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Spatial Analysis of Stream Buffer Setbacks for the Texas Hill Country

Final Report

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1. Introduction

Water, an exceedingly important natural resource, is severely impacted by population growth and unregulated development. The persistent and mounting pressure of increased demand on local water resources significantly impacts reserves and quality. Development, particularly construction, can lead to increased sedimentation and non-point source pollutants entering water systems. All of these strains can negatively affect water quality throughout the Hill Country Region of Texas. It is important, therefore, to have some type of regulation in relation to waterways in order to protect water resources as well as specialized riparian habitat. Implementation of stream setback buffer zones is one solution to help mitigate water resource degradation.

1.1. Background Information

The Texas Hill Country Alliance (HCA) is a non-profit group working to develop a strategic and responsible regional growth plan that reflects their expertise and ideas of land stewardship. A major focus of HCA has been their involvement in creating the *Regional Water Quality Protection Plan for the Barton Springs Segment of the Edwards Aquifer and Its Contributing Zone* (Naismith Engineering, Inc. 2005). This plan (RWQPP) is a comprehensive guide for protecting surface and ground water, and outlines model ordinances and suggested development rules. HCA is currently analyzing the feasibility of RWQPP implementation across the Texas Hill Country as part of a comprehensive sustainable growth plan.

1.2. Objectives

HCA tasked PAKK with the creation and analysis of stream setback buffer zones for the Texas Hill Country. PAKK's objective was to employ GIS capabilities for illustration and measurement of land area identified through the utilization of stream buffer guidelines expressed in the RWQPP. According to the RWQPP (Naismith Engineering, Inc. 2005, p.70) required stream buffer zone widths are outlined below:

Required Buffer Zone Widths (from Stream Centerline)

Stream Contributing Area (Acres)	*Width/Offset (feet, each side of centerline)*	*Total width (feet)*
32 to 120	*100*	*200*
120 to 300	*150*	*300*
300 to 640	*200*	*400*
Greater than 640	*300*	*600*

The watershed data of the complete hydrography layer provided to PAKK describes areas ranging in size from 7,607 to 50,884 acres. Due to the size of these contributing areas, we applied the broadest category of stream buffer zone. The 600 ft total buffer width was generated from applying 300 ft. buffers from the centerline of features within the complete hydrography layer. A dissolve function was employed in order to calculate the amount of acreage per county affected by these buffer setbacks. For location and identification purposes, the resulting maps also have details displayed such as main roadways and urban areas.

The cartographic output provided by PAKK, in addition to data and analysis results, will be utilized by HCA and future GIS analysis teams in continuing to gather and aggregate stakeholder input that will prepare them to embark on a full build-out landuse map. The goal of our project was to construct general overview maps. This executive overview was intended to provide the approximate land area identified by the RWQPP stream setback buffer zone when applied at its greatest extent. The overview maps and calculations of acreage amounts will also assist HCA in facilitating discussions of the many criteria to consider in urban and rural growth planning.

The geographic scope in regard to the stream buffer analysis and land area calculations, is a 17 county area of the central region of Texas called the Hill Country. The geographic scope in regard to the web GIS maps will be 6 of the 17 Hill Country counties including Hays, Comal, Blanco, Kendall, Bandera, & Medina.

ArcGIS 9.3 is particularly useful in the type of analysis we completed for this project. It allowed us to graphically illustrate the stream setback buffers for a study area of large scope in a relatively short period of time. ArcGIS also enabled us to calculate areas of irregularly shaped polygons (i.e., counties and buffer zones) in a fairly easy manner with comparatively less man-hours than if it had to be done manually.

1.3. Literature Review

Conscientious planned growth is vital for any area, whether it be as small as a university campus or as large as the Texas Hill Country. Resource scarcity is a fact of life in many parts of the world, and is becoming increasingly so here in Central Texas, especially in regard to water. Within the last 100 years, Texas has experienced several severe drought periods (The Handbook of Texas Online. 2008). Water is essential for the economy of the Texas Hill Country, with importance ranging from consumption and agricultural needs to tourism and energy production. The United States Environmental Protection Agency (2008) suggests that, “a watershed approach is the most effective framework to address today’s water resource challenges. Watersheds supply drinking water, provide recreation and respite, and sustain life. More than $450 billion in food and fiber, manufactured goods, and tourism depends on clean water and healthy watersheds.”

Communities throughout the United States are involved in studies and actively implementing plans to protect water resources and control pollution due to run-off. Kansas City, Missouri has developed and implemented a stream setback ordinance. The ordinance, which took several years to generate, was used as a key piece of knowledge for several of the city’s ongoing challenges including development codes, environmental practices and wet weather programs. The project conducted a methodical study to evaluate and quantify riparian buffers and stream quality. This information was then used as a basis for low-impact development policies as well as other city based applications. Field observations and stream asset inventory maintain the idea that urbanization, agricultural practices, and loss of stream buffers are negatively impacting the overall stability and quality of streams throughout the city (Schulte et al. 2006). These findings further support the importance of riparian buffers for protecting stream quality (Schulte et al. 2006).

Many studies have been conducted on the analyses of stream setbacks. Non-point source pollution generates 65% of total inland surface water pollution including phosphorous, nitrogen, and pesticides, among others (Narumalani et al. 1997). Therefore, buffer zones for streams are necessary for even the most basic levels of development. Before reaching surface water, the buffer zones allow the pollutants to dissipate through, "infiltration, absorption, uptake, filtering, and deposition (Narumalani et al. 1997)." Studies suggest that buffer zones ranging from 3 to 200 meters are shown to be effective, and the buffers need to be constant across the entire study area. (Narumalani et al. 1997).

Much of the public is becoming aware of the importance of sustaining natural resources. With technology growing at an ever evolving rate, information readily reaches the public allowing community members to become better informed than ever. Public Participation GIS (PPGIS) is being utilized in relation to a wide array of issues ranging from neighborhood development and revitalization to legislative actions to natural resources management. PPGIS typically involves people from different fields of expertise coming together to share knowledge in relation to the topic at hand. This information is translated into a GIS and used to influence and affect future activities.

In a time when government funding has decreased, many non-government organizations (NGOs) are taking it upon themselves to get involved in geospatial analyses to help influence decision making processes, particularly in local government, planning, and development. It has been found that, "…complicated contextual factors in which PPGIS is produced and implemented can constrain community organizations' PPGIS activities and limit the impact of their spatial analysis in decision-making processes that affect them (Ghose and Elwood 2003)."

Because the public generally lack knowledge and skills related to GIS and digital data, technical and analytical expertise and support are needed. Cooperation between multiple institutions, such as NGOs, non-profit groups, universities/colleges, government entities, etc.

needs to transpire in order to fill this void, as PAKK hopes to do so with this current project. However, "…unequal power relations can differentially affect access to GIS and digital data, as well as control over the representations and analyses created with the technology (Ghose and Elwood 2003)." Therefore, "…key organizational factors (such as knowledge, stability, capacity, and leadership)…," can definitely impact interactions between entities (Ghose and Elwood 2003). Through being prepared and working cooperatively, many of these organizations can help shape future actions within their communities.

2. Data

The initial data provided to our group was relatively vast; the previous project groups as well as Marston had created and/or downloaded many files dealing with the contiguous 17 county area. At the outset of the project, much of our team's time was spent searching through and learning about the data available. The team did find that many of the typical preparation obstacles, such as finding and downloading data, converting the datum and projections for all the datasets, clipping and merging areas had been by completed by the preceding teams. Our task was to understand how and when to use this data in order to answer the question posed for the project. To begin we reviewed many files and created several preliminary maps to help us visualize the HCA study area as well as the hydrography and watersheds in urban and rural areas. We also reviewed many similar projects and their work products via the Internet. The Envision Central Texas project was particularly helpful, as it was local and the Hill Country Alliance wanted a similar study of the 17 counties. After meeting with the clients, the decision was made to conduct a sample pilot study of how the RQWPP guidelines (Naismith Engineering, Inc. 2005) may impact total acreage of the 17 county HCA area.

The Hydrography layer proved to be most challenging; we met this challenge by honing our GIS and ArcMap software skills. The complete hydrography was composed of line features representing seven types of hydrography (dam, intermittent lake, intermittent steam, major river, major stream, stream water body and water body). The hydrography layer was not consistent in its portrayal of these water features; they were digitized into multiple line segments to represent one feature. No topology was defined in the hydrography data, hence no network connectivity between segments exists along the features' length. For example, one stream could consist of multiple segments (e.g., West Bear Creek has eight segments), but when displayed in a GIS, appear as a continuous line feature. In addition, to the lack of connectivity between line segments, some features were depicted with two or more lines giving the feature width (e.g., the Colorado River). This representation appears to indicate stream or river banks, not centerlines. We attempted to remedy these questions by several means; one was utilization of software tools to create a centerline and to further breakdown watershed areas were examined. Another avenue explored was making an effort to find additional data for hydrography, possibly a cleaner layer with defined topology. Each option was exhausted within a couple of weeks, we had to work with the hydrography data we had. To facilitate the understanding of possible impacts the inconsistencies of the hydrography data would have on the project, each of the seven types was separated and categorized. Close examination at a scale of 1:100,000 and larger revealed that the majority of the data, intermittent streams, were all represented by single lines; approximately 5% or less of the hydrography features were represented by double or multiple lines.

The final product for the project used a minimal amount of the initially provided data. The two main inputs for the land area calculations were the county shapes and the hydrography lines. The final maps included roads and city limits for locational purposes, the categorized buffers we created, and each clipped county outline.

2.1. Data Information

The information below lists pertinent details about the complete hydrography data layer.

Geometry Type:	Line
Projected Coordinate System:	NAD_1983_UTM_Zone_14N
Projection:	Transverse_Mercator
False_Easting:	500000.00000000
False_Northing:	0.00000000
Central_Meridian:	-99.00000000
Scale_Factor:	0.99960000
Latitude_Of_Origin:	0.00000000
Linear Unit:	Meter
Geographic Coordinate System:	GCS_North_American_1983
Datum:	D_North_American_1983
Prime Meridian:	Greenwich
Angular Unit:	Degree

3. Methods

The careful and methodical review of initial data was at the core of the methodology; understanding the major shortcoming and challenges in the preliminary stages made the analysis of land area impacted by the RWQPP more efficient. The analysis tools utilized were fairly simplistic in technique, but a bit overwhelming in magnitude since there were seven hydrography types across 17 counties, each of which needed to be separated for clear results reporting.

PAKK created GIS models (Appendix III) to streamline and standardize output for analysis in relation to stream buffer creation and land area calculations. The first model accomplished the majority of the analysis work. It completed the monotonous tasks of separating each of the seven hydrography types as well as each of the 17 counties. It then created buffers for each representative line of the hydrography. These buffered areas were dissolved in order to create a single polygon for each of the seven types of hydrography for which areas were calculated. For features made up of single line segments, the line functioned as the stream centerline and the 300 ft. buffer was applied to each side for a total width of 600 ft. For the few features that were represented by double lines, the 300 ft. buffer was applied to each of the lines, resulting in a somewhat wider buffer with the inclusion of water area. When the data layers were displayed at a county-wide scale, the inconsistencies were not conspicuous; however, the acreage calculations were slightly skewed toward a larger amount. It was our opinion that these skewed calculations were a minor amount.

Several test runs of the models were executed and adjustments made as needed to ensure the most accurate results possible. Many minor issues crept up during the analysis phase, some were user errors, while others were functions of the data and tools. The first model assumed all hydrography types would be in all counties; it failed to account for the possibility that some counties might only have a few hydrography types. This assumption caused a malfunction at the merge stage. In order to overcome this, a second model was created using the intermediate data created by the first. This model operates county by county and merges only applicable hydrography buffers.

The use of models in GIS analysis offers many benefits. The user is able to change inputs, output names, parameters, tools used, and the order of use on a single aspect of the analysis. Without this ability, if one input at the beginning of this analysis needed to be changed all other tools would have to be re-run individually. Even though the model took quite a bit of time to create, revise, and run, it was superior to the manual alternative.

3.1. Explanation of Models

The numerous repetitive steps required for this project necessitated the creation and utilization of GIS models (Appendix III) as primary analysis tools.

Functional Steps of Models:

- Select and create layer for each of the 7 hydrography types
- Apply 91.44 m (300 ft.) buffer to each line segment
- Dissolve each type to create individual polygons and calculate their areas
- Select, clip, and calculate acreage for each of the 17 Hill Country counties
- Clip the complete buffered hydrography to each county
- Formula for conversion of calculated area: **(square meter) x (.00247105) = Acre**

3.2. Web GIS

When creating the web GIS using the Manifold software, the purpose was to allow the user to zoom in to a larger scale to see the buffered areas in relation to real-world landmarks, such as parks, roadways, and city limits. The static maps only allow for a generalized scale. PAKK chose to cartographically display six counties (Comal, Hays, Medina, Blanco, Bandera, and Kendall) because we felt mapping the entire study area would result in an unacceptably long download time for the user to load the website as a dynamic map. HCA specified these six counties of interest to them because of the pressure put on these counties by rapid population growth in the coming years. The Manifold map also differs from the static maps in that the complete hydrography layer is treated as only one layer and not broken down into the seven types of hydrography features (e.g., stream water bodies, etc.). We felt that breaking the master layer into many layers would once again put too much strain on the website to load quickly and efficiently.

4. Results

PAKK produced general overview maps for each of the 17 Hill County counties. In addition to the maps, land area for counties and stream setback buffers was calculated.

4.1. Land Area Calculation Analysis

Results of the land area calculations performed are provided in table format (Appendix I). The first column lists each of the Hill County counties in alphabetical order and the second column contains the total county area. The third through ninth columns provide the acreage for the stream setback buffers for each of the seven types of hydrography features. The last column gives the total buffered area per county, which is also area in the county that may be considered incongruous for well-planned sustainable development.

The total land area for the 17 county study location is 113,655,291 acres. Comal is the smallest county (3,678,168 acres), and the largest county (13,566,468 acres) is Edwards. The total land area for the stream setback buffer in the17 county study location is 14,702,973 acres, which is 12.9% of the total study area. Real county contains the least amount (420,736 acres) of stream setback buffer area, and Travis county contains the greatest amount (1,558,711 acres). Intermittent streams make up 83.5% of the total stream setback buffer area, and 10.8% of the total study area.

4.2. County Overview Maps

Static maps were produced to illustrate the project study area and complete hydrography, consisting of seven different feature types (i.e., dam, intermittent lake, intermittent stream, major river, major stream, stream water body, and water body) (Appendix II). These two maps contained the basic input data for analysis and creation of the stream buffer setback. Static maps were also produced to illustrate our analysis results. One map per county was produced as the final cartographic output. The alphabetically ordered county maps (Appendix II) depict the 600 ft. stream setback buffer zones for intermittent hydrography (i.e., intermittent stream) and other hydrography types (i.e., stream water body, major river, major stream, water body, and dam). Each county map also contains a table displaying acreage calculation results for the county and each of the hydrography types.

5. Discussion

Our project has defined the areas of land deemed sensitive to development by the RWQPP stream buffer setback guidelines. The stream setback buffers of the seven different types of hydrography accumulated a fair amount of land area (14,702,973 acres or 12.9%) in relation to the total acreage for the 17 county study area (113,655,291 acres). Although the maps we have provided at the county wide scale provide only a generalized sense of the buffers, the web GIS maps allow users to zoom in and see exactly what areas are within the 600 ft. stream setback buffers. More importantly, the areas in and around city limits and populated places are easily discernable when zoomed in, allowing utilization for future planning of urban build-out.

While the results are clearly displayed, there are some issues with the final visualizations of the buffered areas. As previously discussed, we have had a difficult time dealing with hydrography features represented as dual lines in our software. We assumed these double lines to represent the streams' banks, not the centerline, which resulted in a slight lack of accuracy. The stream flow of a water feature is always changing in relation to the amount of precipitation that is received; thus, making a water feature’s banks constantly changing. The software automatically added a buffer to both lines representing a single feature, which deviated from the 600 ft. buffer size of single line features. While the affect of the wider buffer areas may not be overly exaggerated on a more narrow stream, the results are aberrant for a large lake (e.g., Lake Travis) where the buffer edge terminates in the middle of the water. Because our team lacked time and hydrologic knowledge to manually correct this issue, we had to display the buffered areas as they were produced by the software. However, because 83.5% of the hydrography features consisted of intermittent streams, which were all single line features, the buffer size deviations are not widespread (less than 16.5%) in the data because the other hydrography feature types consisted of only partial double line representations. In relation to the entire study area, the double size buffer deviations are small (less than 2.1%).

If we were to repeat this project, the same issues would arise, and time constraints would once again play a factor. Though, if we had more than a semester to complete the analysis, the data, could be manually altered to change the dual-line features into a single line representation of the stream’s centerline, instead of its banks. This could be physically accomplished through digitizing the water features' centerlines using verified coordinate points; however, this can become quite time consuming to perform accurately.

The complete hydrography layer utilized in this project was based on data from the Texas Department of Transportation (TxDOT). PAKK did attempt to locate different hydrography layers; however, all those publicly available, as well as the one we possessed, were based on TxDOT maps for which features had been digitized. A more accurate data layer would obviously give us better accuracy for calculating the acreage contained within the buffers we created. The total amount of acreage within the buffers would decrease since the buffers would not be overlapping from the double line hydrography features.

Using GIS to solve this problem is ideal from a visualization standpoint, as it spatially depicts areas of concern for HCA quite well. However, it is important to note that these acreage calculations are highly generalized and are not completely accurate in relation to actual ground points.

6. Conclusion

The maps produced have identified areas of land sensitive to development that may aid in municipality implementation of guidelines set forth in the RWQPP. Many municipal areas are in close proximity to streams and rivers, so the analysis is needed not only as a starting point for a plan, but also to educate communities regarding their sensitive locations. In the future, full-scale zoning and potential growth maps will supplement the buffer analyses and be utilized for zoning areas of more specificity, such as residential, commercial, and industrial development.

PAKK hopes that our cartographic results have offered HCA an opportunity to spatially view sensitive areas that can be protected during the projected population booms in the next 30-60 years. The final product of the project will assist HCA, other concerned citizens, and local advocacy groups in the future delineation and implementation of the RWQPP. The realization of such a plan in conjunction with other regulatory forces will serve to smooth the progress of a rapidly growing area in the protection and utilization of limited natural resources, particularly water.

This project was both challenging and informative for our group. We conquered several challenges that have given us the confidence to move forward into GIS related careers. We would like to thank the former GEO 4427 classes that have produced much of the information utilized, as well as the members of HCA that have graciously allowed us to participate in such an important project.

7. References

Ghose, Rina and Sarah Elwood. 2003. Public Participation GIS and Local Political Context: Propositions and Research Directions. URISA Journal. 15: 17-24.

Naismith Engineering, Inc. 2005. Regional Water Quality Protection Plan for the Barton Springs Segment of the Edwards Aquifer and Its Contributing Zone. Regional Water Quality Planning Office Dripping Springs, TX. http://www.waterqualityplan.org/index.php?BODY=finaldraft (last accessed 16 Feb 2009).

Narumalani, Sunil, Yingchun Zhou, and John R. Jensen. 1997. Application of remote sensing and geographic information systems to the delineation and analysis of riparian buffer zones. Aquatic Botany. 58: 393-409.

Schulte, Scott A., Patricia A. Elbert Noll, and Jeffrey Henson. 2006. Riparian Buffer Benefits and Kansas City, Missouri's Stream Setback Ordinance. Kansas City, Missouri Office of the City Clerk. http://cityclerk.kcmo.org/LiveWeb/Documents/ViewAttachment.aspx?q=ue1tUzZCBW%2BQ3B%2FMbZoQnThkrspMJuazgNPeTsmah3n09ic%2Fc5CqQUSx0xvYq%2BWual6M7HuxD0%2ByMqKybZ%2BHPg%3D%3D (last accessed 16 Feb 2009).

The Handbook of Texas Online. 2008. Droughts. Texas State Historical Association, Denton, TX. http://www.tshaonline.org/handbook/online/articles/DD/ybd1.html (last accessed 28 Feb 2009).

United States Environmental Protection Agency. 2008. A Watershed Approach. United States Environmental Protection Agency, Washington D.C. http://www.epa.gov/owow/watershed/approach.html (last accessed 24 Feb 2009).

8. Appendices

Please see the following pages.