs portion, and the main contributing streams (hydrozone data from Capitol Area Council of Governments, stream data from NHD).

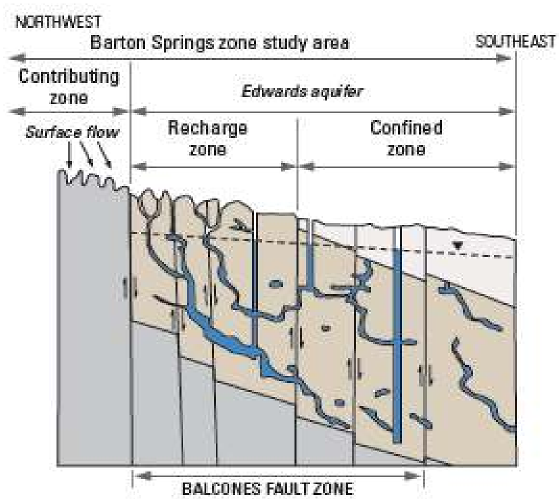

Figure 2. Recharge mechanism to the Barton Springs portion of the Edwards aquifer, from Mahler and others (2011).

City of Austin Growth in Recent Years

Austin and the surrounding area have been rapidly growing in recent years. According to the 2010 census, Travis county is the fifth largest county in Texas with a population of 1,024,266 people, and the population of Travis county grew by 26.1% between the 2000 and 2010 census. The City of Austin grew by 20.4% between the two censuses. Figure 3 shows population data from the 2010 census by tracts. The pink dot in the figure represents Barton Springs. This shows the potential stress placed on the spring given its location in a highly populated area. Along the outer lengths of the contributing streams census tracts are larger and less populated, but nearer to the spring, population density increases. To find an estimate for population in the different hydrozones of the Barton Springs portion of the aquifer, the select attributes by polygon tool was used on census tract data and the approximate polygon shapes for the recharge and contributing zones were drawn. Summary statistics were then used to find the population sum of the selected attributes. It was found that an estimated 106,132 people live in the recharge zone, and 78,707 people live in the contributing zone to the Barton Springs portion of the Edwards Aquifer.

Figure 4 shows land cover change from 1992 to 2001 using the National Land Cover Database Retrofit Land Cover Change (Fry and others 2009). The dataset was created since changes in the mapping legend made it difficult to directly compare land use change between NLCD data from 1992 and 2001. Red areas in the figure represent changes from one type of land use to urban land use (either agriculture to urban, barren to urban, forest to urban, grassland/shrub to urban, or wetlands to urban). The black outlined area represents the recharge area to the Barton Springs aquifer. Although this dataset only represents land use change from 1992 to 2001, it can be seen that a large amount of urbanization is taking place in the recharge zone, and can be assumed that this development has continued.

Figures 5 and 6 are shapefiles for land use inventories in 1990 and 2008 from the City of Austin Spatial Analysis Group of the Planning and Development Review Department. The two shades of green represent open space and rural/undeveloped areas, and the two figures are of exactly the same area. While it is somewhat difficult to compare the two because of the increased detail in the 2008 land use inventory, the general trend of urbanization can be seen, specifically in the western portion of the figure. This could have potential impacts on water quality, as it is part of the contributing and recharge portion of the Barton Springs aquifer.

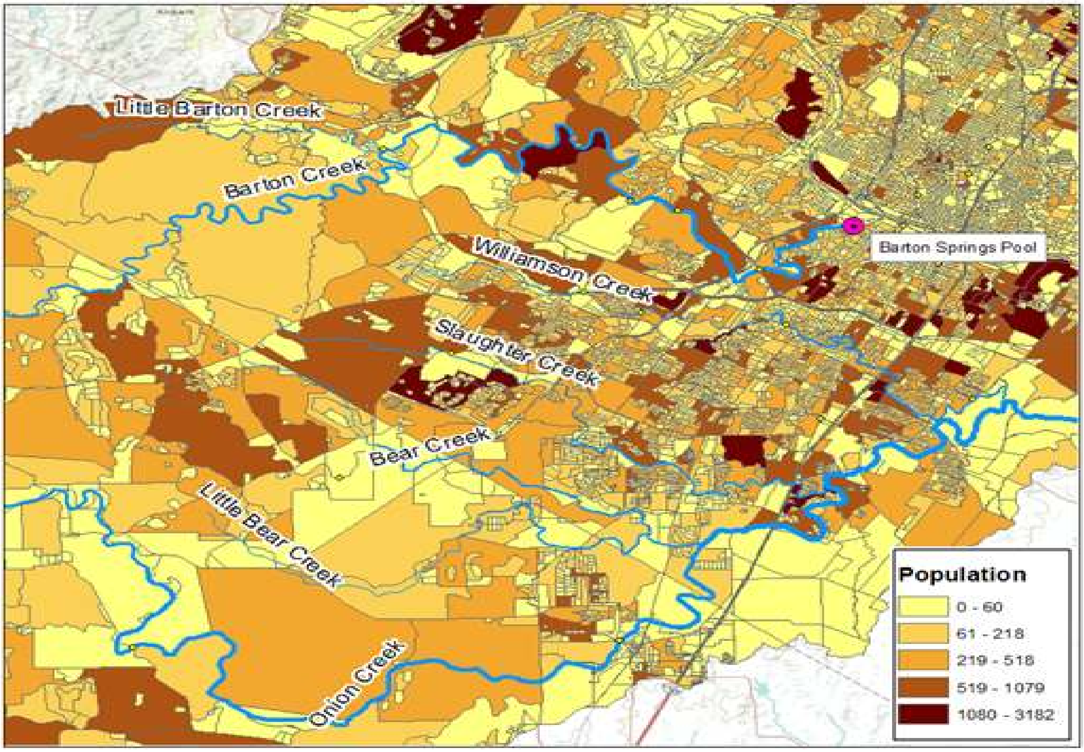

Figure 3. Population of census tracks in Barton Springs area.

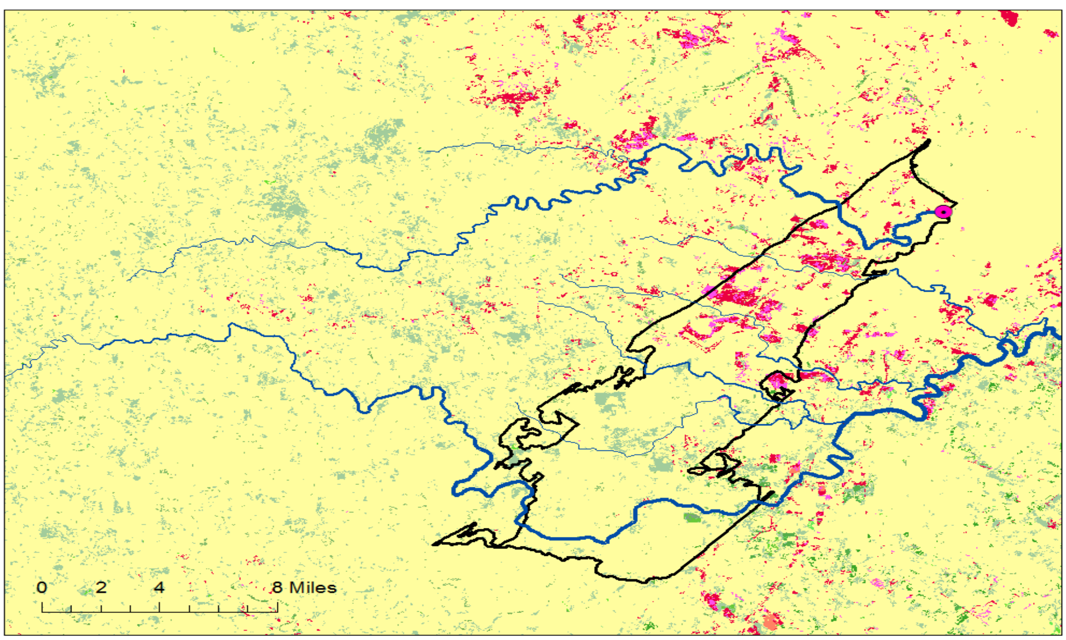

Figure 4. Land cover change from 1992 to 2001 from the NLCD 1992/2001 Retrofit Land Cover Change Product.

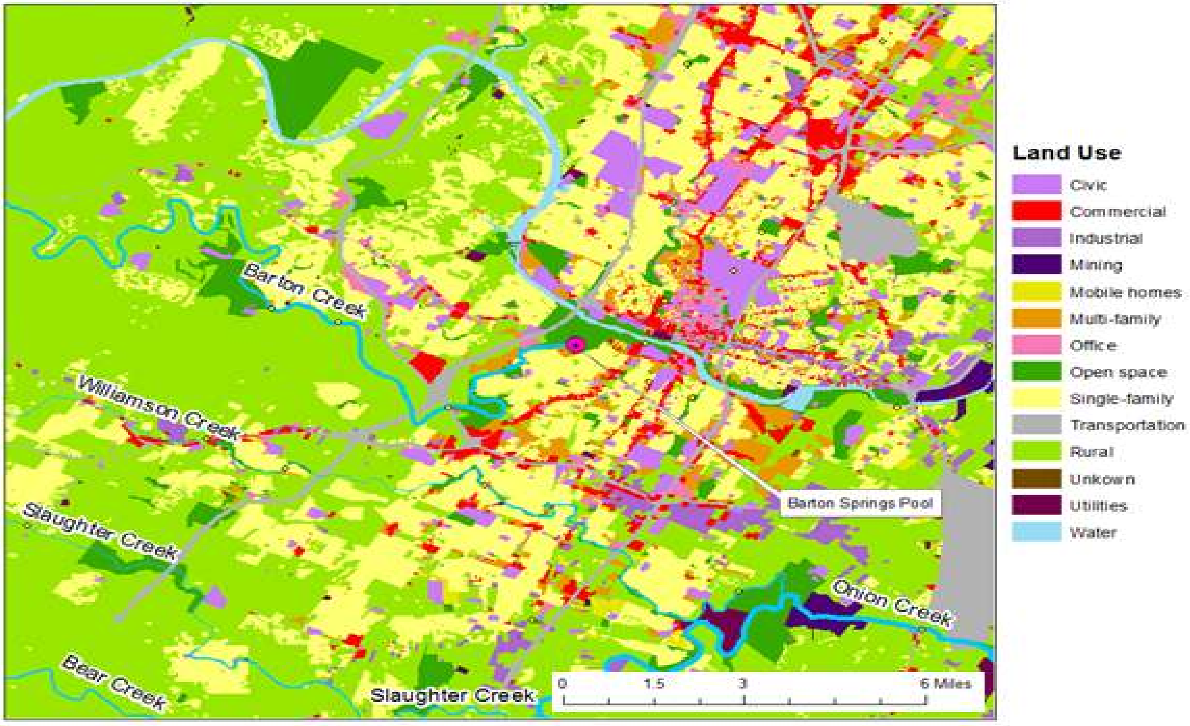

Figure 5. 1990 land use from the City of Austin

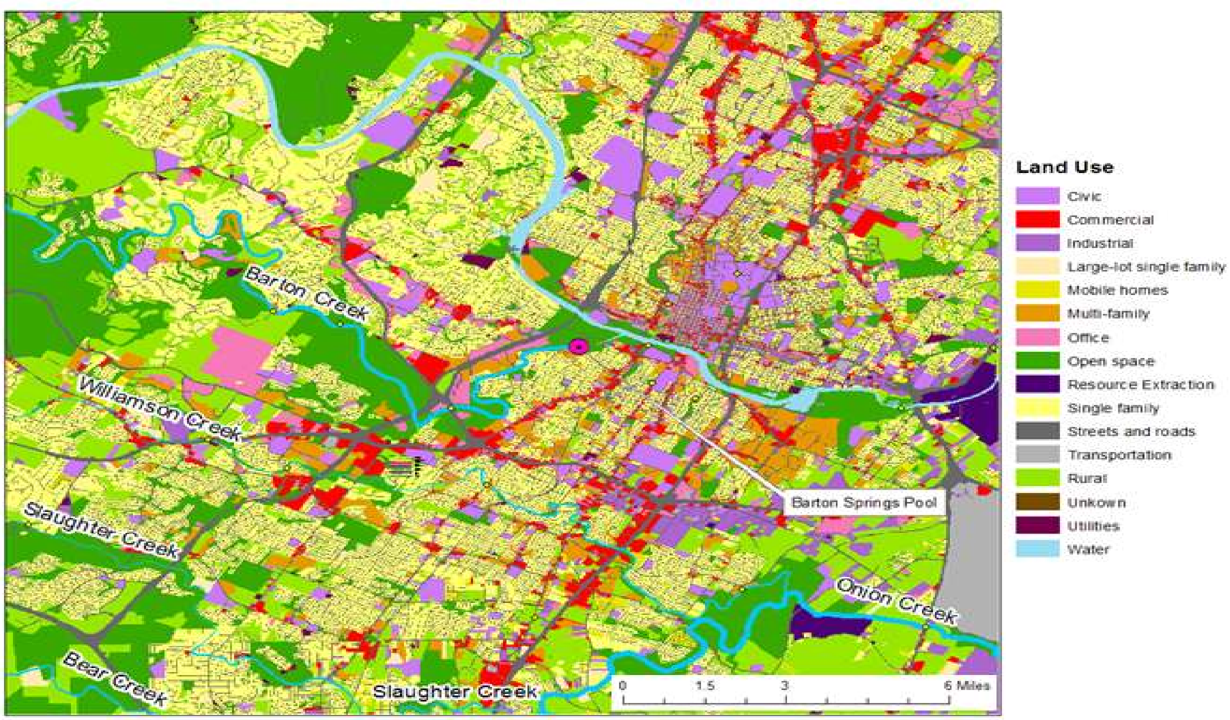

Figure 6. 2008 land use from the City of Austin

Methods

DEM and hillshade layers were added from the City of Austin GIS files. The pits were filled in the DEM and flow accumulation, flow direction, and eventually the subwatershed that drains to each of the eight streamgages used in the analysis was found. The DEM was also used to find the slope in degrees of the study area using slope function in the spatial analyst tools. This figure was not included since the study area was found to be relatively flat with almost all slopes being less than 2.5 degrees.

Eight USGS sites were considered in the analysis, one each on Bear, Onion, Slaughter, and Williamson Creek, 3 on Barton Creek, and one at Barton Springs itself. These sites are listed in table 1 and shown in figure 7 along with the mean annual flow of the contributing streams and the HUC12 subwatersheds (flowlines and flowline attributes clipped from NHDPlus data, and HUC12 data from the GeoSpatial Data Gateway). Site locations were found using the USGS National Water Information System (NWIS) website, selecting sites in Travis and Hays counties and finding sites that were on the desired streams with a long enough period of record. I initially had a large number of sites, but narrowed these down to sites used in a recent USGS Scientific Investigations Report (Mahler and others 2011) plus two more along Barton Creek, in order to compare regional and temporal water quality more effectively. USGS sites were added to GIS by first making an excel table with site coordinates and attributes, adding the table to GIS, and exporting the xy data to create a site shapefile.

Table 1. Eight USGS sites used in water quality analysis.

USGS Site Number	Site Name	Contributing Stream
08155200	Barton Creek at SH 71 near Oak Hill, TX	Barton Creek
08155240	Barton Creek at Lost Creek Blvd near Austin, TX	Barton Creek
08155300	Barton Creek at Loop 360, Austin, TX	Barton Creek
08155500	Barton Springs at Austin, TX	Barton Creek
08158920	Williamson Creek at Oak Hill, TX	Williamson Creek
08158840	Slaughter Creek at FM 1826 near Austin, TX	Slaughter Creek
08158810	Bear Creek below FM 1826 near Driftwood, TX	Bear Creek
08158700	Onion Creek near Driftwood, TX	Onion Creek

Precipitation data was found using NCDC Climate Data Online and selecting for daily surface data for Travis and Hays County from 1990 to 2010. The found stations were added to GIS and Thiessen polygons were found to decide which precipitation station to use for each streamgage. All streamgages were either in or very close to the polygon for the precipitation station at Dripping Springs in Hays County. The precipitation data from this station was used for all streamgages to simplify analysis.

Discharge data and water data for nutrients, microbiological, and suspended sediment were found for the eight sites using the USGS NWIS site. To download the data from the Texas USGS NWIS site, I clicked on water quality, field measurements, and chose site number as the site selection criteria. I typed in the desired site number of one of the eight sites, and clicked on the "parameter group period of record table" option under retrieve water-quality samples. Once the desired parameter group was selected, the data was copied to excel for analysis. These sites were compared spatially and temporally to determine trends in the water quality data.

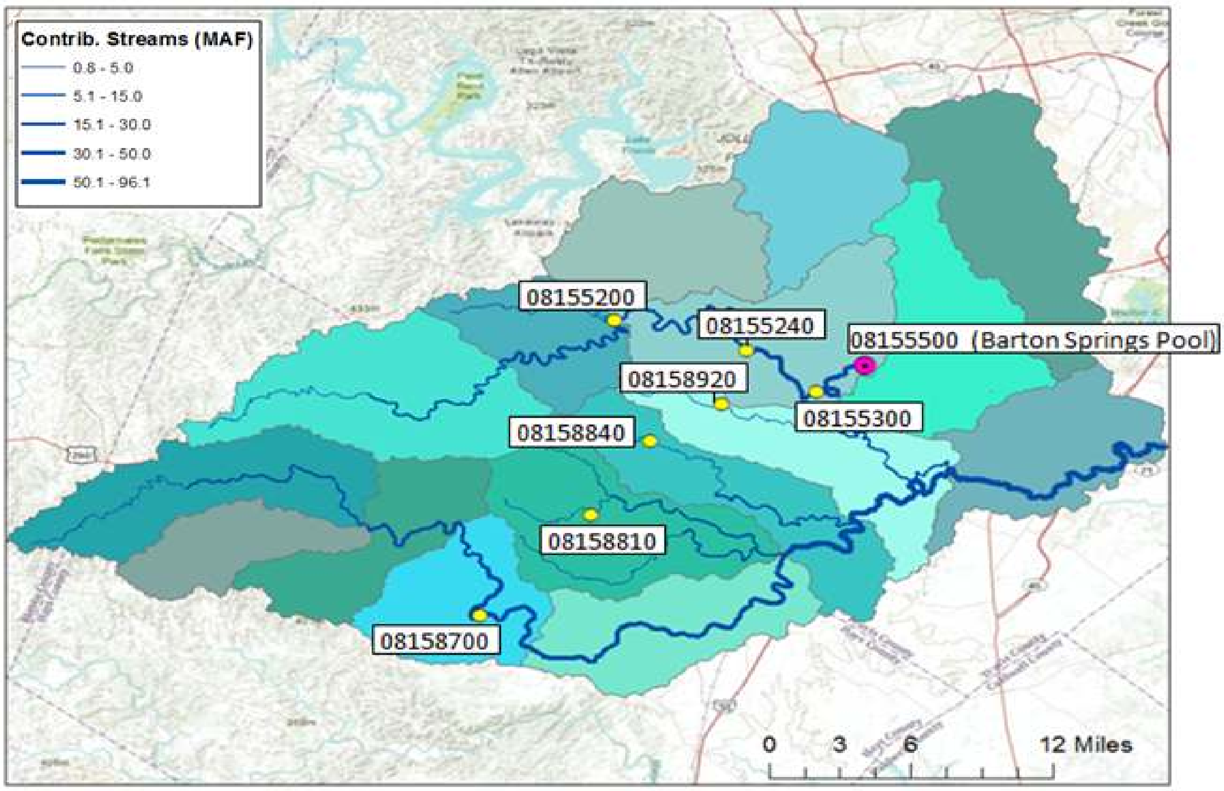

Figure 7. Study area with USGS streamgages used in analysis, contributing streams and their mean annual flow (MAF), and the HUC12 subwatersheds.

Hydrology and Water Quality

Discharge at the sites was plotted with precipitation to see how the streams respond to rain events. Figure 8 shows the discharge at five sites, each on one of the contributing streams, and precipitation. This figure shows that the contributing streams are prone to short periods of rapid streamflow from intense rain events, seen where discharge is steadily low (sometimes recorded as 0 cubic feet per second) and quickly spikes to a much higher discharge. As discussed in the introduction, increased streamflow from storm events can have implications on water quality at Barton Springs by delivering runoff-related contaminants rapidly to the pool with little time for dilution or removal in the aquifer matrix. Figure 9 shows discharge at Barton Springs along with precipitation. Unlike in the streams, discharge at Barton Springs never drops to 0 cfs (its minimum discharge is 13 cfs) because in low-flow conditions, groundwater from the aquifer matrix supplies discharge at Barton Springs. Currently, Barton Springs is experiencing low discharge, possibly because of the serious draught Texas is currently experiencing. Figure 8 and figure 9 show that precipitation directly affects discharge both in the contributing streams and at Barton Springs, with peak discharge occurring one or two days after peak rainfall at Barton Springs. A couple of these events are labeled figure 9, and the rainfall on 9/8/2010 corresponds to Tropical Storm Hermine.

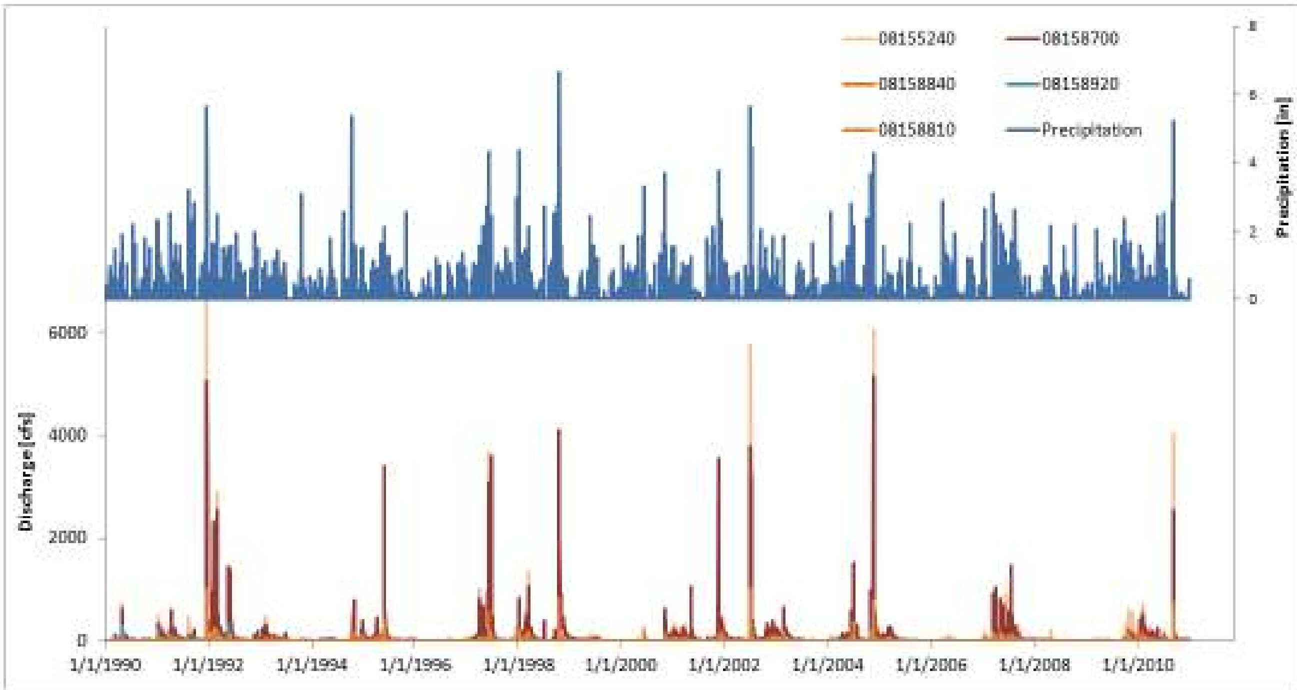

Figure 8. Precipitation data and discharge at streamgages along the five contributing streams.

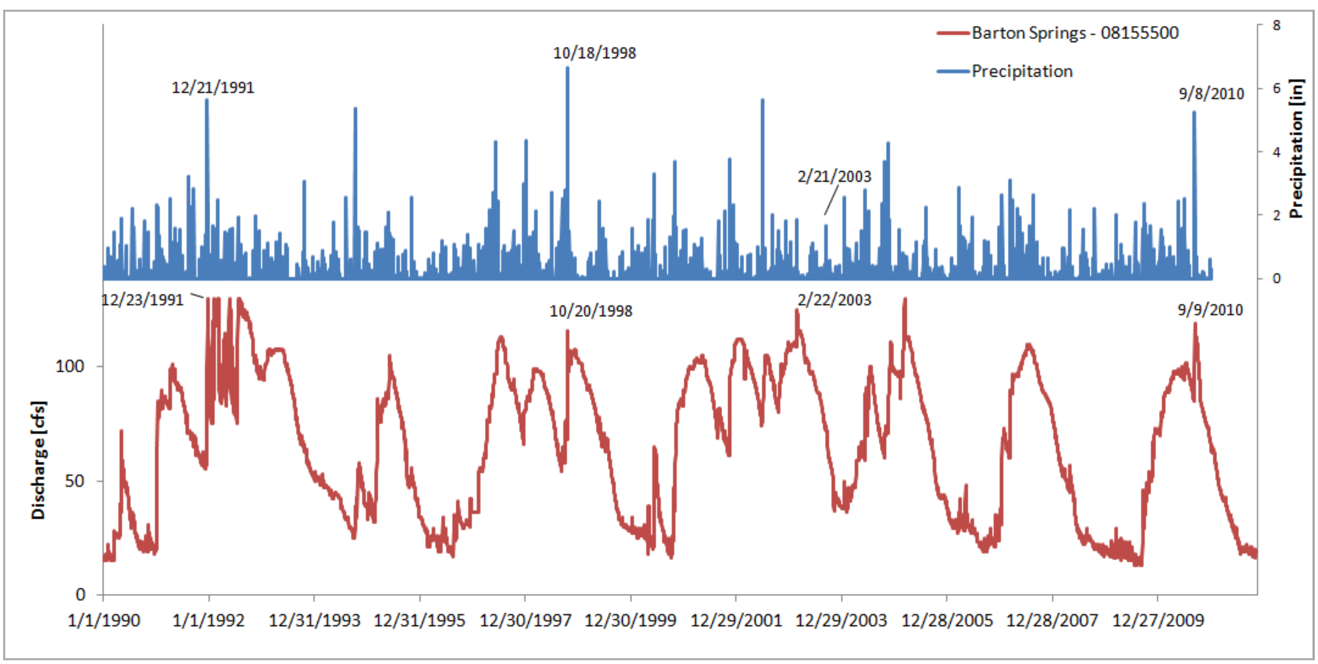

Figure 9. Precipitation data and discharge at Barton Springs

Continuous water quality data was available at the Barton Springs at Austin site (08155500) starting on July 4, 2003 for most parameters (figure 10). Data shows that temperature stays near constant around 20 degrees C, regardless of discharge. A general trend in data is that dissolved oxygen (DO) decreases and specific conductance (SC) increases as discharge decreases. This could be due to Barton Springs' hydrology during wetter and drier periods. As discussed in the introduction, Mahler and others (2011) said that during drier periods, stream recharge contributes much less to Barton Springs' discharge than in wetter periods, when about 80 percent of Barton Springs' discharge is comprised of stream recharge. Groundwater has a higher SC and lower DO than surface water. So when discharge is lower, and groundwater from the Edwards aquifer matrix has the greatest contribution to Barton Springs' discharge, it would be expected that SC would be greater and DO would be lower. Turbidity spikes appear to be related to discharge peaks (corresponding to intense rain events), and peak turbidity occurs on September 8, 2010, when Tropical Storm Hermine hit.

Water quality data for a site on each of the contributing streams, plus two additional sites on Barton Creek, and the site at Barton Springs was downloaded from NWIS. Data investigated included nutrient data, microbiological (for example fecal coliform and Escherichia coli), and suspended sediment. For microbiological data, no parameters had a long enough period of record from 1990 to 2010 to determine trends during these years. Suspended sediment data was collected intermittently, and when plotted, most results looked like they were rain event sampled. When suspended sediment data was plotted with discharge, elevated suspended sediment concentrations in the contributing streams appeared to occur during storm events. However, since most of the suspended sediment data was event sampled, it is difficult to draw conclusions on suspended sediment concentrations and trends during normal flow conditions.

Figure 11 shows filtered nitrate concentrations and unfiltered phosphorous concentrations at three locations along Barton Creek and at Barton Springs. The upper graph in figure 11 shows nitrate concentrations with the red diamond representing concentrations at Barton Springs. In general, nitrate concentrations seem to increase along the length of Barton Creek (site 0815200, the furthest upstream, tending to have the lowest nitrate concentrations, and site 08155240, the furthest downstream, having the highest on Barton Creek), with the greatest nitrate concentrations occurring at Barton Springs. The lower graph in figure 11 represents phosphorous concentrations. Unlike nitrate, no spatial pattern or temporal trend can be seen in the data. Phosphorous concentrations at Barton Springs are the lowest of the four sites, often below the USGS minimum reporting level.

In addition to Barton Creek, phosphorous and nitrate concentrations were analyzed at the four other contributing streams (figures 12 and 13). Nitrate concentrations were low at each of the four stream sites, and were highest at Barton Springs, and concentrations appear to have slightly increased in recent years. No real trends can be seen in phosphorous concentration either spatially or temporally, besides that, unlike nitrate, concentrations are lowest at Barton Springs.

Other nutrient data analyzed included ammonia, nitrate plus nitrite, and orthophosphate. Phosphorous and nitrate were used for analysis because they had enough concentrations above the USGS minimum reporting level to look for trends in the data. When analyzing compounds, the USGS has a value for concentration the lab sets based on the analysis method and the compound that represents the minimum concentration the lab can reliably measure, called the minimum reporting level. When sample concentrations are measured to be below this concentration, the sample concentration is reported as a less than concentration value (referred to as censored values). If many of these values arise, such as the case with many nutrient compounds at the eight sites, trend analysis becomes difficult. Statistical methods can be used to draw conclusions from data with less than values, but in this analysis, it was decided to focus on these two nutrients.

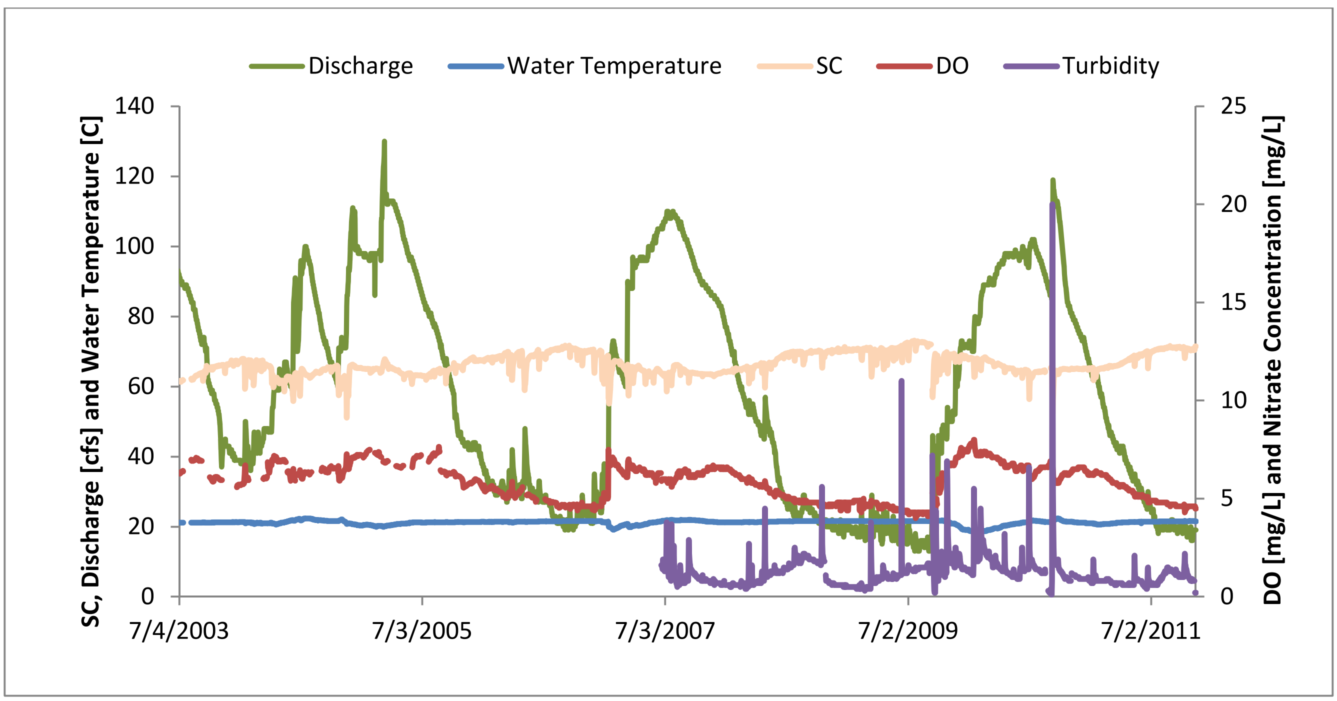

Figure 10. Continuous water quality data at Barton Springs.

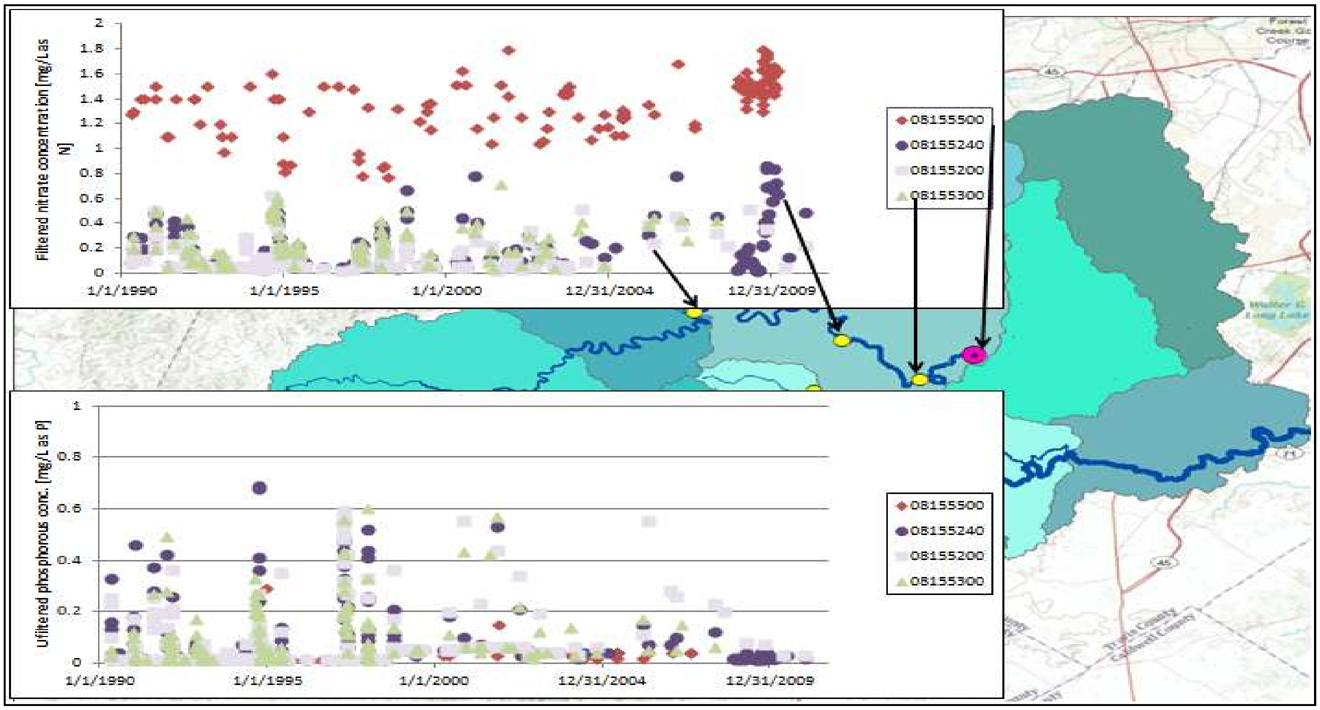

Figure 11. Nitrate and Phosphorous concentrations along the length of Barton Creek and at Barton Springs.

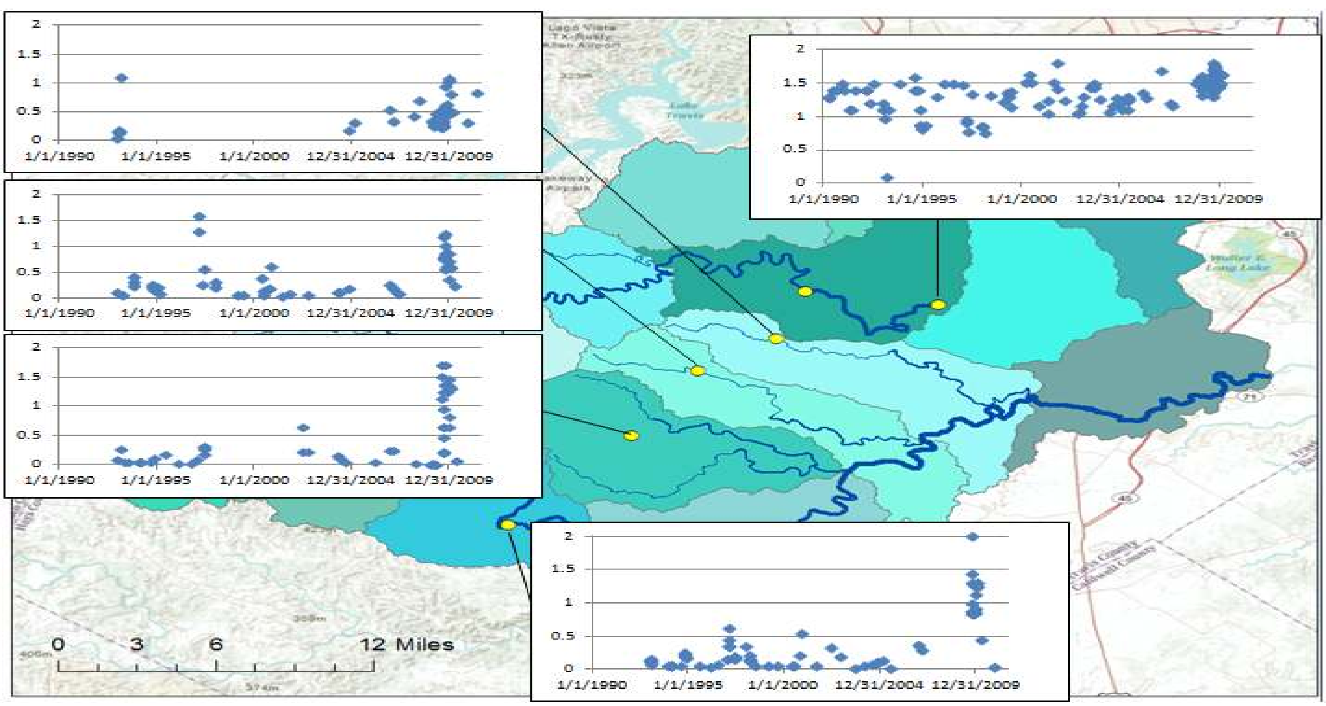

Figure 12. Graphs for filtered nitrate concentrations in milligrams per liter as nitrogen for contributing streams and at Barton Springs.

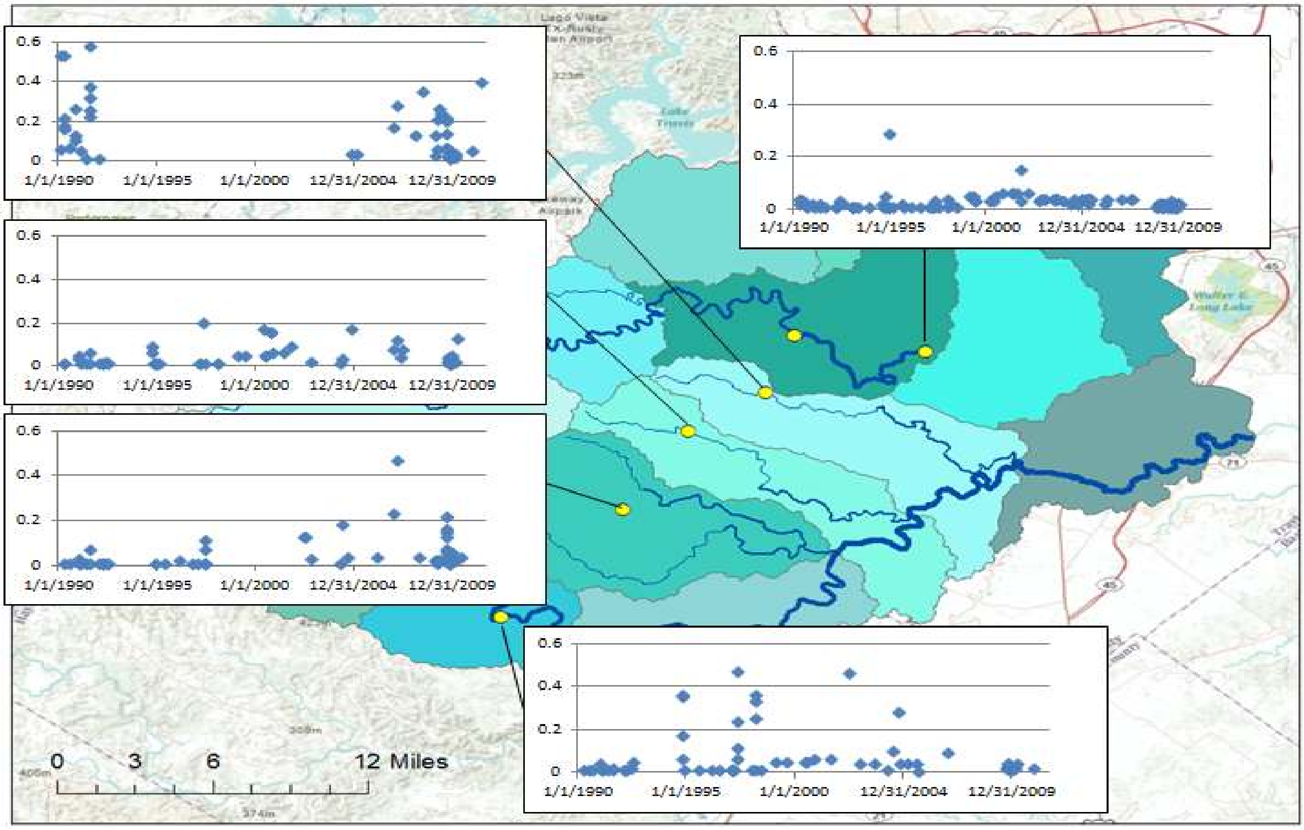

Figure 13. Graphs for unfiltered phosphorus concentrations in milligrams per liter as phosphorus for contributing streams and at Barton Springs.

Conclusion

The Austin area has grown dramatically over the past 20 years and mapping of the hydrozones of the Barton Springs portion of the Edwards Aquifer showed urbanization occurring in both the contributing and recharge zones of the aquifer. This development has the potential to decrease water quality in the contributing streams and therefore the water quality of Barton Springs. This is especially true since hydrographs of the contributing streams showed that the streams are susceptible to periods of high streamflow in the contributing streams in response to precipitation events, meaning stream recharge would have a bigger contribution to discharge at Barton Springs and an increase the possibility of deliverance of runoff-related contaminants to the springs.

Water quality data for eight sites, one each on Bear, Onion, Slaughter, and Williamson Creek, 3 on Barton Creek, and one at Barton Springs itself, was downloaded from NWIS. Data investigated included nutrient data, microbiological, and suspended sediment. In general, nitrate concentrations appeared to increase along the lengths of Barton Creek, having maximum values at Barton Springs. Spatially, nitrate concentrations were similar in concentration on all contributing streams, with many values below the USGS minimum reporting level. Nitrate concentrations at all eight sites have increased slightly over time. This agrees with the USGS SIR findings by Mahler and others (2011). High nitrate concentrations can affect water quality by causing algal blooms when present in high concentration. Besides being aesthetically unappealing, algal blooms can decrease DO concentration when the algae begin to die. If DO dropped enough, it could negatively affect the Barton Springs salamander.

In contrast to nitrate, unfiltered phosphorus concentrations do not seem to exhibit any distinguishable spatial or temporal trends. In addition, unlike nitrate, phosphorous concentrations are lowest at Barton Springs. When plotted with discharge, phosphorous concentrations at sites seemed to be more closely linked to discharge than did nitrate concentrations. Peak concentrations in phosphorous usually occurred at peak discharge, which was not the case with nitrate.

While no firm conclusions can be made from this study on the linkage between development and the effect of water quality in Barton Springs, it did provide a framework of how GIS and water quality data could be used together. When starting the analysis, I was expecting to see higher nutrient concentrations, which would have made trend analysis simpler since there would have been fewer censored values. Statistical programs for dealing with censored data would have been beneficial for data from these sites and maybe would have allowed for a trend to be drawn, or at least more nutrients to be investigated. Another limitation is that this study focused purely on surface water hydrology and quality. Since Barton Springs is groundwater system, for a full investigation, groundwater level data and water quality for surrounding wells must be considered.

References and Data Sources

Capitol Area Council of Governments, Barton Springs hydrozones shapefile, http://www.capcog.org/information-clearinghouse/geospatial-data/

City of Austin, land use, ftp://ftp.ci.austin.tx.us/GIS-Data/Regional/coa_gis.html

NCDC Climate Data Online, climate data, http://www7.ncdc.noaa.gov/CDO/dataproduct

Fry, J.A., Coan, M.J., Homer, C.G., Meyer, D.K., and Wickham, J.D., 2009, Completion of the National Land Cover Database (NLCD) 1992 – 2001 Land Cover Change Retrofit product: U.S. Geological Survey Open-File Report 2008-1379, 18 p.

Geospatial Data Gateway, Watershed Boundary DataSet (HUC12 subwatersheds), http://datagateway.nrcs.usda.gov/GDGOrder.aspx

Mahler, B.J., Garner, B.D., Musgrove, M., Guilfoyle, A., and Roa, M.V., 2006, Recent (2003-05) water quality of Barton Springs, Austin, Texas, with emphasis on factors affecting variability: U.S. Geological Survey Scientific Investigations Report 2006-5299, 83 p.

Mahler, B.J., Musgrove, M., Sample, T.L, and Wong, C.I., 2011, Recent (2008-10) water quality in the Barton Springs segment of the Edwards aquifer and its contributing zone, central Texas, with emphasis on factors affecting nutrients and bacteria: U.S. Geological Survey Scientific Investigations Report 2011-5139, 66 p.

U.S. Census Bureau statistics: http://2010.census.gov/news/releases/operations/cb11-cn37.html

USGS National Water Information System (NWIS), discharge and water quality data, http://waterdata.usgs.gov/tx/nwis/