Paper No. 1546

Paper Title: Using GIS to Integrate Capital Projects for Holistic Watershed Management

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Paper Abstract

The City of Austin's Watershed Protection Department's recent Master Plan calls for solutions that integrate its flood, erosion and water quality missions. Past experience has revealed that single-mission capital improvement projects are more costly (ignoring opportunities and economies of scale) and often create unanticipated negative impacts on the very resources the Department is trying to protect. In short, determining the cumulative impact and synergistic benefit of implementing multi-objective projects in the same watershed is very complex.

The Department therefore developed a system to integrate staff and geographic information from all three missions. At its heart is a GIS tool that combines all the previously disparate data into a single application. Managers of individual projects use the GIS tool to recognize shared problems and connect opportunities. Out talk will demonstrate how project selection and preliminary engineering changes and improves with the use of complex spatial analysis.

Paper Text

The Watershed Protection and Development Review Department (WPDRD) of the City of Austin, Texas is responsible for protecting the natural resources associated with the watershed located within the City of Austin. Austin has a population of 890,245 within its 637 square mile jurisdiction. The City has a wide variety of natural resources due to its unique geographic location along the Balcones Fault, dividing the Texas Hill Country to the west and the Blackland Prairie to the east. The west features rugged, limestone terrain and an environmentally sensitive karst aquifer and is home to several endangered species, including the black capped vireo, the golden cheeked warbler, and several species of salamander which live within the Edward's Aquifer. The eastern portion is characterized by low rolling hills, alluvial soils, and remnant prairies. Texas' Colorado River runs through the middle of town and a series of lakes have been constructed within and to the west of the City. The average rainfall for the City is 33 inches, with much of the rain falling during intense storm events characteristic of what is known as "Flash Flood Alley."

In the mid 1990's WPDRD began work on a Watershed Master Plan to better understand and prioritize the erosion, flood and water quality associated watershed problems. Phase 1 of the Master Plan covered the 17 most populated and most urbanized watersheds, and resulted in an abundance of information on watershed conditions and problems. This data was condensed into numeric problem scores to allow comparison of the nature, complexity, and severity of watershed problems across the City. Phase II will address the remaining 26 watersheds in the City's jurisdiction.

Each year, WPDRD identifies projects for capital funding and implementation, based on the Master Plan prioritization system; the worst problem areas are addressed first, with consideration of cost-effectiveness. The department established a Mission Integration and Prioritization (MIP) Team to oversee project planning, design, and implementation. The MIP Team developed a system to ensure the full "integration" of the department's three key missions: flood, erosion, and water quality control. This paper describes the GIS tools developed to implement this integration and project evaluation process.

Consideration of all three departmental missions has been historically difficult. In the past, a project serving one mission might overlook an opportunity to address one or both of the other missions; worse, it might actually do harm to other missions. For example, a hard-lined channel stabilization project might solve a flood problem but simultaneously exacerbate bank erosion downstream or impair riparian habitat. Similarly, a water quality retrofit pond might fail to incorporate design elements to address flood control needs. Goals were established by the Master Plan for all projects to consider community and public use benefits, which was unevenly addressed in the past.

WPDRD instituted an approach for capital projects development with the objective of implementing sustainable projects that address a combination of erosion, flood and water quality problems. This approach saves both time and money, and insures the implementation of projects that optimize fiscal resources while minimizing unanticipated negative impacts on the waterways. A successful CIP project, once implemented, should result in a measurable reduction of watershed problems within its design area that corresponds to a reduction in the problem scores for the associated missions. The components of the problems scores for each mission are complex, and must be independently analyzed to insure that the project is properly designed to affect a reduction in the associated watershed problems. The following table summarizes the general problem score elements for each mission.

Flooding - Creek Related	• Property protection – as measured by the flood risk associated with property/infrastructure location relative to the 2,20, 25 and 100 year floodplains, based on fully developed conditions • Public safety – velocity of flooding at roadway crossings
Flooding - Localized	• Customer reported drainage complaints
Erosion	• Threatened Property – includes existing and future threats to primary, and secondary structures, public infrastructure, parkland and trees • Future Reach Stability
Water Quality	• Water Chemistry • Sediment Quality • Physical Integrity and Channel Stability • Aquatic Life Support • Contact Recreation • Non-Contact recreation • Receiving water values • Future pollutant loading

Geographic Zone of Influence

One of the first steps to designing an integrated capital project is to analyze the diversity of information that is unique to each problem area, and then to conduct a field analysis that includes the project manager, and a representative for the key departmental missions. To define the area of interest, each proposed project identifies a geographic zone of influence that represents the limits within which potential opportunities might exist for project development which includes multi-mission benefits, and within which potential project impacts on the waterway or on other missions could be expected to occur. It represents the geographic area which should be included in the solution development process. The map representing the Zone of Influence becomes a key element in the field analysis.

The Zone of Influence (ZOI) will vary depending on the type of project proposed. Each project category can have impacts and opportunities which should be considered during planning, preliminary engineering, and the design phase of the project. Project types that are typdically analyzed include Best Management Practice (BMPs) such as ponds for treatment of both water quality as well as flooded and erosion control, that range from sedimentation filtration ponds to detention/extended detention or wet ponds. Other project types include in channel modification for erosion stabilization, flood control, vegetative and habitat enhancement, creek channel crossing such as culverts and bridges, storm drain improvements and property acquisition.

The Zone of Influence (ZOI) should be evaluated to determine the multi-mission benefits that might exist, as well as the negative impacts that could result. The ZOI is evaluated for known existing problem areas, as well as impacts to, or opportunities to benefit the floodplain, natural and traditional character of the waterway, potential impacts to channel stability, priority woodlands, Critical Environmental Features such as springs, wetlands or recharge features, and the presence of Public Land.

Base Map Development

A GIS base map file was developed to share with the 18 project managers. Each project manager used the map to create their own customized map of individual project areas. The map file had to combine both the considerable number of Watersheds Master Plan map elements with a wide array of additional, relevant GIS coverages produced by the City of Austin. It was therefore a challenge to create a map which was both complete and not confusing for the project manager, many of whom were neither familiar with GIS nor the Master Plan elements for missions other than their own. The final product was, therefore, experimental and preliminary. In the end, over 30 map applications (MXD files) were created to evaluate as many projects in the 2007 fiscal year budget cycle. We anticipate making changes and improvements to the base map as described later. Data coverages included in the base map are as follows:

Layers	Type	Description
Erosion Control		
Master Plan Erosion Scores	Line	Color-coded stream centerlines based on scores.
Priority Erosion Projects	Polygon	Future planned projects
Erosion Complaints	Point	Structures & resources threatened (from citizen complaints)
Master Plan Problem sites	Polygon	Structures & resources threatened (from consultant studies).
Geomorphic Reach Buffer	Polygon	Channel status: stable, in adjustment, or in transition.
Water Quality		
Master Plan Water Quality Scores	Line	Color-coded stream centerlines based on scores.
WQ monitoring sites	Point	Water quality monitoring sites.
Sector Boundaries	Polygon	Old city plan subareas.
Springs	Point	Critical environmental feature.
Rimrock	Polygon	Critical environmental feature.
Woodlands	Polygon	Priority & other significant woodlands.
Other Features	Polygon	Grasslands, wetlands, etc.
Localized Flooding		
Storm Drains	Line	Existing storm drains (incomplete).
Inlets	Point	Existing storm inlets.
Suggested Stormdrains	Line	Needed storm drains.
Suggested Inlets	Point	Needed storm inlets.
Local Flood Complaints	Point	Citizen complaint locations.
Creek Flooding		
Master Plan Creek Flooding Scores	Line	Color-coded stream centerlines based on scores.
100 Year Innundation depths	Point	Structures in flood plain from Master Plan.
100-year Flood Plain	Polygon	New & old flood plain info.
Integrated Scoring		
Master Plan Integrated Scores	Line	Color-coded stream centerlines based on averaged scores for water quality, erosion, and flood control.
Base Map		
2003 Color Aerial	Image	High resolution aerial photograph.
Watershed Boundary	Polygon	Watershed boundaries.

Layers	Type	Description
Watershed Management Areas	Polygon	Master Plan subwatersheds (point & polygon)
Creeks	Line	Stream centerlines.
Lakes and Rivers	Polygon	Larger bodies of water.
Contours	Line	2-foot contours.
Parks & Preserves	Polygon	Permanently protected open space.
Ponds	Point	Structural flood & water quality controls.
Waterfront	Polygon	Development overlay district along lake.
Big Roads	Line	Major arterials and highways.
Streets	Line	Streets (major & minor).
Address Point	Point	Street address locations.
Railroads	Line	Railroad tracks.
2003 Transportation	Polygon	Road, driveway & parking lot polygons.
2003 Buildings	Polygon	Building footprints.
Recharge zone	Polygon	Edwards Aquifer recharge zone outcrop boundary.
Soils	Polygon	Soil Conservation Service soil types.
Jurisdiction	Polygon	Austin city limits & extraterritorial jurisdiction, other city limits & ETJ.
Subdivisions	Polygon	Subdivision polygons.
TCAD parcels	Polygon	Tax appraisal district properties.
City of Austin Property	Polygon	Land parcels owned by the City of Austin.
Neighborhood Plans	Polygon	Planning areas (defined by City).
Neighborhood Associations	Polygon	Neighborhood & homeowners associations (defined by citizens).
Water Mains	Line	Water distribution lines.
WW Manholes	Point	Wastewater manholes.
WW Mains	Line	Wastewater collection lines.

Application Example: West Bouldin Creek

One of the first projects to be examined and evaluated using the GIS base map was a potential water quality retrofit pond located in a small, urbanized watershed named West Bouldin Creek. Figure 1 shows the location of the creek within Austin. Figure 2 shows a closer view of the watershed and shows the Zone of Influence for one of the selected projects in the watershed.

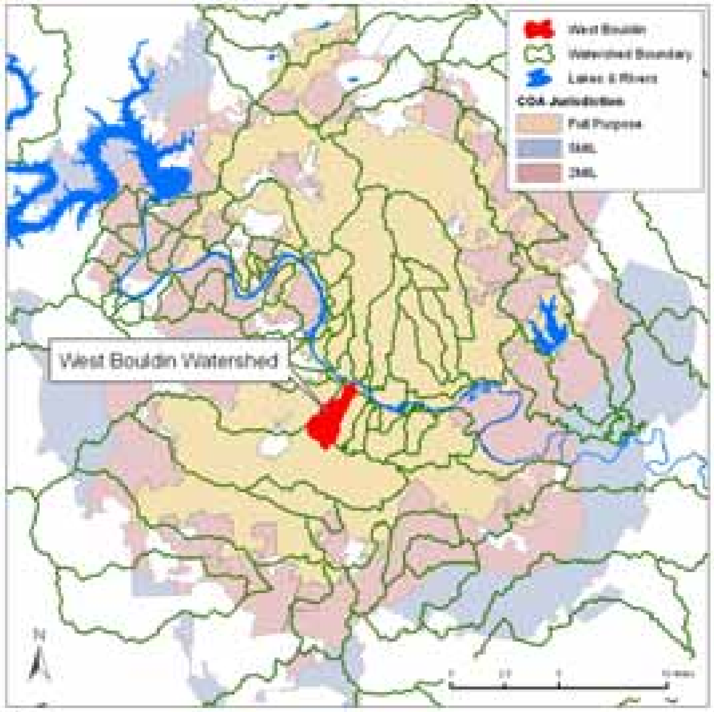

Figure 1. Watersheds in Austin, Texas, featuring West Bouldin Creek.

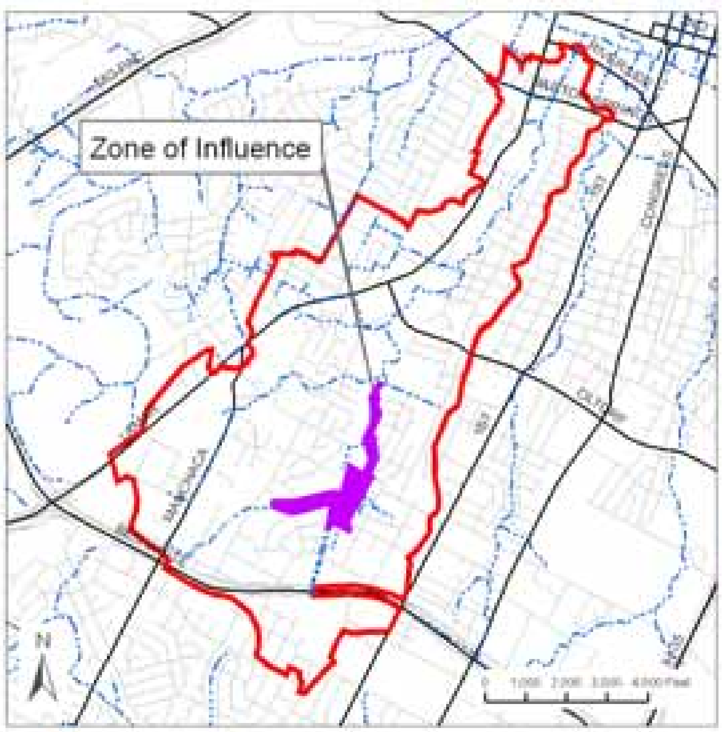

Figure 2. West Bouldin Creek close-up.

This creek features most of the problems of highly developed basins. Grouped by the three WPDR missions, the problems were as follows:

- **Erosion:** bank erosion and downcutting, risk to adjacent buildings, property, and infrastructure.
- **Water Quality:** lack of baseflow, poor water chemistry, compromised riparian habitat, unstable banks, significant pollutant loads to Town Lake downstream.
- **Flooding**
    - **Local Flooding:** flooding in streets and buildings from antiquated, under-sized storm drains.
    - **Creek Flooding:** flooding in streets, building, and bridges from watershed-wide sources, including an 80-home mobile home park built almost directly in the 2-year floodway.

The presence of problems from all three missions was typical of much of Austin. It also called for integrated solutions which might, ideally, solve more than one set of problems and, at a minimum, would not compound those same problems. The “lead mission” on this particular project was Water Quality. The managing (project) engineer reviewed the available data and noted the classic dilemma of urban creeks: widespread imposition of impervious surfaces (roads, roofs) had led to a dramatic shift in stream hydrology: violent, erosive storms during rainfall events and a near-total decline in stream baseflow in the periods between storms. The older age of the surrounding development meant that virtually no structural water quality—or even flood detention—controls had been built during the watershed’s buildout. This fact depressed virtually all water quality scoring indicators, such as aquatic life support and riparian habitat.

Therefore, the project engineer began to investigate whether hydrologically favorable locations existed to retrofit a pond type of water quality control to capture and regulate the release of stormwater. The GIS maps provided a wealth of information not only to determine the location of a pond but also view it in relationship to the other problems of flood and erosion. Figure 3 shows a close-up of the Zone of Influence area for the water quality project. In this case, the ZOI was directly adjacent to a localized flooding problem area to the east and a creek flooding problem downstream to the north. The map showed the best possible scenario: available land, owned already by the City of Austin, was available directly along the creek. (Most frequently, urban buildout in older areas has already developed the most favorable sites before they can be used for stormwater management.) The parcel was owned by the City of Austin's Electric Utility, and it drained approximately 30% of Bouldin Creek, including most of the headwaters. This was a most propitious find, and the project engineer immediately began working with the various groups identified by the mapping exercise.

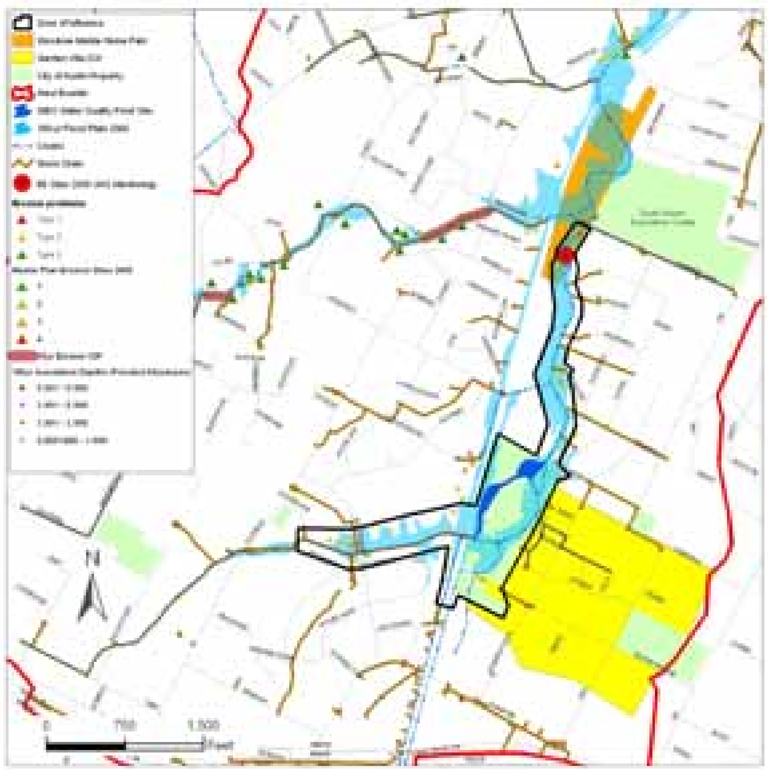

Figure 3. Zone of Influence for West Bouldin Creek Water Quality Project

The project manager first contacted the Electric Utility and arranged for the land to be transferred to the Watershed Protection Department. He then worked with the localized flooding engineers to plan for protection of creek banks and storm drain outfalls alike in the upcoming storm drain upgrade project. Conversations with the creek erosion engineers revealed that no buildings or infrastructure were directly threatened in the project area, but that the stream banks and channel through the reach were degraded and unstable. The project engineer thus incorporated a restoration project to stabilize the banks and remove invasive plant species from the riparian zone.

Next, the creek flooding engineers were consulted, who then examined the possibility of using some of the proposed pond's storage capacity to address peak flooding flows. The two groups collaborated on calculating the benefits. The main problems were those of the mobile home park downstream, and it was determined that the best solution with the highest flood relief benefit was a property acquisition (so no extra flood storage was required in the water quality pond). Meanwhile, an unrelated private development was proposed directly in between the proposed water quality pond and the mobile home park buyout, also along a major City of Austin park. A proposal was developed to link, via a greenbelt, the various public and private properties to provide both a permanent stream buffer and access for public recreation. Arrangements for these easements and facilities are now underway and appear promising. The resulting interactions with the private developer and area neighborhood association representatives also identified the need to undertake a major stream cleanup and trash removal project in the area.

In the end, the preliminary project identified a potential extended-detention biofiltration (bioretention) pond which could be built off-line (not in the direct path of the mainstem of the creek). Figure 3 shows this preliminary pond footprint. A schematic and photo of a bioretention are shown below. The project is slated to facilitate public access and education. The greenbelt connectivity will enable the area to be more easily and safely used by the public.

Schematic of Bioretention Facility

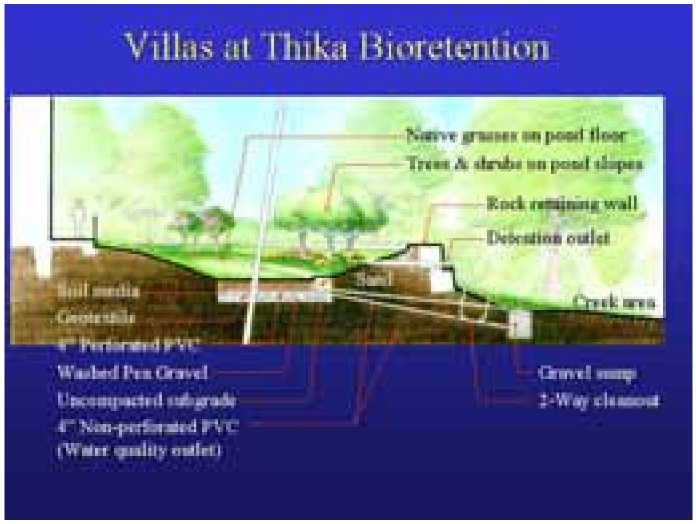

Photo of completed bioretention facility

In the end, the GIS mapping system devised for the project was useful on several levels. It combined an otherwise unmanageable number of data inputs into a coherent, visually intuitive form. The project engineer was able to interpret and address information from all four departmental missions as a result. The maps were also used extensively to guide creek field work for the project. In the course of this work, both the limitations of some of the map layers (features missing, features indicated but not present, etc.) and challenges to GIS implementation (how to best accommodate a large volume of new field data) became evident. However, both challenges will serve to better focus staff time and energy for future data collection efforts, and are relatively straightforward to address. .

We are now examining ways to better structure our monitoring and collection efforts. In all, the actual use of the data in GIS reveals the strength of its spatial presentation.

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