THE PERSONAL GEODATABASE AS A BMP FOR STORMWATER MANAGEMENT

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ABSTRACT

NC State University implemented the use of GIS for urban forest inventory and management in 1997. Since that time other University departments have taken advantage of GIS as a tool to effectively manage operations for both the natural and built environment.

As the scope and use of GIS technology progressed over the past 10 years, so has development of campus infrastructure. Due in part to a University bond package passed in 2000, NCSU has 40 major construction projects slated through 2009. These new buildings bring new sources of runoff and loss of green space; both requiring construction of additional stormwater management components to efficiently and effectively manage water quality impacts. State and Federal laws mandate water quality protection through stormwater management practices. In response to this mandate, NCSU has a MS4 permit encompassing 2,110 acres of intensively managed urban landscape. In 2005, NCSU Environmental Affairs began GIS development for the campus stormwater system.

Base design for this system was the development of an ESRI geodatabase. Design guidelines included:

1. Use of personal geodatabase to simplify implementation but allow for multiple users.
2. Enable database connection to construction management system for immediate use in stormwater structure inventory, including links to ancillary documents.
3. Design for future uses such as modeling water movement through the system and pollutant removal within the network of treatment areas.
4. Ability to integrate spatial and tabular data with other campus departments and local agencies.

If done correctly, the geodatabase becomes a BMP for the stormwater management system.

KEYWORDS. Geodatabase, stormwater, BMPs.

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INTRODUCTION

NC State University (NCSU), a land-grant institution founded in 1887, has a main campus comprised of 2,110 acres in Raleigh, NC. Like many urban universities it is growing rapidly, as is the city that surrounds it. In 2000, the citizens of North Carolina passed a bond package for the University of NC system for major renovations and new building construction on each of the sixteen campuses. Consequently the NCSU campus now has 40 major construction projects slated through 2009. Currently six projects are complete and sixteen are in progress (NCSU Facilities Division, 2006). These new buildings bring new sources of runoff and related losses of green space that require development of additional stormwater management systems. This paper explores the use of a GIS to design and manage the stormwater system.

The project study area is the main NCSU campus located in southwest Raleigh (Figure 1). Raleigh, a city of over 300,000 people (City of Raleigh, 2006), is the State Capital and home to five universities. NCSU is the largest university in the city and operates its own municipal storm sewer system. Like other government agencies, the university must adhere to Clean Water Act requirements to protect water quality. The NC Department of Environment and Natural Resources, Division of Water Quality (DENR, DWQ) is the permitting agency that monitors compliance with the Clean Water Act's National Pollutant Discharge and Elimination System (NPDES). NCSU has a permit for NPDES and falls under the requirements of the Phase II Small Municipal Separate Storm Sewer System (MS4). The NCSU Office of Environmental Affairs has developed a stormwater management program in accordance with the requirements of its current NPDES and MS4 permits. The goals of the Stormwater Management Program are (NCSU Stormwater Management, 2006):

- To the protect health and safety of the environment, the campus population, and the general public;
- To address both stormwater quality and stormwater quantity concerns; and
- To meet or exceed federal and state requirements regarding stormwater.

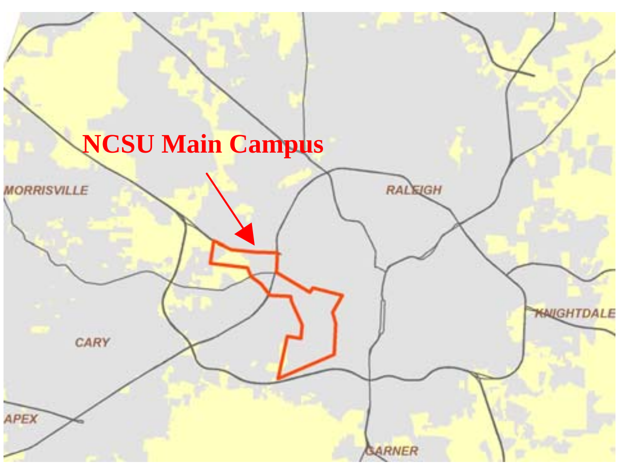

Figure 1. NCSU Main Campus located in southwest Raleigh, NC.

GIS on Campus

The use of Geographic Information Systems (GIS) has been in place in the classroom and research programs for over 20 years at the University, but only put into operation for facility and resource management during the past 10 – 15 years. NCSU Transportation, the Facilities Division, Grounds Management and the Campus Police department actively use GIS to inventory and manage resources. In 1997 Grounds Management began development of an urban forest spatial database by converting existing AutoCad files of campus and a Paradox database of the campus forest tree inventory into a seamless GIS. The resulting system continues to grow and improve as a management tool for maintenance of the urban forest canopy and landscape areas. This project is an effort to interconnect the stormwater program with the landscape GIS and facilities management CAD system.

METHODS

In the fall of 2005 the Division of Environmental Health and Public Safety, Office of Environmental Affairs, began a process to inventory campus stormwater system structures. Through a service agreement, the Center for Earth Observation (CEO) in the College of Natural Resources agreed to work with the Stormwater Program staff to build the GIS to support this inventory. The CEO staff hopes to use the results of this project as a model to assist other agencies with implementation of similar GIS applications.

A primary goal of the project is to demonstrate compliance with the MS4 permit and with the Neuse River Basin pollutant reduction requirements (NC State University, 2006). The Stormwater Management program developed a *Stormwater and Nutrient Management Guidelines* publication as part of the permit requirements. This plan outlines guidelines to minimize adverse impacts of stormwater runoff during construction and post development. To do so, best management practices (BMPs) for nutrient reduction are put into place for projects that disturb greater than 0.10 acre (NCSU Stormwater Management, 2006). BMPs are the major components of the stormwater system. Long term GIS objectives are to build a storm sewer system network documenting pipelines, outfalls and BMP treatment units to measure the effects of the system on water quality. This spatial and tabular data framework also provides a system to track maintenance of system components, record corrective actions, monitor pollutant reduction techniques and test functionality. The GIS is part of the documentation system and one of the evaluation tools outlined in the performance measures of the Stormwater Management plan.

Needs Assessment and Data Model Analysis

A data layer inventory and needs assessment were conducted prior to design and deployment of a campus stormwater system GIS. Spatial data layers from NCSU Campus, the City of Raleigh, Wake County and the State of North Carolina were all evaluated for use in the new system. Table 1 summarizes the spatial and tabular data needs for the stormwater program.

Due to its use by other campus departments and cost savings through the University's site license, ESRI's ArcGIS is the chosen software for this project. After assessing data needs, pros and cons for each of the two types of ESRI geodatabase models were evaluated. A geodatabase is structured for use with relational database management systems (RDBMS), allowing users to keep, or build, tabular databases in other software formats, such as MS Access or Oracle then

Table 1. Spatial and tabular data needs assessment.

Parcel Stormwater System – Data Needs	Availability
Parcels: (area surrounding construction or redevelopment projects)	No – described only on hardcopy stormwater plan
Treatment Units (BMP Type): Devices to remove nutrients from stormwater on each site	No – visible on orthophotos for most areas (does not include recent additions)
Outfalls: Devices that transports stormwater off the parcel site	No – visible on orthophotos for most areas
Connections / Pipes: linear representation of water flow from and between devices into local waters or adjacent parcel.	No – knowledge from stormwater personnel, on plan documents
Impervious Surface: paved areas,	Yes – from City of Raleigh, but not up to date
Impervious Surface: building footprints	Yes – from NCSU Campus, but some discrepancies with new construction
Impervious Surface: walkways	Yes – from NCSU, but only as polyline showing walkway edge
Pervious Surfaces: remaining area within parcel	No – some visible from orthophotos
Related tabular information: Stormwater plan on file, maintenance requirements, nutrient removal data by BMP type	Yes – but some information not structured / formatted for use in GIS
Topography	Yes – most areas up to date with 2 foot contours from NC DOT
Orthophotography	Yes – 2004 color at 6 inch resolution (2005 released 6/06)

link that information to spatial data. Data from all sources is available for query and display in ArcMap. The personal geodatabase model is simple and ready to implement out of the box. The multi-user geodatabase requires more software and hardware to deploy, but is more robust in editing and data management capabilities. Table 2 outlines the basic differences between the two geodatabase types (ESRI, 2005).

Design Guidelines

Database design guidelines were established after careful review of project goals and evaluation of gaps in spatial data availability. As a result the project was divided in two phases: data development and network connections. The initial phase is focused on data development to create both spatial features and tabular records for components that make up the stormwater system. The second phase of geodatabase development will focus on creating a network to connect the components documented in phase one.

Table 2. Comparison of geodatabase types.

Geodatabase Type	**RDBMS**	**Comments**
Personal Geodatabase	Microsoft Jet Engine (Access)	Multiple Users (view) Single User Editing Size Limit: 2 GB Versioning not supported
Multi-user, or versioned geodatabase	Oracle Oracle w/ Spatial or Locator IBM DB2 IBM Informix Microsoft SQL Server	Requires ArcSDE Supports – multi-user editing – versioning Size Limit: file size and number of users dependant on RDBMS in use

Guidelines for design and development of the geodatabase are threefold:

1. Enable database connection to the campus construction management system for immediate use in the inventory of stormwater structures including links to access ancillary documents
2. Design for future expansion and uses such as modeling water movement through the system and pollutant removal within the network of BMP treatment areas such as bioretention areas, infiltration basins and wetlands.
3. Provide ability to integrate spatial and tabular data with that from other campus departments and/or local and state agencies.

RESULTS

Due in part to the cost of additional hardware and the software requirements of a multi-user geodatabase, the personal geodatabase model was selected to develop the stormwater system GIS. With only two Stormwater Program staff members designated to work with the GIS, the personal geodatabase is suitable for the project editing requirements.

Phase one priorities are to develop data layers representing parcels, BMP treatment units, outfalls and on parcel streams. Set up as the Parcel Stormwater System (PSWS) geodatabase, we designed a framework, or template feature dataset, allowing staff members to develop each of the new layers using existing spatial data as a backdrop or reference layer. Table 3 lists the background spatial data layers and new feature layers making up PSWS Geodatabase design project.

Data Development Process

One goal in the GIS design was to provide easy methods for data entry as staff entering the data has little GIS training or experience and will use the software on an infrequent basis. Data entry procedures that include drop down menus or look up tables for attribute edits greatly improve efficiency in the data development process. By design, a RDBMS offers these types of editing and data maintenance techniques. The relational database capabilities of the geodatabase model automate data entry methods that, in earlier GIS data models, often required custom scripts.

Table 3. Final data layers.

Existing Spatial Data: Background / Reference Layers	**PSWS Data Development**
NCSU Campus Basemap:	Feature Dataset
– Paved areas (polyline)	– Parcel (polygon)
– Building footprint (polygon)	– BMP treatment unit (polygon)
– Campus walkways (polyline)	– On parcel stream (polyline)
– Athletic fields / courts (polygon)	– Outfalls (point)
– Hydrography (polyline – city planimetrics)	Tabular Data
– Topography (polyline – NC DOT)	– BMP information
City of Raleigh:	– BMP maintenance tasks
– 2004 Orthophotography / 2005 available 6/06 (Raster – 6 inch resolution / true color)	

As previously stated, the data development process for the stormwater system involves "heads-up digitizing," or drawing on screen, using the existing data as background reference layers. The BMP treatment unit components, a polygon feature geometry defining unit boundaries, are the predominant structures for inventory and include attribute information describing BMP function. The feature layer was designed using the stormwater program's 14 types of treatment units for nutrient reduction, each representing a subtype in the treatment unit feature layer:

- No treatment
- Extended detention wetland
- Pocket wetland
- Pond / wetland system
- Wetland detention basin
- Extended dry detention basin
- Bioretention area
- Grassy swale
- Riparian buffer
- Filter strips / level spreaders
- Infiltration devices
- Open sand filters
- Closed sand filters
- Manufactured devices

In addition to streamlining data structure and adding indexing functions, the subtype value allows easier attribute editing when adding features on screen. For example, when creating new features for the BMP Treatment Unit layer, a drop-down list permits the user to easily select unit type (Figure 2).

The values (subtypes) for the BMP layer are automatically populated in the attribute table, thus reducing editing time and eliminating later problems such as misspelled words. All other feature attributes are manually entered from the hard copy stormwater plans.

Since each BMP treatment type has a standard set of characteristics associated with nutrient removal, a simple table containing BMP standards was also added to the geodatabase. This "lookup" table lists each of the fourteen BMP types, as coded in the spatial layer, and includes

Figure 2. Drop-down list showing BMP subtypes during ArcGIS edit session.

additional attributes listing nutrient removal and water quality values for each. As a many-to-one relationship, this attribute table may be joined to the BMP spatial layer for the user to view and query. Table relationships are yet another method to improve editing quality and simplify database maintenance. For example, as technology changes, so will best management practices for water quality. If a new BMP is put into use, or values associated with nutrient removal are modified, the geodatabase information may easily be updated, requiring only edits to the informational table rather than editing each spatial feature that contains a particular attribute.

<u>Geodatabase Organization</u>

In designing the geodatabase, it was quickly determined that two geodatabases were needed in the organizational structure. Existing data layers that make up the campus basemap are subject to frequent updates by the Facilities Divisions. Similarly, frequent updates by Wake County and the City of Raleigh are outside the control of the Stormwater or CEO staff.

Project data were organized in two separate geodatabases; MainCampus and PSWS. MainCampus includes data layers outside edit control of the Stormwater program such as NCSU Facility data for campus buildings and paved areas as well as a raster catalog dataset containing orthophotography from the City of Raleigh. Much of this information is updated on an annual basis. The two geodatabase design allows for data outside the control of the Stormwater Program to remain separate but easily accessed and updated in a manner seamless to the Stormwater staff. The PSWS geodatabase remains in their control for editing to maintain data integrity (Figure 3).

DISCUSSION

The personal geodatabase simplified setup and deployment for this project, but presents limitations in utilizing full capabilities of the relational database. Even though the staff entering and updating data is small in number, the absence of versioning capabilities causes concern for maintaining data integrity. While the personal geodatabase model does not permit versioning, or data checkout, it does restrict editing to one user at a time by placing a "lock" on editing when the geodatabase is in use by another. Even so, strict procedures are followed when editing and/or updating a geodatabase on the server.

New spatial and tabular data may be added to the PSWS geodatabase as components are placed in the system. Currently, a related table referencing maintenance tasks associated with each treatment unit type is under development. Once spatial features representing treatment units

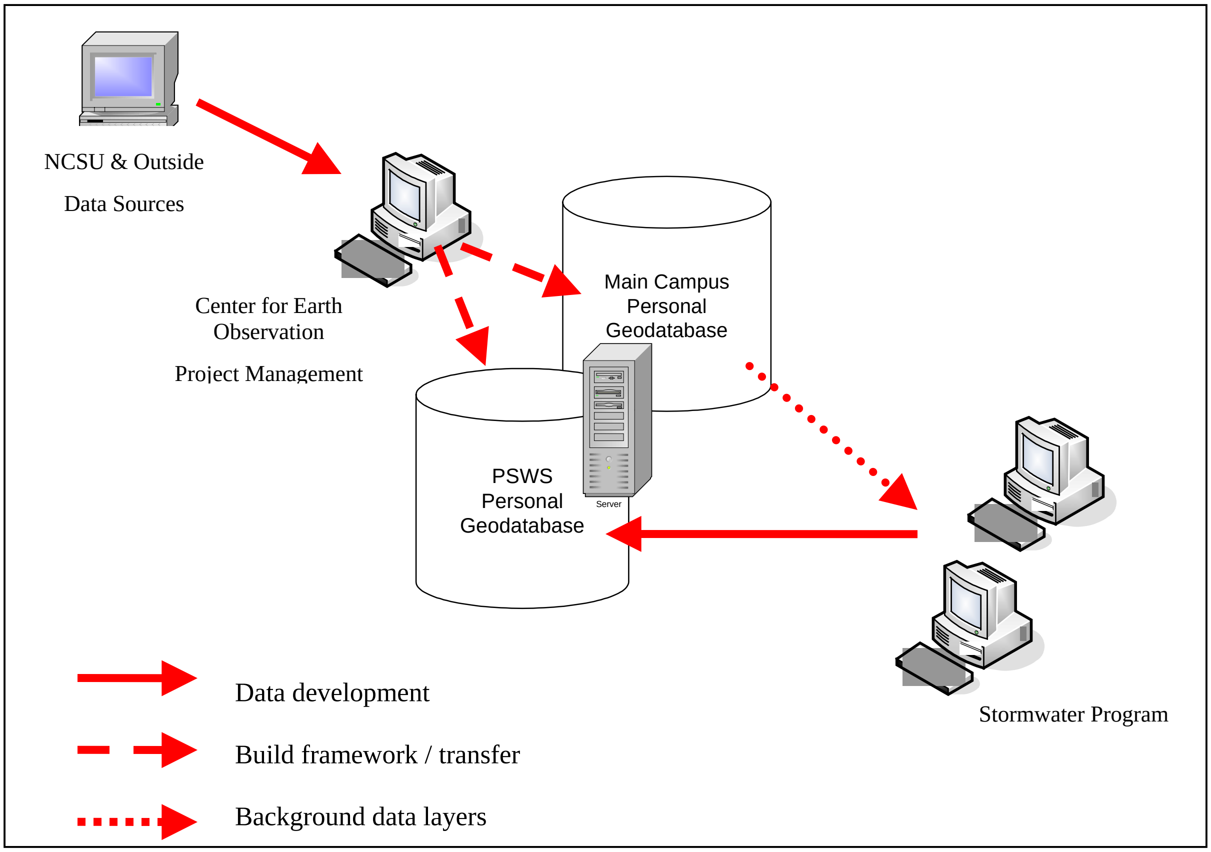

Figure 3. Geodatabase organization and data flow for PSWS.

(system inventory) are complete, a new feature dataset representing the schematic network connecting treatment units to outfalls and outfalls to stream or neighboring parcels will be added as a geodatabase dataset. Additionally, design of the PSWS personal geodatabase allows for future upgrade to an ArcGIS geodatabase. The upgrade will require server with ArcSDE installed and system IT support to assist in hardware management matters. The ArcGIS geodatabase structure will improve data integrity and dramatically increase the capability of expanding the relational database system.

As data is developed for the Stormwater system it may be shared for viewing with other campus GIS users. NCSU Campus GIS Users include the Campus Police, Transportation, Grounds Management and now the Stormwater Management program. Representatives from each of these departments, the CEO and the NCSU Library Geospatial Data Services group meet regularly with Facilities Management to discuss and coordinate data collection efforts. This coordination of efforts ensures newly created data aligns with the campus basemap of buildings, streets and sidewalks. As a result, Grounds Management staff may utilize stormwater system locational data to dictate staff assignments in completing proper maintenance for stormwater system structures. This too is part of the water quality monitoring system and performance measures outlined in the Stormwater Management Plan. An accurate stormwater system inventory becomes fundamental in planning maintenance and management tasks, monitoring compliance with state and federal mandates, or even reporting to first responders in case of chemical spill emergencies.

CONCLUSION

Besides the rapid loss of green space, the related water quality impacts of road and building construction demand an efficient and effective tool to assist with natural infrastructure management on campus. Proper facility and resource management not only enhances campus aesthetics, but protects water quality. Documenting compliance with water quality requirements for federal and state monitoring agencies can be greatly augmented through implementation of a GIS. An easily accessible inventory showing BMP structure locations, linking to nutrient removal information and evaluating system success are but a few of the details managed through this GIS. As this land-grant University has a responsibility to demonstrate proper stewardship of its natural resources, effective tools to monitor and report such activities in a simple manner is essential to remain in compliance with stormwater permits.

The techniques used to build this GIS and results that are still forthcoming are examples of the University at work in its extension and engagement mission to develop learning partnerships as well as further education opportunities for the greater community. As the City of Raleigh and Wake County use GIS to manage infrastructure, protect resources and measure similar information, NCSU Grounds Management uses GIS to manage the urban forest, landscape areas and campus walkways. Campus Police also have a GIS in place to protect persons and property within the university boundaries. A well designed database management system is a best management practice and model in providing the ability to move data between these campus and non-campus departments and agencies for the most efficient method to manage man-made resources for protection of the natural resources.

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