USING GIS TECHNOLOGY IN THE DEVELOPMENT AND MAINTENANCE OF A STORMWATER UTILITY(1)

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ABSTRACT

Many applications using Geographic Information Systems (GIS) technology exist today. From facility mapping to inventory management, from land use analysis to trash collection routing, GIS technology is enhancing the ability of government agencies to provide services to its citizenry. At times though it appears as if the technology has outpaced the ability of individuals to design uses for the technology in a cost-efficient and cost-effective manner. At others times it appears as though there is a rush to acquire the latest technology before a clear and well-defined use for the technology has been developed. This article is intended to present a study in the development of a stormwater utility, as a funding mechanism, and illustrate but one government application using GIS technology.

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1 Reproduced with permission, the American Society for Photogrammetry and Remote Sensing. Brown, Dirk S., Using GIS Technology in the Development and Maintenance of a Stormwater Utility. GIS/LIS Annual Conference Proceedings, 1997.

This paper outlines the process the city of Columbus used in developing a stormwater utility. It sketches why there was a need for a utility, how the utility was developed, and how the utility is currently being maintained. Both the development and maintenance aspects are addressed with specific reference to the role GIS technology played in the process. It highlights how automated mapping alone is insufficient to track, manage, and analyze attribute data. It demonstrates that tabular data is easily accessed through relational database systems while the graphics can be maintained through computer-aided drafting packages. In turn, it outlines how both the graphics and non-graphics data can be linked through customized routines and programs. Such application development lends itself to meeting business-critical needs.

BACKGROUND:

Before proceeding to the particulars of how GIS technology was brought to bear on providing a public service, a brief summary of events surrounding the development of a municipal GIS application is in order. In October, 1990 the Federal Environmental Protection Agency (EPA) promulgated regulations which required municipalities, with populations greater than 100,000, to apply for a National Pollutant Discharge Elimination System (NPDES) permit in two parts. Part One, to be submitted by November 1991, required the following items: (1), general information; (2), description of legal authority; (3), pollutant source identification information; (4), discharge characterization; (5), field screening for illicit connections; and (6), outline of resources to complete Part Two. Part Two, to be submitted by November 1992, required the following items: (1), quantitative sampling data; (2), conventional pollutant data; (3), stormwater master plan proposal; and (4), a fiscal analysis of projected Capital Improvement Project (CIP) and Operations and Maintenance (O & M) expenses.

The city of Columbus raised its stormwater fee by approximately 180% in 1991. These additional monies were used to fund compliance with the EPA permitting process. Because the time line for compliance was short, the city opted to maintain its then current method for generating revenues on sanitary sewer consumption as measured by a water meter. Since this method bore no relation to the problems associated with stormwater runoff, the Department of Public Utilities committed to reviewing the available methodologies and selecting an equitable one.

After review, the city of Columbus, Department of Public Utilities, Division of Sewerage and Drainage (DOSD), opted to develop a new rate structure by which to charge for stormwater services. The adoption of the new rate structure evolved through two phases of development: Phase One, the stormwater utility conceptualization phase; and, Phase Two, the stormwater utility implementation phase. The most critical aspect of the first phase was the selection of an appropriate rate structure from among the alternative rate methodologies.

STORMWATER UTILITY DEVELOPMENT:

DOSD chose the so-called impervious area methodology as its basis for charging for stormwater services. A methodology was selected which created a two-tiered rate structure. In the first tier, a flat fee was assigned to all single-family residential properties within the corporate boundaries of the city of Columbus. Presently, the rate is $1.64 per ERU per month (an ERU is a billing unit that stands for Equivalent Residential Unit and equates to 2,000 square feet of impervious area - the statistically-defined average of impervious area on a single-family residential piece of property). The second tier of the rate structure assigns a calculated fee to non-single-family residential properties based on the actual amount of impervious area (defined as, but not limited to, asphalt, concrete, blacktop, and rooftop) on individual properties. (See Table 1 for an example of how stormwater fees are calculated).

Table 1
Stormwater Fee Calculations

Formula : [Impervious Area(variable)/2,000(sq ft constant)] = ERUs(rounded to whole number) x Daily Rate($0.0818) x Days in Billing Period(varies) = Bill
Residential: (2,000/2,000) = 1 x $0.0818 x 91 = $7.44 per quarter
Non-residential: (26,895/2,000) = 13 x $0.0818 x 31 = $32.97 per month

As the competition for scarce public resources increases, it is imperative that municipalities provide the most efficient and cost-effective dispensation of services possible. In line with that belief, the city of Columbus opted to apply GIS technology to the development of a stormwater utility. The city broadened the concept of automated mapping to include an inventory of impervious areas. The city discovered that there are five crucial components to the successful implementation of the impervious area methodology. First, properties with impervious area must be identified; second, the area on the identified properties must be measured; third, the measurement of the area must be assigned to a billable account; fourth, a calculated bill based on the area must be generated; and fifth, the charges must be collected.

The last couple of components pertain more to the mechanics of generating accounts receivables. Discussion of them and other accounting functions related to stormwater service billing will be left for a later date. For our purpose, we are more concerned with talking about the role GIS technology had in aiding the city with the first two components. It should be noted, that the most efficient implementation of GIS technology would also include a discussion of the third component. However, linking the GIS with a real-time billing system database poses questions of data integrity and maintenance that have not been completely worked out. Suffice it to say for now though, any evaluation of developing a stormwater utility, with the use of GIS technology, must account for writing records to an account, in real-time, for which the city is not prepared to generate a receivable yet (i.e., the digitization of a new build site plan may be completed before the actual construction of the site has taken place).

As there is a correlation between the amount of impervious area on a property and the amount of stormwater runoff the property generates, using GIS technology to measure impervious area allowed for the development of billing system which was easily understood and readily maintainable. The measurement of impervious area represents a critical component of a municipal GIS application designed to enhance the delivery of municipal services. One of the criteria which the city used to evaluate which rate structure was most suitable was ease of implementation.

The availability of technology which allowed for an automated measuring process facilitated the development of an accurate and equalized fee structure. Using digitization tools allowed the city to calculate impervious areas with a high degree of accuracy. This accuracy further strengthened the legitimacy of the rate structure. Current processes in place in Franklin County allowed the city to extract the greatest amount of benefit from existing systems. Implementation was furthered eased by the fact that Franklin County had already invested much in the development of an electronic basemap.

IMPERVIOUS AREA MAPPING:

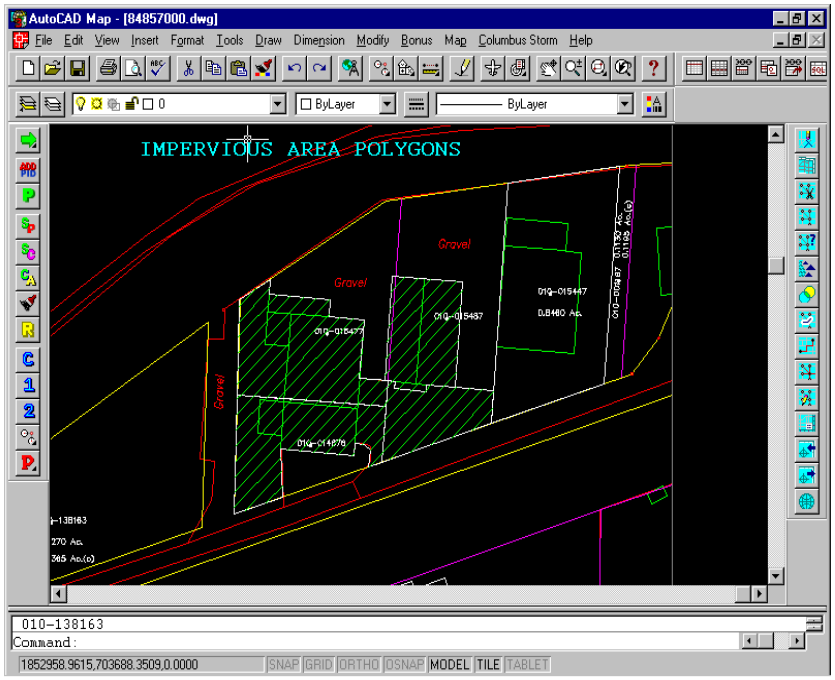
One of the critical elements of a viable stormwater utility is the development, and continued maintenance, of a master database containing all the records of non-residential properties' impervious areas. DOSD decided to develop an automated mapping system which would archive all non-residential impervious areas within the corporate boundaries of the city of Columbus. Again, this decision was aided by the availability of geographic information from Franklin County's GIS development process. As properties are developed, and redeveloped, updating of the billing records is essential. It is less efficient to store hard copy records in and retrieve the information from flats files, than to access an automated system whereby data can be quickly recalled, evaluated, and reproduced.

The measurement process entailed the following: (1), the utilization of the Franklin County GIS basemap; (2), the identification of non-residential properties; (3), the adoption of an automated mapping system; (4), the development of computer routines and programs to generate customized screens, reporting tools, indexing scripts, security mechanisms, and editing functionality; (5), the translation of county and city data into utility-specific data; (6), the incorporation of new development, redevelopment, and annexation plat map information; and (7), the digitization of non-residential property data.

At the same time that Franklin County was moving to unveil its GIS to the public, the stormwater utility was able to use the rectified aerial photographs produced for the County, and the basemap produced for the County to begin the city's process of measuring impervious areas. Although the city bore a cost to obtain useable copies of the data, the city was able to save enormous expense by not having to fly the county again and digitize the planimetric data all over. Further, utilizing cadastral features like parcel boundaries, which were already reconciled for the county in developing its base map and digitized, saved much time and effort in getting the utility implemented.

Identifying non-residential sites was easy once a decision had been reached as to what constituted such a site. Using the county's appraisal code system, we were able to color code all non-residential properties and digitize only those sites that matched the identifying criteria. Consequently, the maintenance issue of keeping track of all sites that had porches, or garages added and the cost-inefficiency of tracking that work was avoided. (See Panel 1 for an impervious area polygon.)

Panel 1



MAPPING SYSTEM CONFIGURATION:

Since it was recognized then that the city as a whole would be moving to a comprehensive GIS involving inter- and intra-agency cooperation some time in the future, the stormwater utility had to position itself to migrate, if necessary, to a fully functional GIS while maintaining its position of having current cadastral, planimetric, and attribute data. This problem was addressed by selecting an AutoCAD-based GIS mapping system. The graphics are stored in AutoCAD while the non-graphics are stored in FoxPro. A link is established between the two software packages with LISP routines and .PRG programs. Customized screens and menus were developed for both.

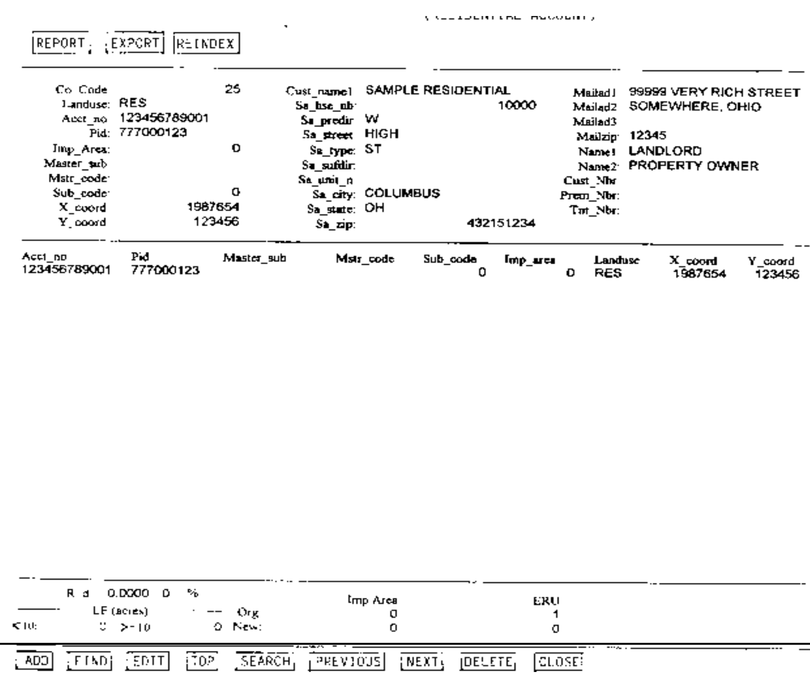
Since a city-wide GIS was not yet developed , we decided to install an electronic data interchange program (EDI) that allows us to update our non-graphic records on an as-needed basis. The attribute database is comprised of two tables (the city table stores unique attributes like customer name, billing address, and account number while the county table stores unique attributes like owner name, tax duplicate mailing address, and X/Y coordinates associated with the parcel and the state plane coordinate system) and with their index files take up approximately 250MB of a dedicated drive. In both AutoCAD and FoxPro, customized menus and screens have been developed that allow users to view selected data from the tables. The stormwater utility has also implemented a credit program whereby qualifying non-residential property owners can receive a discount in the stormwater service fee. A specialized program was developed which allows us to track the discounts received, whether they are basin or channel related, and by how much the bill goes down.

Although this does not paint a picture of a true GIS, we still have much of the functionality associated with one. We are still able to perform complex queries and through SQL statements automate much of our attribute data replacement processes. Further, with inter-agency agreements forged within the city, we are able to secure constant updates and ensure that our tables are current. We have installed limited access to the drives that hold the data and have security procedures in place that limit the type of editing access one has. We can produce reports from the screen and export the data to different file formats (e.g., .XLS or .WK4. Some parameters that are written into the application are variables like the rate or the square feet equivalent of an ERU. These parameters can be edited through limited, secured-access, procedures. (See Panel 2 for an example of a customer maintenance screen that allows for attribute tracking.)

In this environment, data was converted into .DBF tables and .DWG files. The layering scheme that was developed was a short list of all the layers available from the county. It omitted layers that contained topographic data like contours. An important part of the development process was recognizing the limits of the application and not trying to maintain too much data. Once a fully functional GIS was being conceptualized, then discussion could be held as to the responsibility of accessing and maintaining the multitude of layers or entities.

Panel 2
Customer Inquiry/Maintenance Screen

IMPERVIOUS AREA MAPPING MAINTENANCE:



An essential activity of the impervious area mapping application, is the daily maintenance required to incorporate new development, redevelopment, and demolitions. The permitting process of the city requires that developers submit site plans for review and approval. The city has specific drainage requirements for all sites. As part of the maintenance process, and in order to ensure we operate as efficiently as possible, a three-pronged process, incorporating graphic data, has been implemented. First, all potential new developments are required to have a certified address in order to apply for a building permit. The Engineering and Construction Division of the city (ECD) requires all developers to submit all multi-address sites in digital format (AutoCAD). We have forged an inter-agency agreement with ECD that gives us a copy of the same plans. Second, all new site developments require drainage plan approval. As part of DOSD's drainage approval process, we have stipulated that all developers submit an electronic copy of the site plan, along with the hardcopy. Finally, once a site is permitted we get a hardcopy of the site plan from the Division of Regulations. We digitize the impervious area from one of these three sources.

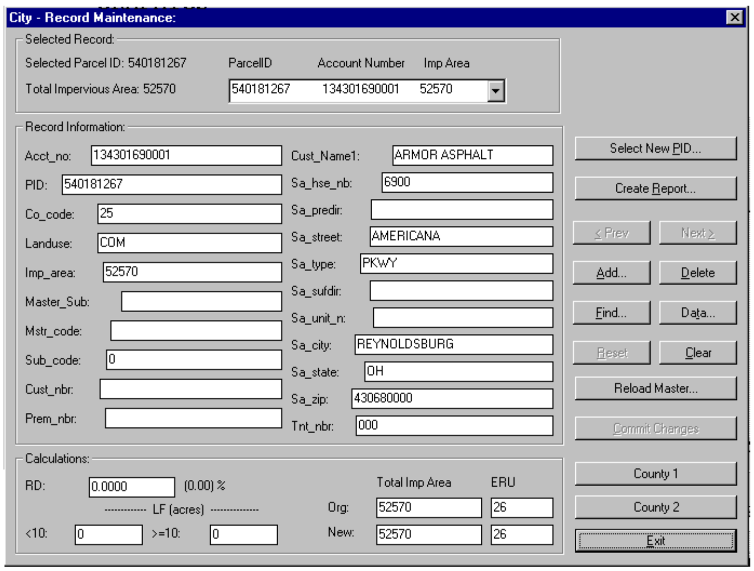
The storage and maintenance of graphic depictions of impervious areas is conducted through a process of digitization (i.e., the computerized plotting of points and the calculation of areas within those points). A separate layer consisting of impervious area polygons was added to the database. This layer is in addition to the layers dedicated to buildings, parking lots (non-gravel), private drives, roads, rights-of-ways, sidewalks, parcel boundaries, corporate boundaries, and consolidation boundaries (a polygon which groups parcels and/or accounts that are billed to the same account). Although we primarily are concerned with impervious area features only, the lack of a city-wide dedicated GIS forces us at times to incorporate and digitize public roads, streets, and rights-of ways.

In order to digitize the site properly, if the plan that was being used was in hard copy format, we have to calibrate the digitizing tables first. If parcel boundaries are on the site plan and have not changed, we can calibrate the digitizing based on three points of the plan. However, where significant parcel splits have taken place (e.g., farm land purchased and then subdivided for further development), we may have to digitize the roads, etc ... first in order to establish reliable control points from which to digitize. This is made possible through an agreement with ECD to furnish us with right-of-way dedications when necessary.

In those instances where the plans are not available, we have instituted a process whereby we can extract necessary graphic data from quarterly-issued CDs, obtained from Franklin County's GIS Division, and update our basemap accordingly. With a LISP routine, we are able to add parcel centroids to our basemap. We can then use another LISP routine to create the impervious area polygon and write the calculated area to a .DBF file. Another LISP routine will create a running total of area attached to individual polygons (e.g., buildings of an apartment complex) and hatch the area simultaneously. These processes are further automated by accessing them through a customized pull down menu. (See Panel 3 for an example of a customized menu option that displays attribute data connected to a parcel centroid. The attribute data is displayed after clicking on the centroid.)

PANEL 3

PARCEL ATTRIBUTES ATTACHED TO GRAPHICS



Further automating and enhancing our process is our ability to use the agreements forged between engineering firms, other city agencies, and us to submit site plans in digital format. With digital copies of sites, we are able to bypass the effort of digitizing the building footprint and other planimetric data first. Rather, we can import the plan and proceed to create the impervious area polygons for the subject site.

Typically, we are able to secure the impervious area calculation long before the subject site is actually constructed and ready to be charged a fee for stormwater services. A mechanism we use to alert us to when an account should begin being billed is when the water meter is installed and set. Administratively, it would be cost-inefficient for us to monitor each non-residential site to ascertain its stage of development. The point of this discussion is to make the reader aware of a potential hazard when attempting to utilize the GIS technology completely.

Obviously the impervious area calculation can be written to whatever field or table than can sustain a relational database link. However, we do not wish to charge the customer prematurely. Consequently, we still use manual updating as part of the impervious area mapping process - namely, the placement of the calculated area to a billable field and the insertion of a code that will prompt the bill to be generated in proper cycle.

The initial digitization process employed on existing developments relied on the ease of using the GIS technology to distinguish between impervious and pervious surfaces. Having different layering schemes for each type of entity allowed for an efficient digitization of existing structures. Supplementing this tool with aerial photographs, prepared at similar scale to the drawing files, allowed for photogrammetric analysis to be conducted to distinguish between graveled and non-graveled surfaces.

CONCLUSION:

The availability of GIS technology has allowed for the development of a municipal GIS application that speaks directly to the needs of today. Stormwater management can be conducted effectively because there is a reliable funding source available. Capital improvement projects can be undertaken and continued maintenance can take place because monies are available to pay for the projects. GIS technology has allowed for an equalized fee structure to be developed. The minimization of customer complaints, resulting from a consistent measurement process, represents an enormous savings in public goodwill and enhances the delivery of public service. Many applications are being considered today. The development of a stormwater utility, with an accurate and equalized fee structure, reflects but one application of the technology.