IMPLEMENTING A GEOGRAPHIC INFORMATION SYSTEM FOR A RURAL WATER AND SEWER COMPANY: A CASE STUDY OF THE NEWBERRY COUNTY WATER AND SEWER AUTHORITY.

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ABSTRACT

This thesis details the implementation of a Geographic Information System (GIS) in the Newberry County Water and Sewer Authority (NCWSA). NCWSA saw a need to implement GIS to help capture knowledge from a long time employee and better manage and map their system. They were previously referencing paper as-built drawings when questions arose about their water distribution system. The objective of this thesis is to implement a functional GIS for NCWSA, while addressing their budget constraints. This research emphasizes the initial planning process, database design, data acquisition, implementation phases, and a pilot implementation.

The methodology used in the implementation is derived from previous literature and case studies involving GIS implementation, however, there are some differences in order to meet the needs of NCWSA. Through the pilot implementation, NCWSA has utilized the GIS on a daily basis. The GIS has aided in planning for future capital projects, providing accurate information to maintenance crews during line breaks, and reducing the time required to search for hard copies of as-built drawings, just to name a few. In conclusion, future planning and additions are addressed along with looking at new technology that may help distribute the GIS information to field crews.

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ACKNOWLEDGEMENTS

Thanks to the Newberry County Water and Sewer Authority for allowing me to use their organization as a case study. They were also instrumental in providing input during the data creation and sharing the existing data on file. I would also like to thank Tad Abraham from Abraham Land Surveying for providing data, facilities, and equipment during this project.

CHAPTER 1 INTRODUCTION

Small rural water utilities are charged with distributing water throughout a sparsely populated area and managing those distribution systems for infrastructure, maintenance, and analysis. One of the biggest challenges is managing information about maintenance of the existing infrastructure and construction of new infrastructure (Shamsi 2005). While this statement was directed toward big cities and larger utilities, it still holds true for the small rural utility company. Geographic Information Systems (GIS) provides the tools for water utilities to efficiently map and manage their assets (Vega 2009). Shamsi (2005) stated that GIS provides the ideal means of describing water and sewer infrastructure along with identifying problems, recommending solutions, and scheduling and recording maintenance activities. A GIS stores both attributes and images of pipes, valves, meters, manholes, and numerous other objects with spatial locations (ESRI 2007). GIS has therefore become a central tool used by water and wastewater utilities not just for mapping, but for improved management of their assets (Baird 2011). GIS can be used to more efficiently manage the distribution system during normal operation or during emergency situations.

While GIS allows managers and operators the ability to efficiently manage their water distribution, it also gives them the capability to maintain updated maps. Lyon and Clifford (2008) documented that current and accurate maps are critical to water districts operations, not only for maintaining infrastructure and providing decision making support, but also ensuring compliance with government regulations. Paper maps do not lend themselves as easily to frequent updates. Changes must be made in pen or pencil on the paper map and then the paper map must be reprinted on frequent intervals. GIS provides a comprehensive asset inventory and accurate mapping system for utilities (Lyon and Clifford 2008). Baird (2011) mentioned that GIS is needed for base maps, infrastructure and utility management, planning, demographic analysis, incident tracking and other uses. GIS allows utilities to maintain an up-to-date and accurate location of all assets while increasing operational efficiency and enhancing customer service. GIS enables water and wastewater utilities to make better decisions, reduce response time, and realize cost savings (Baird 2011).

Larger water utilities have well documented their implementation, use, and benefits from GIS. However, research can be hard to find for small rural water utilities that may not have the capabilities, personnel, or budget to spend on implementing a GIS. Rural water utilities like Newberry County Water and Sewer Authority (NCWSA) may be at a disadvantage to urban utilities when it comes to GIS. Burns and Kenny (2005) and Vega (2009) both referenced urban utilities that have the budget capacity to house and employ a GIS staff. While NCWSA does not have the budget to hire a GIS staff member, they recognized the need and benefits of a functional GIS. Small utilities have all the big-city needs to have access to accurate information, but don't have the same financial resources to build and maintain it (Harp 2009). One of the most important needs of NCWSA is to capture the knowledge of an employee who has been with NCWSA for twenty-eight plus years. This employee can probably locate ninety percent of the assets and identify their size and pipe material. While the NCWSA budget may not match those of urban water utilities, they can still benefit from the research that has been completed at the larger utilities.

RESEARCH OBJECTIVES

This study attempts to implement a geographic information system (GIS) for the Newberry County Water and Sewer Authority (NCWSA). NCWSA is a small rural water utility that has a limited budget allocated to GIS. The primary objective is to implement a prototype GIS for NCWSA in order to better manage their water distribution system. Secondary objectives include identify phases of implementation, analyze current data, digitize water mains, capture attribute data from paper maps and a long term employee, address hardware and software options, and implement a pilot GIS. When this research project started, NCWSA was using paper maps to manage their assets. They had previously tried to implement GIS before; however, that attempt was unsuccessful. Through this study, some of the issues that led to an unsuccessful implementation are addressed.

STUDY AREA

NCWSA maintains water and sewer infrastructure in Newberry County, South Carolina (Figure 1). Newberry County is located in the central piedmont region of South Carolina between the Broad and Saluda Rivers (Newberry County Chamber of Commerce 2002). It lies approximately one hour away from Columbia, the state capital. Newberry County encompasses 631 square miles and had a population of 37,508 people in 2010 (South Carolina Association of Counties 2011). Total population ranks 27th out of 46 counties, while the persons per square miles rank 28th with a value of 59.4 (South Carolina Association of Counties 2011). Newberry County is home to eight towns and cities which include: Chappels, Little Mountain, Newberry, Peak, Pomaria, Prosperity, Silverstreet, and Whitmire (Figure 1).

NCWSA does not operate over the entire county. Figure 2 shows the water and sewer lines throughout the county. Currently the sewer main data is not complete, but it does not exceed the boundaries of the water main data. The towns of Newberry, Prosperity, and Whitmire all manage their own water distribution system. NCWSA primarily focuses on areas in the county that would not have access to municipal water systems. Currently, NCWSA has 4,000 taps that serve approximately 10,800 people. There are approximately 325 miles of water lines that distribute potable water. The sewer system is smaller with 400 taps and service to approximately 1,080 people. There are approximately 75 miles of sewer lines, with 120 manholes and 35 lift stations (Richardson 2011). Figure 2 illustrates a distinct lack of water mains in the Northeast section of the county. Much of this area is owned by the United States Forest Service and is sparsely populated.

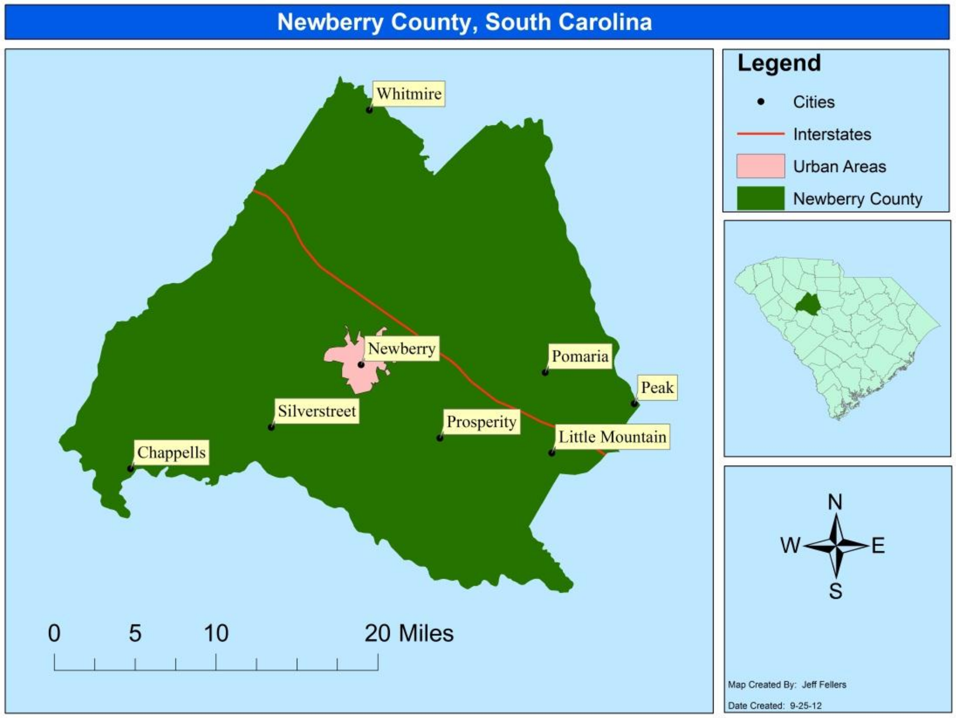

Figure 1 Study Area

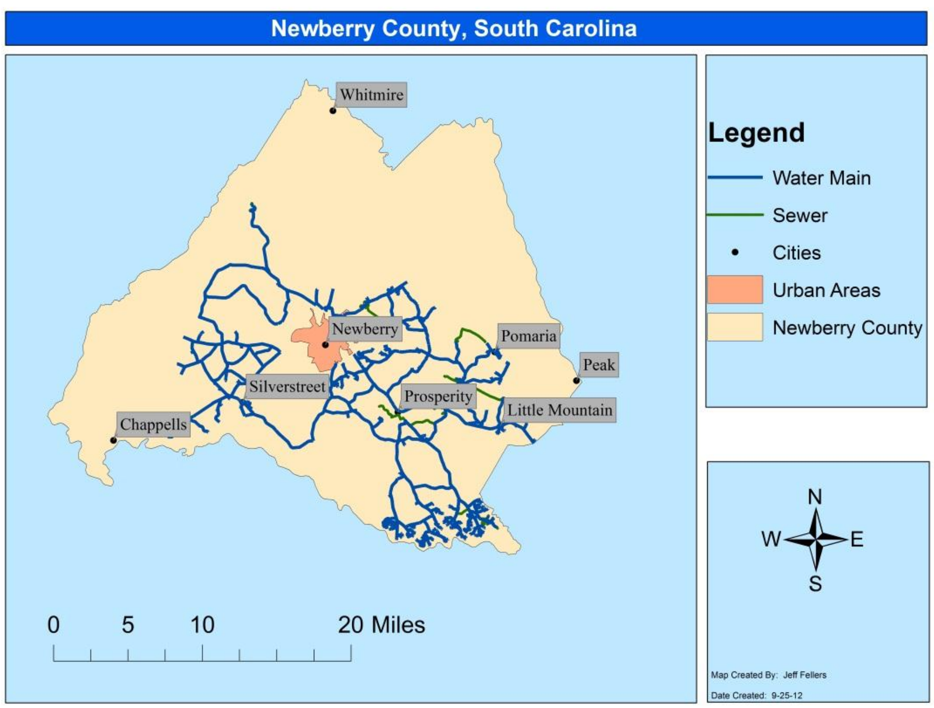

Figure 2 NCWSA Water and Sewer Main Distribution

CHAPTER 2 LITERATURE REVIEW

GIS APPLICATIONS FOR WATER UTILITIES

Applications are the driving force behind any technology. They are what enable that specific technology to be useful. GIS is no different; without applied use the technology is useless. Shamsi (2005) described an application as an applied use of a technology. GIS applications have the potential to enhance the management of water and wastewater systems. Water industry GIS applications that are of particular importance are mapping, monitoring, modeling, and maintenance (Shamsi 2005). While NCWSA may not use all the applications that a large water utility would use, it is still beneficial to document some of the applications that have been used by large and/or small water utilities.

GIS applications are numerous and really only limited to one's imagination (Shamsi 2005). However, typically applications for water related operations fall under database maintenance, access and query, facilities analysis, project tracking, and system interfaces (Cannistra 1999). Cannistra (1999) and Miner (2005) both listed numerous applications that would interest NCWSA during their GIS implementation. NCWSA could benefit from an updated facilities map and production of standard maps that Cannistra (1999) listed under database maintenance applications. This would replace NCWSA's outdated paper maps that they currently reference. In 2004, GIS database maintenance was also listed as the number one geospatial application in the water/wastewater industry (Miner 2005). NCWSA would also like their GIS to allow access and query applications. In these applications, Cannistra (1999) grouped querying customer billing data, generating mail list, and access assets inventory along with several others. Customer information must be accessible in the GIS database for most applications (Cannistra 1999). Linking the customer information within the GIS is an important consideration for NCWSA. Customer information can be linked in four ways: by building, by parcel, by meter, and by address (Cannistra 1999). Another key application that NCWSA is interested in is work order management. Work order management is important across the industry. It was ranked as the second most popular geospatial application in 2004, ranked second in 2003, and first in 2002 in top geospatial applications (Miner 2005). Water utility companies are asset-driven and rely on those assets to provide service at a minimal cost (Ray 1996). Maybe this is one reason work order management is so important throughout the industry. GIS applications provide industries the ability to save time and money along with integrating data and information into one manageable system (Shamsi 2005).

PLANNING PROCESSES FOR WATER UTILITIES GIS

The NCWSA is a rural water utility that does not have the resources to fully implement a GIS in the way a large urban or municipal utility may. However, there are some elements in the planning process that should be similar between the two. Vega (2009) documented several elements and goals from the City of Tampa’s strategic plan during the implementation of their GIS that are beneficial to all GIS implementations. The users were divided into four major groups which included engineers with management functions, engineers with technical functions, technicians, and administrative personnel (Vega 2009). NCWSA has only three groups, but keeps a similar structure of engineers, technicians and administrative personnel.

Vega (2009) provided a critical analysis of the GIS plan for the City of Tampa, Florida. The first step was to explain to users the possibilities of GIS applications so users would have an understanding of information products that were needed for their job in managing the water distribution system. Like the City of Tampa, many of NCWSA employees have very little knowledge of GIS, and in order for the users to provide useful input during a needs assessment, this is a step that must be included in NCWSA's plan. Vega (2009) listed the goals of the GIS strategic plan, and while all of the goals would not be obtainable for NCWSA, some are appropriate to consider. For instance, defining required resources and associated skills, establishing standard operating procedures, and evaluation are a few of the goals that NCWSA shares with the City of Tampa.

Tomlinson (2007) described ten stages that have evolved over planning large and small implementations in detail. The size and the nature of the organization determine which stages are the most relevant to the situation (Tomlinson 2007). Because NCWSA is a small water utility, it does not require the full ten stages. The stages that benefit NCWSA the most are conducting a technology seminar, describing the information products through a needs assessment, creating a data design, determining system requirements, and planning the implementation. Through these planning stages NCWSA can create a GIS that can help them manage their water distribution network in a more efficient manner.

The Ocean County's Strategic Plan presented by Shamsi (2005) provided detailed information on planning a needs analysis to help in the GIS implementation planning. Shamsi (2005) listed the following eight typical steps that are found in a needs analysis:

Step 1: Identify stakeholders - Identifying the stakeholders includes all the people who will utilize the GIS. No matter what the size of the utility, there will be stakeholders.

Step 2: Talk to stakeholders - It is important to establish formal communication methods to understand the needs of the GIS. Shamsi (2005) listed four methods that can be employed, which are introductory seminar, work sessions, focus groups, and interviews. Depending on size and budget the first three methods are optional; however, the last method is almost always necessary (Shamsi 2005). The interviews allow a number of selected stakeholders to identify the needs, uses, and requirements the organization has in mind for the GIS (Shamsi 2005). In the case of NCWSA, interviews are the most effective and efficient means of communications. Since NCWSA is a small utility, the interviews allow personal contact on a regular basis to ensure the vision and goals of the GIS are captured during the needs assessment.

Step 3: Inventory resources – Inventories of the GIS related resources such as maps and drawings, spatial and tabular data, databases, IT resources, and the staff skills and interests help describe the as-is condition of the organization (Shamsi 2005). While NCWSA may not have all of these assets, it is important to research what is available and may be useful during the implementation process.

Step 4: Establish need priorities – Shamsi (2005) stated that it is not feasible to implement a large number of applications simultaneously, so the needs should be prioritized. Organizations that are paying for the GIS want to see a return on their investment (Shamsi 2005). NCWSA is no different and they want something that can benefit their utility rather quickly.

Step 5: Create system design – System design encompasses mapping, database, software, hardware, and user interface. Shamsi (2005) stated that approximately 75% of typical GIS costs are related to data conversion and creation. Since NCWSA has a limited budget, it is important to minimize this process to get the most out of their budget.

Step 6: Conduct a pilot project – The pilot project allows an organization to test a strategy before committing to an implementation (Shamsi 2005). Through this process an organization should be able to evaluate the GIS design and determine if it is the appropriate method to use for the full scale implementation.

Step 7: Prepare an implementation plan – The implementation plan should provide information on specific actions such as schedule, cost, staffing, training, operation and maintenance (Shamsi 2005). Shamsi (2005) also stated that phased implementation is preferable. NCWSA has to implement their GIS in phases to match their yearly budget allocations.

Step 8: Conduct the final presentation – The final presentation is conducted for the same audience that attended the introductory seminar (Shamsi 2005). Since NCWSA will be actively involved in the entire process, this step will probably not be necessary. However, a presentation to their Board of Directors does play an important role in educating the Board about the benefits of GIS and the progress that is being made.

GIS DATABASE DESIGNS FOR WATER UTILITIES

Database design is a very important aspect to a successful GIS and its applications. Designing a GIS database is the most difficult part of developing GIS applications (Shamsi 2005). Successful GIS applications require a database that provides appropriate information that is accessible and useful by all users (Shamsi 2005). NCWSA will have a variety of users with access to GIS. The users will range from an engineer, administrative assistant, office manager, and field technician. It is important to remember during the database design that all these users have different experience levels and different needs. Shamsi (2005) listed three steps that are involved in database design. First is the conceptual design which does not depend on hardware or software, second is the logical design that depends on software, and third is the physical design that depends on hardware and provides a detailed definition of the structure and content (Shamsi 2005).

Being budget limited, NCWSA needed a database design that would not consume their entire yearly GIS budget. Inlet Beach Water System (IBWS) of Florida used Environmental System Research Institute, Inc.'s (ESRI) water utilities data model as the foundation for their GIS (Mitchell and Carter 2007). They contracted a private engineering firm to modify the data model to meet their requirements determined through a needs assessment. ESRI's water utilities data model is available for download through their website for all utilities to use. This enabled NCWSA to have access to a database template, which reduced the time and cost to design an entirely new database. With modification, the ESRI water utility template can meet the needs of the NCWSA.

The ESRI water data model contains a ready-to-use data model that can be configured and customized for use with in water utilities. It is designed so it can be deployed with no modifications or it can be highly customized to meet the needs of specific requirements (Grise *et al.* 2001). Grise *et al.* (2001) provided a description of an implementation of the data model that occurs in three stages.   Stage one focuses on planning and design. The utility examines their existing system and compares features in their system to features in the ESRI water data model. Through the comparison, the utility identifies features that do not match between the utility's system and ESRI's water data model. Once these differences are identified, the model can be customized to meet the utility's needs. Stage two involves creating the geodatabase. With the ESRI data model, a utility can use a geodatabase provided or they can create their own custom geodatabase. In the case of NCWSA, it is beneficial to use a database already created with modification within the schema. Once the geodatabase is created it can then be populated with data. After the geodatabase contains data, the utility can then move to stage three, where the utility puts the model to work. The geodatabase is shared and data is made available for use. Maps and layer files are shared through the network so users can access that data for specific tasks. Grise *et al.* (2001) provided a general overview on just the implementation of the data model. While it is not a plan to implement a full GIS, it does provide an understanding of how the data model can be used and implemented.

CASE STUDIES

To determine how best to help NCWSA acquire data, it was important to look at how other utilities had collected data for GIS. Hardin County Water District Number 1 (HCWD 1) is a rural water district in Kentucky that has collected data. With the help of Spatial Data Integration, Inc. (SDI), HCWD 1 personnel undertook a complete inventory of the existing geospatial information (Lyon and Clifford 2008). During the inventory, HCWD 1 quickly found that the origin and quality of data was unknown (Lyon and Clifford 2008), which is similar to that of NCWSA. NCWSA has a small amount of GIS data that was created by an engineering firm. However, that data has no metadata and has not been checked for positional accuracy or attribute accuracy. The next question is if any of the data be salvaged to help save time and money instead of having to recreate it. HCWD 1 was faced with the same issue and their solution was to sample 300 features to determine accuracy of existing data (Lyon and Clifford 2008). HCWD 1 used sub-meter GPS data from the 300 sampled locations to compare to the original geospatial data. Lyon and Clifford (2008) quickly determined that the average error of 30-150 feet between features would mean that HCWD 1 would need to recollect the entire system. Unfortunately, NCWSA does not have the time or resources needed to collect their entire system. Previously, the engineering firm had collected points all along the water mains to help draw their locations. This was done with NCWSA employees estimating where the line was buried and a third party technician taking a GPS reading. With unknown data quality and accuracy, it must be assumed that this data would probably not be used. The question then, is whether there is another method of capturing water mains that would not be labor and time intensive and still provide quality data. HCWD 1 personnel digitized the water mains to help reduce cost and then collected field locations for other features such as water meters (Lyon and Clifford 2008). SDI then added service lines and taps to connect the features to the water mains. Finally, HCWD 1 personnel performed the final quality control to ensure that service lines were connected to the appropriate water main (Lyon and Clifford 2008).

The data collection for an entire system can be a daunting task. The Inlet Beach Water System (IBWS) experienced this first hand in 2001 when they tried to inventory the system features by GPS coordinates (Mitchell and Carter 2007). They quickly realized that budget constraints limited their ability to hire trained personnel and purchase the appropriate hardware and software (Mitchell and Carter 2007). IBWS then partnered with Metric Engineering, Inc. to convert all of the company's engineering data into digital format. IBWS and Metric Engineering, Inc. then began the process of locating hydrants, valves, meters, manholes, and pump stations (Mitchell and Carter 2007). Like IBWS, NCWSA does not have the budget to hire trained personnel. However, case studies like IBWS and HCWD 1 proved that budget limited water utilities can still have a successful GIS.

Crawford (2012) documented the implementation of a water, sewer, and electric GIS for the City of Calhoun, GA that is similar to the NCWSA. NCWSA does not have the electric component, but the size of the water and sewer system is comparable. During the needs assessment, Crawford (2012) first interviewed the staffs to establish an overall set of goals and objectives. His next step was to gain a better understanding of their business processes through evaluating the existing data that was currently being used and identifying applications that the departments could benefit from. Lastly, Crawford (2012) determined the number of users that would be accessing the system from each of the departments. These steps are similar to the process that is examined during this study; however, since NCWSA is one department it will only have to be conducted with one group of users that operate both the water and sewer distribution systems. Crawford (2012) also gave insight to how data was created to populate the GIS. Features such as valves, hydrants, and water meters were field located with handheld GPS in order to accurately place the lines. It appears as though Crawford used these attributes to aid in locating where to draw the water lines. NCWSA does not have the ability to locate all those features in a timely manner so the methodology for data collection will vary.

Crawford (2012) implemented some web mapping applications to provide the utility with the ability to locate, query, and analyze different data sets. On top of that field crews have the ability to access data from tablets and smartphones in the field. This is an application that could benefit NCWSA to help provide field mobility. With the City of Calhoun (Crawford 2012) being similar to this study it has proved to be a valuable resource to establish and compare methodologies for the implementation of a GIS for NCWSA.

CHAPTER 3 PLANNING AND ASSESSMENT

PREVIOUS GIS IMPLEMENTATION

Prior to this case study, NCWSA had previously tried to implement GIS. They contracted a private firm to collect data on water mains, valves, and hydrants. This collection was done with an unknown mapping grade GPS unit. After the data was collected, it was then transferred to an engineering firm that was in charge of integrating the data into a GIS. NCWSA became disheartened with the progress of the GIS and the lack of products produced. NCWSA employees did not know and did not have immediate access to the data. Since 2004, they had invested over $150,000 and had not seen any progress to benefit their daily operations. NCWSA became discouraged and began to re-evaluate how they should implement GIS.

NCWSA had several major issues that needed to be addressed to ensure successful implementation of the GIS. First was their lack of knowledge about GIS. They did not clearly know what they wanted from GIS; they just knew it could be beneficial to their daily operations. This led to a lack of communication between NCWSA and the engineering firm. There was no plan, needs assessment, or GIS seminar conducted. The engineering firm was just collecting point data and storing it in a shapefile. Secondly, NCWSA has a minimal budget for GIS. This restricts how quickly their GIS can be completed and implemented. Lastly, NCWSA does not have a dedicated staff member assigned to GIS. The head engineer is leading the effort, but he has little knowledge of the capabilities of GIS and many other responsibilities that distract him from GIS planning. With this in mind, NCWSA decided to change the direction of their GIS implementation and allow this study to address and oversee the implementation of their GIS. In order to insure the GIS implementation continues after this study a local GIS and surveying company (Abraham Land Surveying) was included during the entire process to allow for a smooth transition. Abraham Land Surveying has the data collection equipment, hardware, and software in place, which will allow NCWSA to allocate their GIS budget to planning and populating the GIS.

DATA SOURCES

The first challenge of this project was locating the data and obtaining it. NCWSA was able to obtain all the shapefiles and data that the engineering company had been working with. However, the data did not contain any metadata or supporting documents that would aid in accuracy, quality assessment, or description. Table 1 lists the shapefile that contains the collected data given to NCWSA, along with an estimated description of what the shapefile contains and the attributes that were collected. The description is estimated by attribute fields and visual reference to determine what the feature is actually representing. It appears that all field collected points were stored in one shapefile, with the *FeatType* field delineating the feature. For instance, a fire hydrant located in this file is labeled hydrant in the *FeatType* field. Table 2 lists the contents of the personal geodatabase that the engineering firm had created. Again there was no metadata associated with this information and therefore some of the descriptions of the data are best guesses. The *map_grid* geodatabase appears to be the file used to draw the water mains and create a digital map. However, the engineering firm appeared to test several methods during drawing the water mains judging by the list of feature classes in Table 2. This is speculation since there is no metadata to clarify what these feature classes are or how they were created. None of the files located in the *map_grid* geodatabase are used during this project, due to the lack of knowledge on their quality and accuracy.

Data for this project came from four different sources: Newberry County GIS, the private engineering firm, Abraham Land Surveying, and the study itself. The Newberry County GIS coordinator willingly shared aerial and parcel data with NCWSA. The aerial data contained flights at 100 meters, 200 meters, and 400 meters. The 100 and 200 meter flights are not county-wide. Data was also created by Abraham Land Surveying through the location of features with GPS. There was also data created during the study such as water mains and sewer mains that were digitized. Table 3 lists all data sources, with their attributes and descriptions.

Table 1 Shapefile of Data Collected by Engineering Firm

File Name	File Type	File Description	Attributes Fields	Attribute Description
ncwsapoints_orig	Point	Contains all points that were located with a GPS unit	Comment	Contains comments such as post, date, valve type, cap
			DateCollec	Contains date data was collected
			FeatType	Contains item name such as fitting, system valve, hydrant, etc.
			GObjectID	Contains Number but unsure what they mean
			GPSGrade	Contains "M" which is assumed mapping grade
			GPSOperat	Contains initials of operator
			Manufactur	Only contain names associated with Hydrants
			Seat Diamet	Associated with Hydrants
			Size	Associated with valves
			Status	Associated with valves, contains open and closed
			Subtype	Contains text that is associated with the FeatType

Table 2 Personal Geodatabase Acquired from Engineering Firm

Personal Geodatabase	Feature Dataset	Feature Class or Topology	Type	Description
map_grid	Utilities	ncwsapoints1	Point	All points collected with GPS Unit. Includes valves, Hydrants, fittings, etc.
		utlities_Topology	Topology	Rule must be larger than cluster tolerance (Tolerance set to 5 feet)
		grid_33x44_150ftscale	Polygon	Gridlines at 150 foot scale
		grid_33x44_200ftscale	Polygon	Gridlines at 150 foot scale
		Hydrants	Point	Location of hydrants
		ncwsalines_Smoothline	Line	Drawing of the water mains
		ncwsalines_Smoothline_20	Line	Drawing of the water mains
		ncwsalines_Smoothline_50	Line	Drawing of the water mains
		ncwsalines_Smoothline_75	Line	Drawing of the water mains
		ncwsalines_Smoothline_bezier	Line	Drawing of the water mains
		ncwsalines_WSAedited	Line	Drawing of the water mains
		ncwsalines_WSAedited_Smooth25ft	Line	Drawing of the water mains
		ncwsapoints_orig	Point	All points collected with GPS Unit. Includes valves, Hydrants, fittings, etc.
		orig_lines	Point	Short line segments throughout water system. Unsure what this data represents
		orig_lines_1	Point	Short line segments throughout water system. Unsure what this data represents
		point_dispers_linear_25ftspace_all	Point	Appears similar to ncwsapoints_orig
		point_dispers_linear_spjoin	Point	Appears similar to ncwsapoints_orig

Table 3 Datasets Used in the NCWSA GIS

Datasets	Attribute Fields	Description
Water Mains	Pipe Diameter Pipe Material Date Installed	Maps water mains throughout the NCWSA distribution system. Created during the study. Accuracy +/- 5 feet
Water Meters	Unique Meter Identification Number Type/Manufacturer	Locates meters and stores unique identifier so it can be referenced with customer database. Collected by Abraham Land Surveying. Accuracy +/- 1 cm
Hydrants	Manufacturer Hydrant type	Locates fire hydrants. Used selection tool to clip hydrants from ncwsapoints_orig. Accuracy +/- 30 feet
Sewer Force Main	Pipe Diameter Pipe Material Date Installed	Locates and maps sewer force main lines. Created during the study. Accuracy +/- 5 feet
Sewer Gravity Lines	Pipe Diameter Pipe Material Date Installed	Locates and maps sewer gravity lines. Created during the study. Accuracy +/- 5 feet
ncwsapoints_orig	Comment DateCollec FeatType GObjectID GPSGrade GPSOperat Manufactur Seat Diamet Size Status Subtype	Provided by engineering firm. Contains all points that were collected with a mapping grade GPS unit. Accuracy +/- 30 feet
Aerial Photographs		Provided by Newberry County GIS.
Parcels		Provided by Newberry County GIS.
Road Centerline		Provided by Newberry County GIS.

NEEDS ASSESSMENT

A series of planning sessions were scheduled to better understand what NCWSA needed and wanted from GIS. These planning sessions helped NCWSA better understand GIS and what it could do for their utility, which enabled them to have meaningful input into their GIS. The planning sessions led to examining different data models that would meet their needs and goals, fit with the data that had already been obtained and with the future data they planned to collect. It was determined that a pilot study would be implemented before completion of the GIS to insure that NCWSA was comfortable with the GIS and its functionality. The pilot implementation would also give NCWSA better insight into which data should be included in future phases of the GIS implementation. While full implementation will not occur in the time frame of this study, the completed phases will give NCWSA a useful product, which will allow them to learn the system with a more hands on approach.

In May of 2010 this study began with discussing the existing expenditures on GIS, the current state of the system, and the feasibility of leaving the current GIS provider. In order to understand what had been done by the previous contractor, an electronic copy of all the GIS data was requested by NCWSA. Before a needs assessment was performed, the data was analyzed to determine exactly what data had been collected, the quality of that data, and whether or not it could be useful during the planning process. Attribute accuracy and completeness was analyzed with the help of NCWSA personnel, and Abraham Land Surveying was instrumental in helping determine positional accuracy quality. With the end of the fiscal year approaching at the end of June, it was important to make best use of the funds that were still available. The first planning meeting focused on what could be produced quickly to provide a useful information product by the end of the fiscal year. This meeting also served to be beneficial in laying out the goals and expectations that NCWSA wanted from a GIS. From this meeting a list of the most critical needs and wants was established, which are:

1. Water Main Data Layer (pipe diameter and material)
2. Sewer Main Data Layer (pipe diameter and material))
3. Locate Water Meters (account number, serial number, make, date)
4. Locate Man Holes (elevation, unique identification number)
5. Locate Pump Stations
6. Work Orders
7. Field Mobility
8. Software and Hardware

In order to keep the project moving forward it was important to identify the need that could be implemented quickly and provide a benefit to daily operations. This was designated as phase 1 of the project. For planning purposes, phases for the NCWSA GIS implementation were broken down into the fiscal years. For instance phase 1 was the remaining fiscal year for 2010, and phase 2 was the fiscal year of 2011. It was determined that the water main line data would be the focus for phase 1. It was important to NCWSA to be able to access pipe material and diameter in instances of maintenance and emergency situations. They also needed the ability to produce a map of their water mains in a short period of time. For instance, if an industry is looking to move into the county, they would want to know if water utilities are available at a prospective site. The first information product was a water main data layer that provided pipe diameter and material of all water mains throughout the NCWSA system. The goal was to complete this phase by the end of fiscal year 2010 so a product would be available to show the NCWSA Board of Directors, who had become apprehensive about GIS since the last contractor had failed to produce a beneficial product.

The planning process has been very fluid since the budget limits the amount of data products that can be implemented in a fiscal year. At the beginning of each fiscal year a new planning session is scheduled with all parties involved to determine the needs of NCWSA from the GIS and determine if plans for the future phases need to be adjusted. In essence, there is a new needs assessment done each fiscal year. This has been beneficial because as NCWSA gains a greater understanding of GIS and how it can benefit their daily operations, they are able to adjust their needs assessment each fiscal year.

Phase 2 began in fiscal year 2011. With the water main data completed in phase 1, NCWSA reassessed their critical needs listed in the first planning session. It was determined that phase 2 would center around creating a sewer main data layer, locating water meters, and locating manholes as these were a priority for NCWSA. The sewer main data is the most important component of this phase and should be completed first. It was not possible to locate all water meters and manholes on the yearly budget, but it could be done in increments over several years and span several phases of the project. Phase 2 also included implementing the free version of ArcGIS Explorer on NCWSA computers so they could view and pilot the data that had been created, such as the water main data.

Future phases are re-evaluated every fiscal year as mentioned above; however, there is a plan from the initial planning meeting to add more features. While they have not been designated into phases, it is important for NCWSA to add work orders and field mobility to their GIS. With fiscal year 2012 beginning, this project is now in phase 3. Phase 3 involves finishing the collection of water meters and manholes, while exploring options of field mobility with the available data. Since the future phases are delineated each fiscal year based on a re-evaluation of the NCWSA needs and budget, the product feature classes for those phases remain dynamic.

CHAPTER 4 PILOT IMPLEMENTATION

NCWSA has found that working with a private consultant that understands their goals and budget constraints has led to a better planning process and more productivity. Planning sessions are scheduled on a regular basis to establish specific goals for each fiscal year based on available funding. The previous GIS consultant wanted to complete the GIS system quickly and wanted a large outlay of cash at one time. This consultant did not want to consider planning a GIS on the NCWSA budget limitations over phases. The previous GIS consultant met initially with the NCWSA staff to plan the project and utilized NCWSA staff to aid in field collection. However, it was a brief meeting and future discussions about goals and progress were minimal. This led to poor planning and a product that was not usable. Through a series of steps NCWSA has implemented a minimal GIS that is already proving to be beneficial. Listed below are a series of steps that led to a successful implementation of data into NCWSA GIS.

GEODATABASE DESIGN FOR WATER SYSTEM

A data model was needed that would fit the immediate needs of the NCWSA along with the future needs, without depleting the budget. The local government geodatabase template that can be downloaded from ESRI has a feature dataset that was developed primarily for water utilities. Through modifications, this template meets the needs of NCWSA without the expense of creating a new design.

An entity relationship (E-R) diagram was created from the needs assessment to help understand how the feature classes would interact within the database. Figure 3 shows the entity relationship diagram for the water system. The water system is composed of five major features that NCWSA wanted to include in their data model initially. The water mains are linear features that contain information about the pipe diameter, type, and size. Connected with the water mains are valves that allow the water to be shut off at that location. Laterals connect into the water main line to supply water to hydrants and water meters.

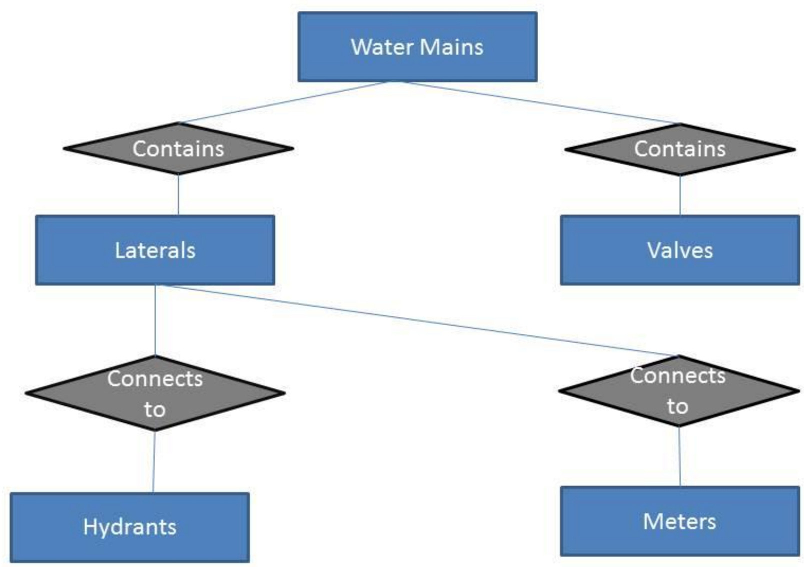

Figure 3 Water System Entity Relationship Diagram

Tables 4 to 8 show the feature class information products that need to be created for phase 1 of the project as discussed during the needs assessment. Not all of the dataset and attribute fields from the ESRI template are needed. These tables list the dataset and attribute fields that are important and critical to NCWSA. While there will probably be more fields created with future advancements, the ones listed in the tables below are the fields required for NCWSA to have a functional GIS to meet their needs.

Table 4 illustrates the attributes that were captured in the water main feature class. NCWSA needed to capture the pipe material and diameter from paper maps and have them available digitally. In order to collect as much data as possible to meet their needs, only the pipe material and diameter were recorded for the water main feature class. Install date was left as a field because a few of the water lines have known install dates. Hopefully, as new lines are built or old lined replaced, the install date can also be updated in the system.

Table 5 displays the valve feature class. NCWSA already had the valves located previously, but there was no attribute data associated with the valves. The locational data was loaded into the *wSystem_Valve* feature class. Since that data only had location, this information product only contains attributes for valve type and date installed. NCWSA will edit the attribute data during the digitization of the water mains and maintenance in the field.

Table 4 Water Main Feature Class Information Product

Feature Class: wMain	Alias: Water Mains
Description: Network of water mains in NCWSA system.	
Data Source: NCWSA Digitized Data	
Geometry Type: Polyline	
Field	Description
ObjectID	Assigned number by GIS program
Material	Material of the pipe
Diameter	Diameter of the pipe
InstallDate	Date pipe was installed

Table 5 Valve Feature Class Information Product

Feature Class: wSystemValve	Alias: Valves
Description: Shut off valves located on the water main	
Data Source: Features located by private engineering firm	
Geometry Type: Point	
Field	Description
ObjectID	Assigned number by GIS program
ValveType	Type of valve (Ex: Gate Valve)
InstallDate	Date valve was installed

Table 6 lists the attribute data for the lateral line feature class. This class represents the connections between hydrants and meters. NCWSA just needed pipe material and diameter for their information. Install date was also left so it could be updated as new lines are installed and replaced. The lateral line feature class has no data since NCWSA does not contain any information on paper maps for laterals. This data will be addressed after water meters and hydrant data have been fully populated.

Table 7 shows the attribute information for the water meter feature class. The water meter locations were collected by survey grade GPS units and therefore fields were created for latitude, longitude, and elevation. In order to match NCWSA records and customer databases, all of the fields in the water meter feature class were created separately from the ESRI water data model.

Table 8 shows the hydrant feature class. Like the valves this data had also been collected previously. NCWSA wanted three classifications of hydrants for their system. Hydrants, post hydrants and blow-off valves comprise this feature class. They are delineated in the *Hydrant_Type* field. Manufacturer field was kept from the ESRI data model template to populate that field during routine checks and maintenance.

Table 6 Lateral Line Feature Class Information Product

Feature Class: wLateralLine Description: Lateral lines that connect to the water main line Data Source: NCWSA Digitized Data Geometry Type: Polyline	Alias: Laterals
Field	Description
ObjectID	Assigned number by GIS program
Material	Material of the pipe
Diameter	Diameter of the pipe
InstallDate	Date pipe was installed

Table 7 Water Meter Feature Class Information Product

Feature Class: wMeter Description: Water meters in the NCWSA system Data Source: Located with survey grade GPS system from Abraham Land Surveying Geometry Type: Point	Alias: Water Meters
Field	Description
ObjectID	Assigned number by GIS program
Coord_X	Latitude coordinate
Coord_Y	Longitude coordinate
Coord_Z	Elevation
Description	Indicated if a water meter is present or just a box
Serial	Serial number of the meter
Box_Type	Type of box the meter is housed in
Meter_Size	List the size of the meter
Meter_Manufacturer	Meter manufacturer
Notes	Field for comments regarding the meter
Pt_Num	Number assigned by Abraham Land Surveying
Account_Num	NCWSA customer account number

Table 8 Hydrant Feature Class Information Product

Feature Class: wHydrant Alias: Hydrants Description: Hydrants, post hydrants and blow-off valves in NCWSA system Data Source: Features located by private engineering firm Geometry Type: Point	
Field	Description
ObjectID	Assigned number by GIS program
Manufacturer	Manufacturer of the hydrant
Hydrant_Type	List the point feature as hydrant, post hydrant or blow-off valve
Comments	Field allows for notes or comments on the hydrant point feature

GEODATABASE DESIGN FOR SEWER SYSTEM

Figure 4 shows an entity relationship diagram that was developed for the sewer system during the needs assessment. While the sewer system was not implemented in phase 1, part of the system was implemented in phase 2. All of the sewer main lines and gravity lines were digitized into the GIS. NCWSA has two gravity systems within their network and both function in a similar manner. The low energy treatment and transportation system (LETTS) is found primarily around the lake and does not contain manholes. The system consists of specially designed septic tanks, service lines, collection lines and pump stations. NCWSA is primarily interested in mapping the collection lines. LETTS primary function is to transport waste to a pump station. The gravity lines contain manholes, which have been located along the lines, and transport waste to a pump station just like the LETTS. Pump stations are used to pump waste from a lower elevation to a higher elevation. The pump stations then transfer the waste to force mains to be delivered to a treatment facility. Treatment facilities are not listed on the E-R diagram since they will not be modeled until a later phase.

Table 9 describes the sewer force main feature class. Like previous classes only a few of the attribute fields were used in the data product. The main objective was to capture location, pipe material and diameter. The pipe material and diameter are information that was easily obtained either through paper maps or current employees. As this system is implemented, NCWSA hopes to grow the number of attributes that are contained in the data products.

Table 10 contains information related to the gravity sewer line feature class. NCWSA does not maintain a large number of gravity sewer lines. Their primary objective is to locate these lines and maintain information on pipe diameter and material.

Table 11 contains the LETTS feature class, which is very similar to the gravity feature class. Attribute information will be the same as the gravity feature class as location, pipe material, and pipe diameter are the important information for these lines currently.

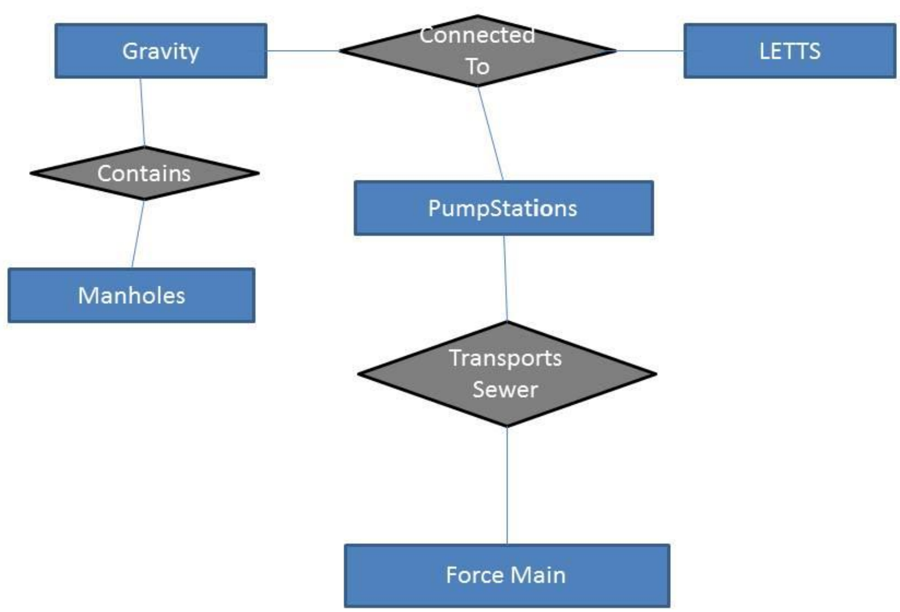

Figure 4 Entity Relationship Diagram for Sewer System

Table 12 lists the sewer manhole feature class information product. Manholes were located with survey grade GPS. An attribute was created to store the survey elevation on the rim of the manhole. As the system continues to grow in the future, this information could help with modeling or analysis.

Table 13 lists the information product for the pump station feature class. The pump stations were located manually through survey grade GPS. Within most of the pump stations there are wet wells and valve vaults that NCWSA wants to document in the system. NCWSA also wanted to know if each pump station had a quick disconnect, pump horse power, the type of pump, and the discharge diameter. These attribute fields were added to the feature class to store that information.

Table 9 Sewer Force Main Feature Class Information Product

Feature Class: ssPressurizedMain	Alias: Sewer Force Main
Description: Network of the force main sewer lines in the NCWSA System. Data Source: NCWSA Digitized Data Geometry Type: Polyline	
Field	Description
ObjectID	Assigned number by GIS program
Material	Material of the pipe
Diameter	Diameter of the pipe
InstallDate	Date pipe was installed

Table 10 Gravity Sewer Line Feature Class Information Product

Feature Class: ssGravityMain	Alias: Sewer Gravity Mains
Description: Network of gravity sewer lines in NCWSA system. Data Source: NCWSA Digitized Data Geometry Type: Polyline	
Field	Description
ObjectID	Assigned number by GIS program
Material	Material of the pipe
Diameter	Diameter of the pipe
InstallDate	Date pipe was installed

Table 11 LETTS Feature Class Information Product

Feature Class: ssLETTS Description: Network of LETTS systems in NCWSA sewer system. Data Source: NCWSA Digitized Data Geometry Type: Polyline	Alias: LETTS
Field	Description
ObjectID	Assigned number by GIS program
Material	Material of the pipe
Diameter	Diameter of the pipe
InstallDate	Date pipe was installed

Table 12 Sewer Manhole Feature Class Information Product

Feature Class: ssManhole Description: Sewer manholes located on gravity lines Data Source: Located with survey grade GPS system from Abraham Land Surveying Geometry Type: Point	Alias: Sewer Manholes
Field	Description
ObjectID	Assigned number by GIS program
Description	Describe the manhole
Survey_Elevation	The elevation of the rim of the manhole
Notes	Field for comments regarding the manhole
Pt_Num	Number assigned by Abraham Land Surveying

Table 13 Pumpstation Feature Class Information Product

Feature Class: ssNetworkStructure Alias: Pumpstation Description: Pump stations pump sewage from gravity mains into force mains. Data Source: Located with Survey grade GPS system from Abraham Land Surveying Geometry Type: Point	
Field	Description
ObjectID	Assigned number by GIS program
StructType	Delineate valve vault and the wet well located in the pump station
QD_Flange	Delineates if the pump has a quick disconnect flange
HP	List the horse power of the pump
ABS	Indicates if the pump is an Allan Bradley Logic pump
Discharge_Dia	List the diameter of the discharge pipe
Name_1	List the common name of the location that employees would recognize.
Pt_Num	Number assigned by Abraham Land Surveying

The blank schema file geodatabase template downloaded from ESRI contained more information than NCWSA was interested in or needed. In order to modify the geodatabase, the original schema was then renamed to Water_System. All other feature datasets were removed from the template since NCWSA was only interested in water distribution. Figure 5 shows the geodatabase schema and its contents that comprise the local government geodatabase. There were a few modifications that needed to be made in order to efficiently input data into the model. These modifications were made to the data model template that was downloaded in 2010, which has since been updated. The old nomenclature is used for this project. Some of the domain names have changed with new versions of the local government geodatabase on ESRI's website.

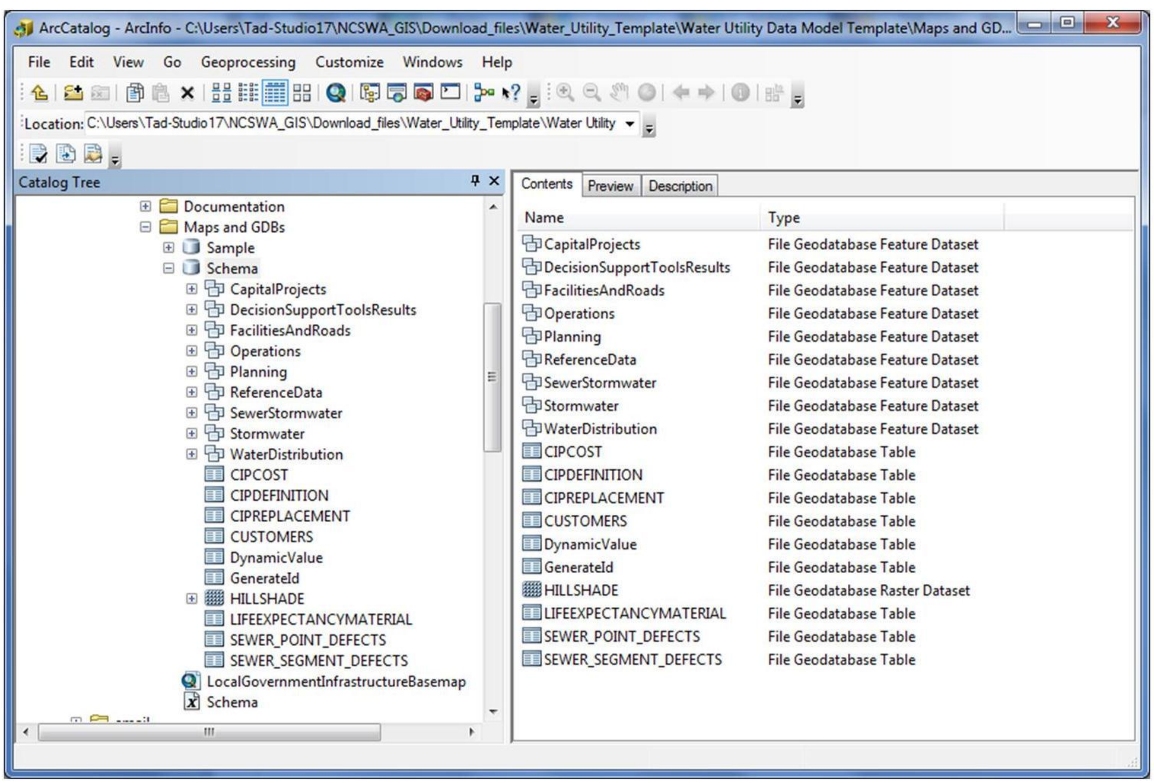

Figure 5 Contents of the Local Government Geodatabase

Changes to the domain properties increase efficiency during the data creation. The domain name *wMaterial* refers to the pipe material on the water main lines. Figure 6 shows the initial settings of the *wMaterial* domain in the schema database. NCWSA primarily utilizes three pipe types, so to simplify the database, all values were deleted with the exception of DI (ductile iron), OTHER (other), and PVC (PVC). C900 (C900) was also added to the coded values. Figure 7 shows the new characteristics of the domain.

Since the hydrant data from the engineering firm was going to be used and merged into the geodatabase, there were some modifications to the wHydrant layer in the geodatabase. A *wHydrantType* domain was created to house nomenclature for the type of hydrant. NCWSA wanted in-ground blow offs, post hydrants and hydrants to be delineated in the system. To reference the *wHydrantType* domain, a new field had to be created in the *wHydrant* feature class. The field was labeled *Hydrant_Type*.

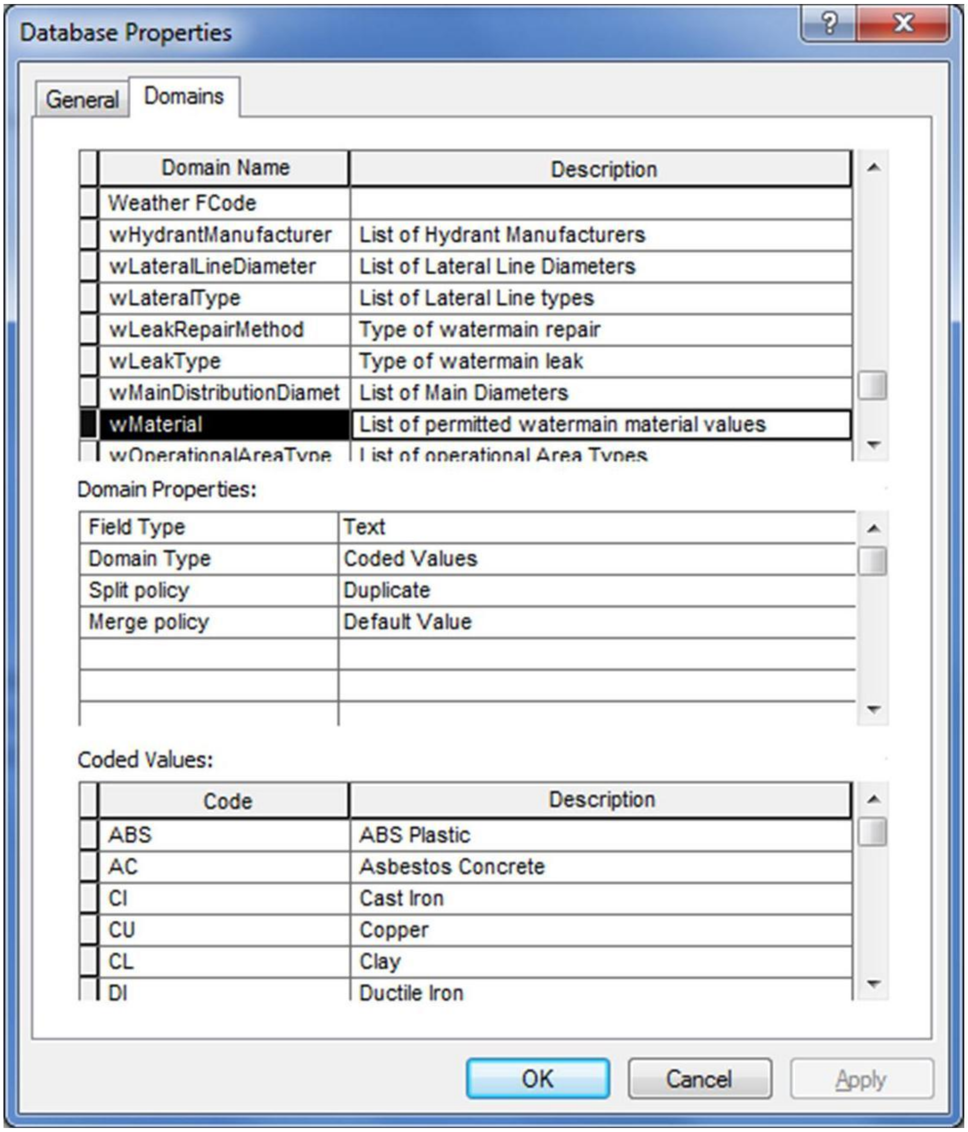

Figure 6 Initial Settings of the wMaterial Domain

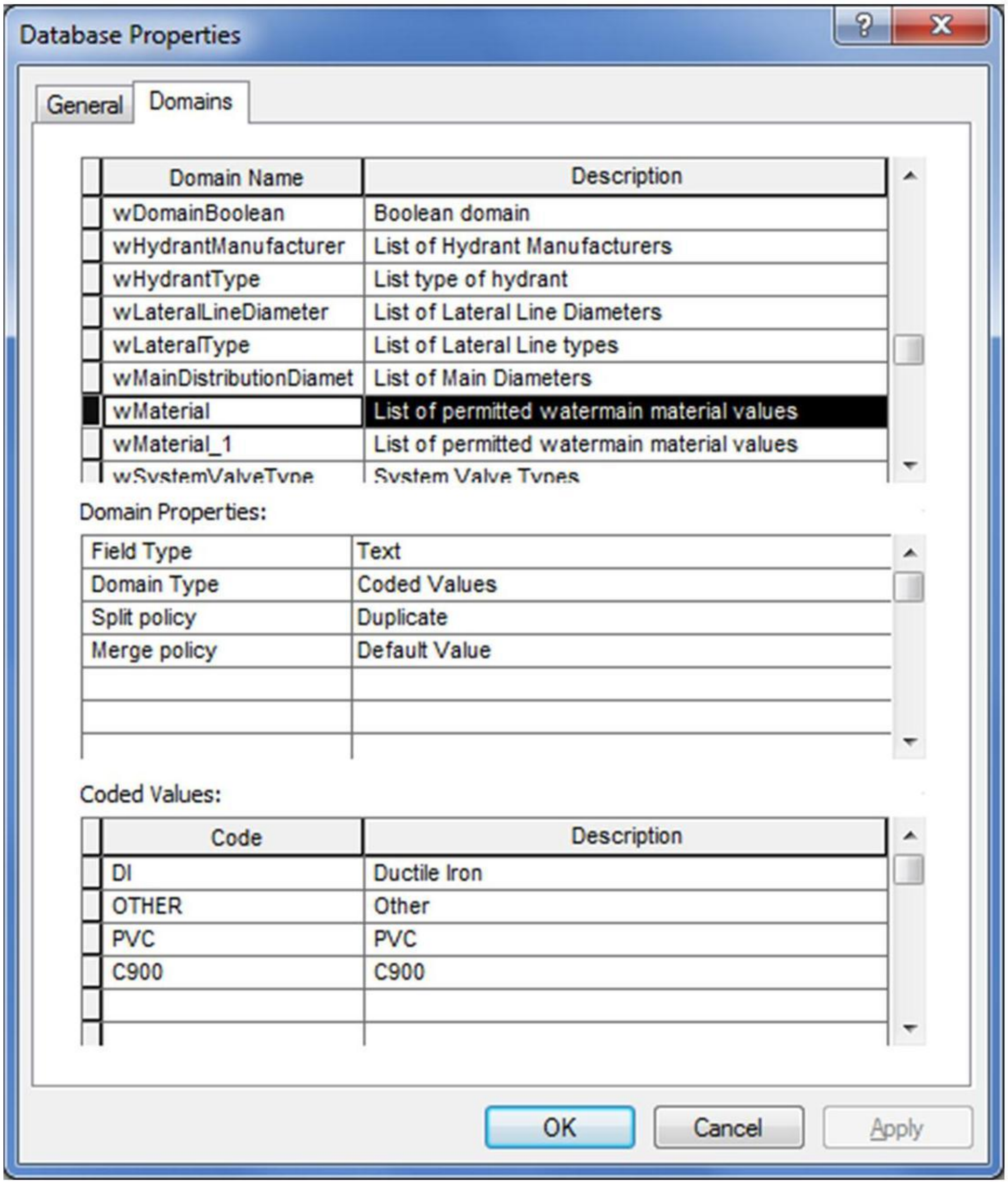

Figure 7 Edited Settings of wMaterial Domain

POPULATING DATA

The data analysis led to the conclusion that the water main data had to be recreated. Pipe diameter and material were the most important attributes for NCWSA. Heads-up-digitizing was the method used to create the feature class for the wMain feature class. In order to achieve the best possible locational and attribute accuracy several sources of information were referenced which included:

1. GPS located fitting points acquired from the previous engineering firm
2. As-built paper maps
3. Imagery
4. Field experience from a long time employee
5. Road centerline data
6. Parcel data

The project started by digitizing as many of the lines as possible through the GPS located fitting points. This was done by taking a series of fitting points and measuring the distance to the road centerline. The average was then calculated to determine average distance from the road centerline. This allowed use of the trace function to trace the road centerline and establish an offset to digitize a line that was more representative of a water main. This provided a water main line that followed the curvature with the road instead of just connecting the fitting points and having sharp edges. In the instance where the road centerline data was incomplete or inaccurate, the aerial photograph was used for heads-up digitizing or the parcel layer was used for a trace with an average offset established from the fitting points. Quadrant maps were printed to help keep track of the areas that had been digitized. After the water mains were digitized, two NCWSA employees reviewed the entire system line by line. During this review the as-built drawings and the long term employee were essential to ensure that each line was located as accurately as possible and the attributes were correctly populated. Pipe diameter and pipe material were recorded for each water main, and date of installation was added if known.

The hydrant data collected by the engineering firm needed to be used until funds could be allocated to collect quality data. This at least gives a visual representation of where the hydrants are approximately located. In order to capture the hydrant data, ncwsapoints_orig shapefile was used to extract all the hydrant points that were collected from the previous engineering firm. The wHydrant layer was created from the extracted data to use within the GIS.

DATA VIEWING

NCWSA was anxious to get the data in-house and start using it. The biggest obstacle was that they did not have the budget to purchase software or hardware and still continue to build their GIS. Another consideration was the fact that only the water main data had been completed along with the hydrant data that was captured from the previous engineering firm. Instead of purchasing ArcGIS software to view a minimal amount of data, it was decided that ArcGIS Explorer would be used to allow NCWSA the ability to view their data in-house. Figure 8 shows a screen shot of ArcGIS Explorer and how it is used to view the water main data. This software gives NCWSA the ability to view the GIS data and run a few simple queries on their existing computer hardware. ArcGIS

Explorer has allowed NCWSA employees the ability to use the data without having to learn how to use complex GIS software. Employees have been able to access information without the hassle of searching for paper maps of a water main data. Pipe diameter and material are easily accessed either through an address search or query of the water main feature. This pilot implementation has given NCWSA a better understanding of how they use the data, what additional data may be needed, and what direction they want to go for future additions. With hands-on experience employees are more capable of providing feedback and useful input for future additions to the GIS.

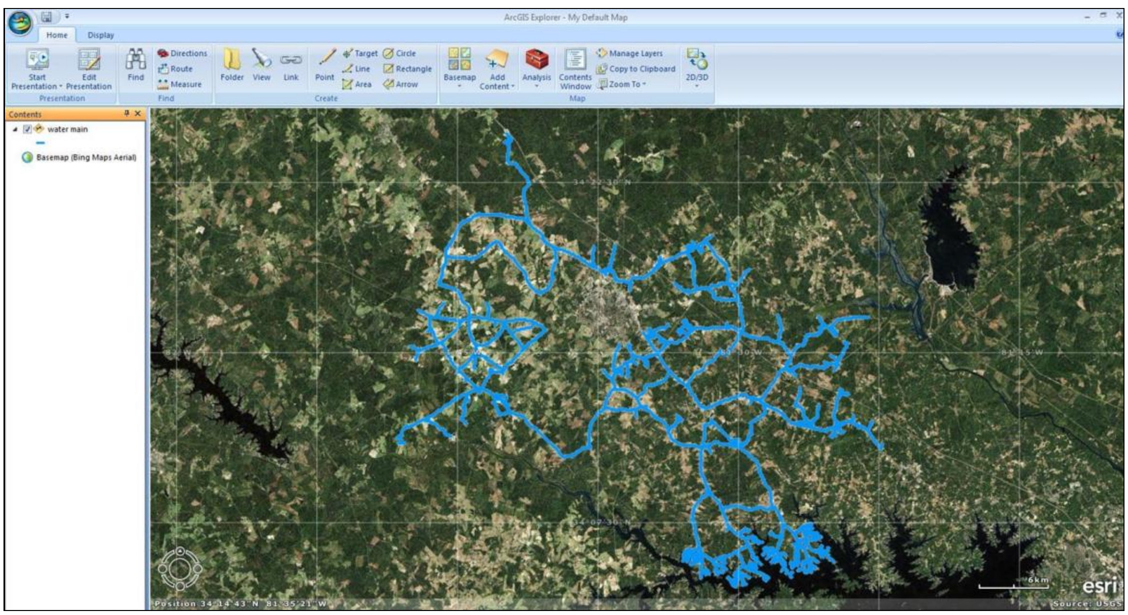

Figure 8 Screen Shot Image of ArcGIS Explorer Showing Water Mains

Through the pilot study five employees at NCWSA have access to view the GIS data through ArcGIS Explorer. This has given employees the ability to use minimal tools to see how GIS can help assist them in their daily work load. They use the current GIS system on a daily basis to plan future capital projects, determine if water service is available to a specific parcel, and to provide maintenance crews with accurate information (such as pipe size, pipe material, and location) when responding to line breaks. Through the pilot study, NCWSA has found that the GIS system has improved their productivity by reducing the need to search for hard copies of construction or as-built drawings.

FUTURE IMPLEMENTATION PLAN AND TRAINING

NCWSA wanted the GIS to continue to grow. They were pleased with the progress of the water mains and the product that was produced in phase 1. The focus was now on phase 2 which included digitizing the sewer main data, locating manholes and locating water meters. The highest priority in this phase was the sewer main data. It consists of force main, gravity main, and LETTS system features. The LETTS systems within the NCWSA were typically designed as stand along systems that allowed small communities or developments a method to collect and treat waste water in a central area instead of individual septic systems. As the LETTS system ages, measures are being taken to incorporate those systems into the NCWSA overall waste water system.

Like the water main, the most important attributes needed for the sewer mains were diameter and pipe material. The method for developing the sewer main data was similar to that of the water main. Heads-up-digitizing was used to draw the lines using aerial photographs, computer aided design (CAD) files supplied by an engineering firm, and as-built paper drawings. This was done for all three features which include force mains, gravity mains, and LETTS. Each feature was then reviewed by NCWSA staff members to ensure that the lines and attributes were correct.

With the budget remaining from phase 2 field data collection of manholes and water meters began. This process is conducted using survey grade GPS locational equipment and then merged into the geodatabase. The manholes are about 90% complete while the water meters are about 30% complete. Collection of the water meters will have to continue through several fiscal years as the budget allows.

It is never too early to begin thinking about future phases of the GIS. NCWSA would really like to see a work order system that would allow employees a more efficient way to document maintenance. They would also like to have access to GIS in the field for repairs and maintenance procedures. While this does not fall into the initial planning of phase 2, these are some high priorities for NCWSA that may result in restructuring the goal in the near future as more data products are available to them.

The only training that has occurred is a one-on-one session with each employee on how to use ArcGIS Explorer. Time was spent with each employee that would be using the viewer, and they were instructed on how to use the basic functions such as zoom, pan, and search. They were also taught how to use the query function to search for specific features such as pipe diameter or pipe material. These training sessions have proven adequate for the short term during the pilot implementation. However, when a full system is implemented with more complex software and tools, some of the budget will have to be allocated to train the staff.

NCWSA GIS IN ACTION

The GIS system has also proven beneficial for several map productions with very short notice. In one instance an industry was searching for properties to locate a new business and needed to know if water and waste water services were available throughout the county. A representative with the industry contacted NCWSA and requested a map to show where services were located so when industry representatives were in town, they could visit suitable locations. With GIS, a map was quickly produced that showed where water and sewer lines were located throughout the county. GIS proved beneficial in another instance when NCWSA received short notice of a grant to help fund an automated meter system. NCWSA once again needed a map of the water mains by the end of the business day. While the GIS was not complete, the digitization of water mains throughout the county was completed. With the water main data complete, a map was quickly produced that met the needs of NCWSA. Figures 9 and 10 show the examples of the map provided to the industry representative and the map created for the grant request, respectively. NCWSA was able to benefit from their GIS even before the initial phase had been completed.

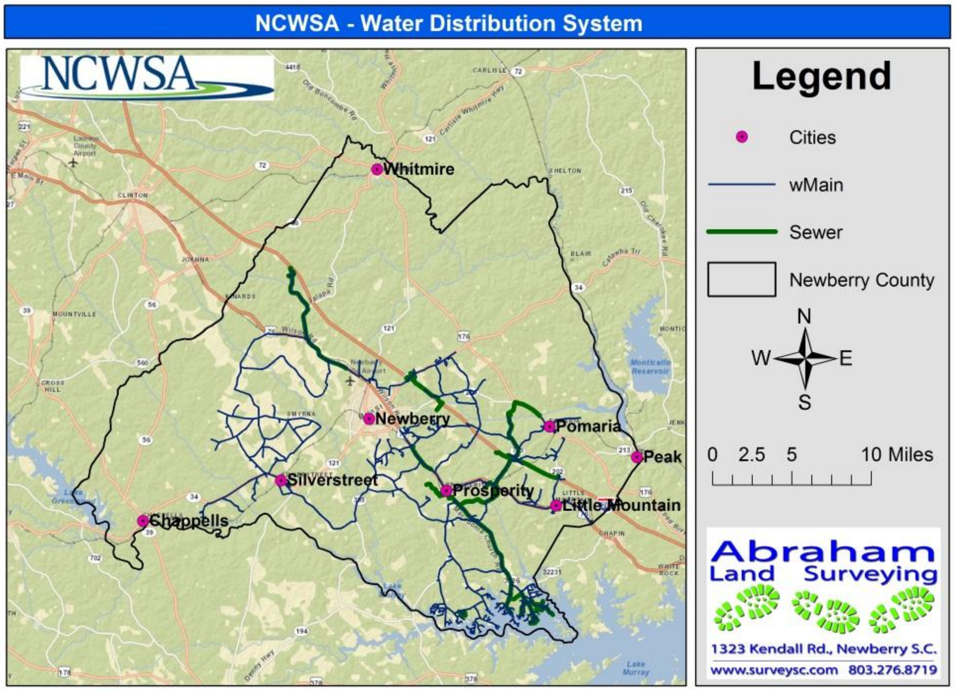

Figure 9 Map Showing Water and Sewer Service in the County

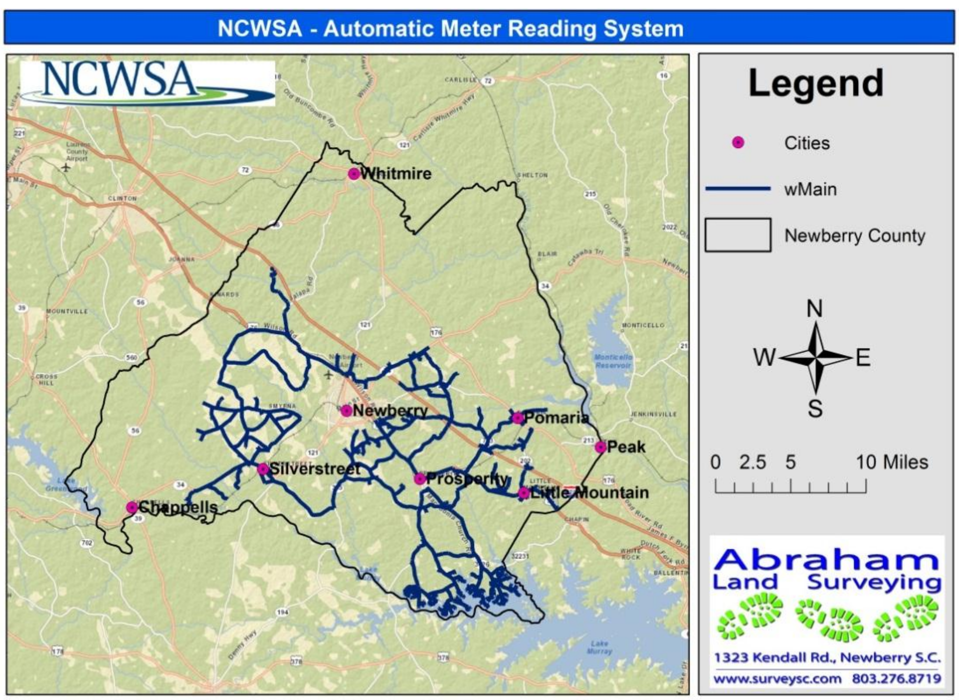

Figure 10 Map Created for Grant Request to Implement Automatic Meter Readers

New technologies are continuing to be developed in the GIS field. This project has implemented several new advances that may help NCWSA access GIS in the office and the field. Servers and handheld equipment with special software are required to implement a mobile GIS. NCWSA would eventually like to have GIS in the field; however, the hardware and software would strain their budget and put creating information products on hold. ESRI is promoting ArcGIS Online as a new web based service (Cloud) to house GIS data. Subscription information has not been released as of early 2012, but it has the possibility to offer GIS capabilities to organizations that cannot afford all the hardware and software required to operate a mobile GIS. As this technology continues to advance, it will be interesting to see if NCWSA or other small rural water utilities could benefit.

Another advance that coincides with ArcGIS Online is tablet computers, for instance the iPad or Android tablets. They have the ability and applications to access the ArcGIS Online data remotely. With the appropriate set up, data can be viewed, edited and collected right on the tablet computer. Currently, NCWSA is testing an iPad using data loaded into ArcGIS Online. Through ArcGIS Online and the ESRI application, the iPad can display and retrieve data about the NCWSA water distribution system. It also has a GPS feature that would aid in location. Figures 11, 12, 13, and 14 show some images captured from an iPad accessing information from ArcGIS Online on the NCWSA GIS as a test study. NCWSA employees are already seeing the benefit in using the iPad by aiding in identifying pipe diameter and pipe material on site. If the iPad proves to be an effective tool to access GIS in the field, it may also be effective in a work order management system. Additional research on the iPad and the new technologies could provide insight to NCWSA and smaller organizations that need access to GIS in the field. If the iPad functions like expected, it could give NCWSA an affordable option for mobile deployment of their GIS.

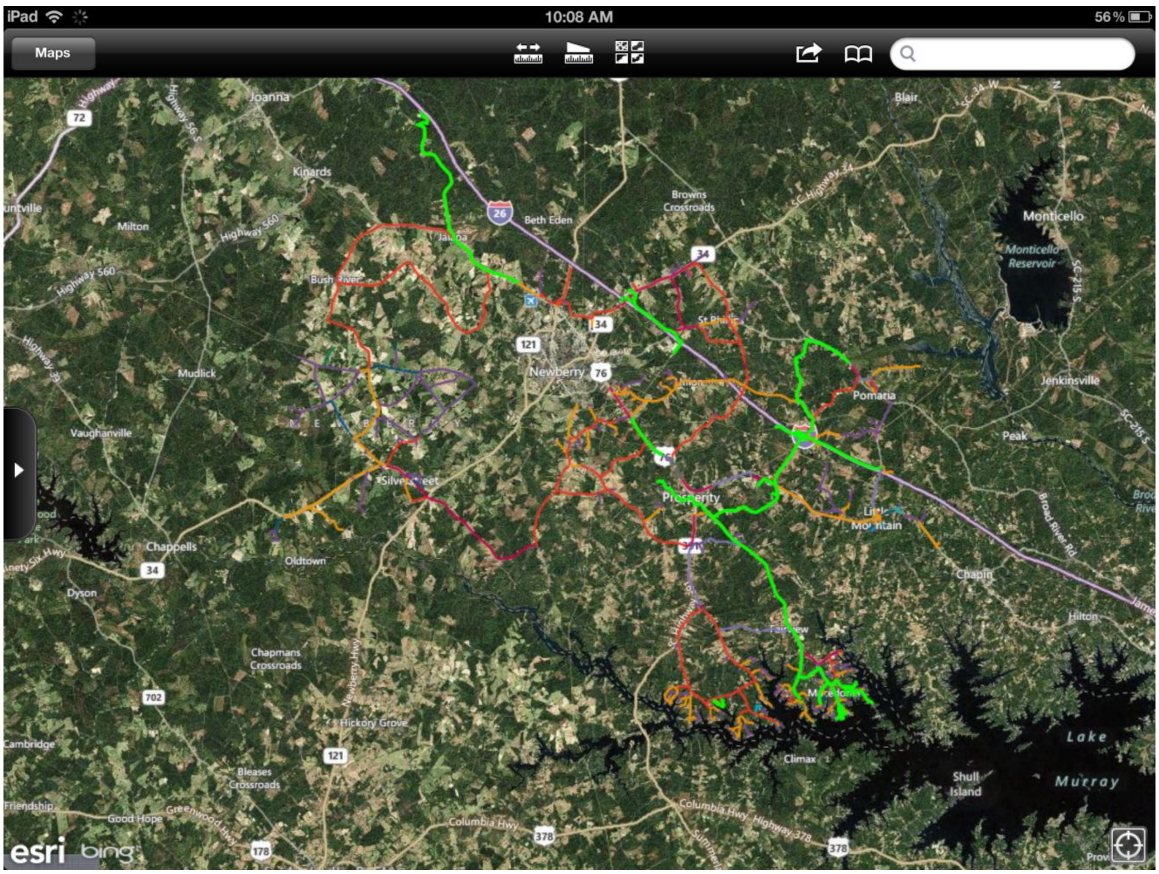

Figure 11 Image of Entire Water System from the iPad

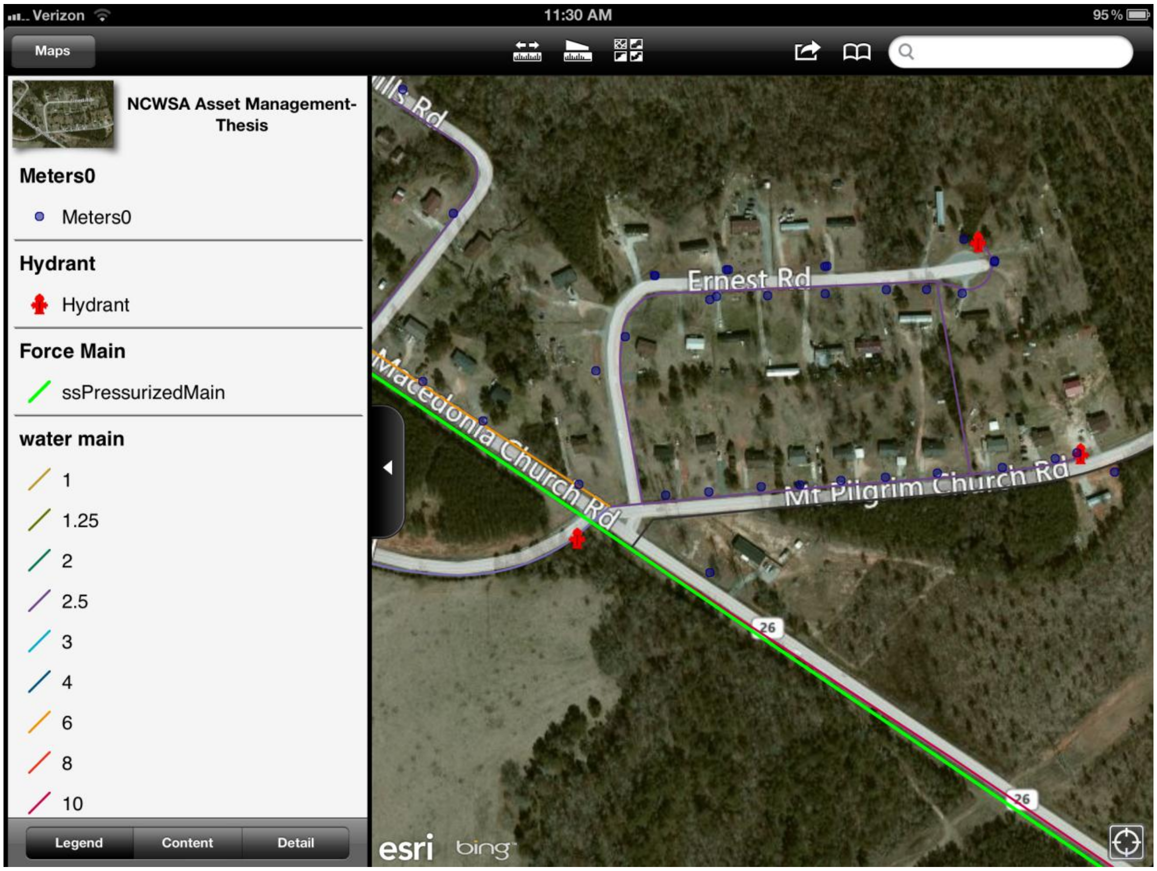

Figure 12 Image of a Zoomed in Section Showing Water Meters, Hydrants, and Water Mains.

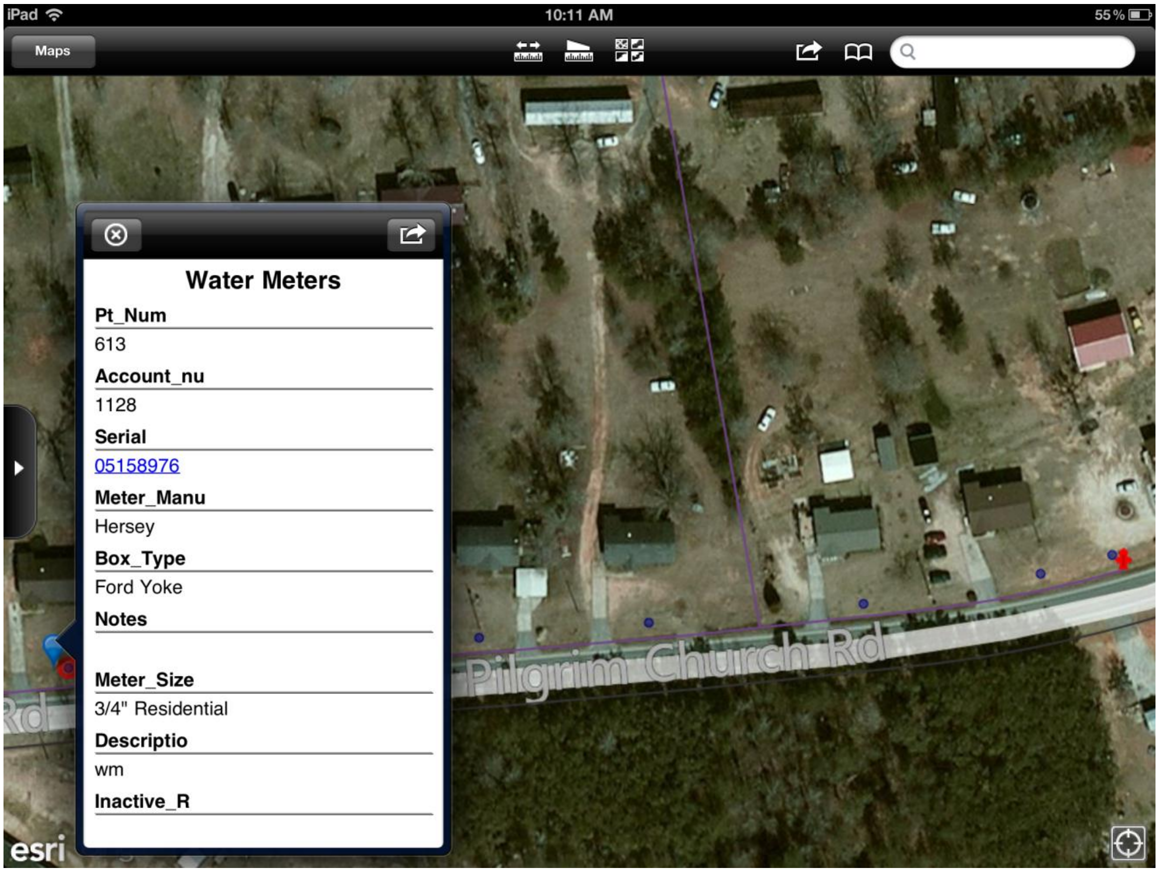

Figure 13 Image Showing Attribute Information When a Water Meter Is Selected

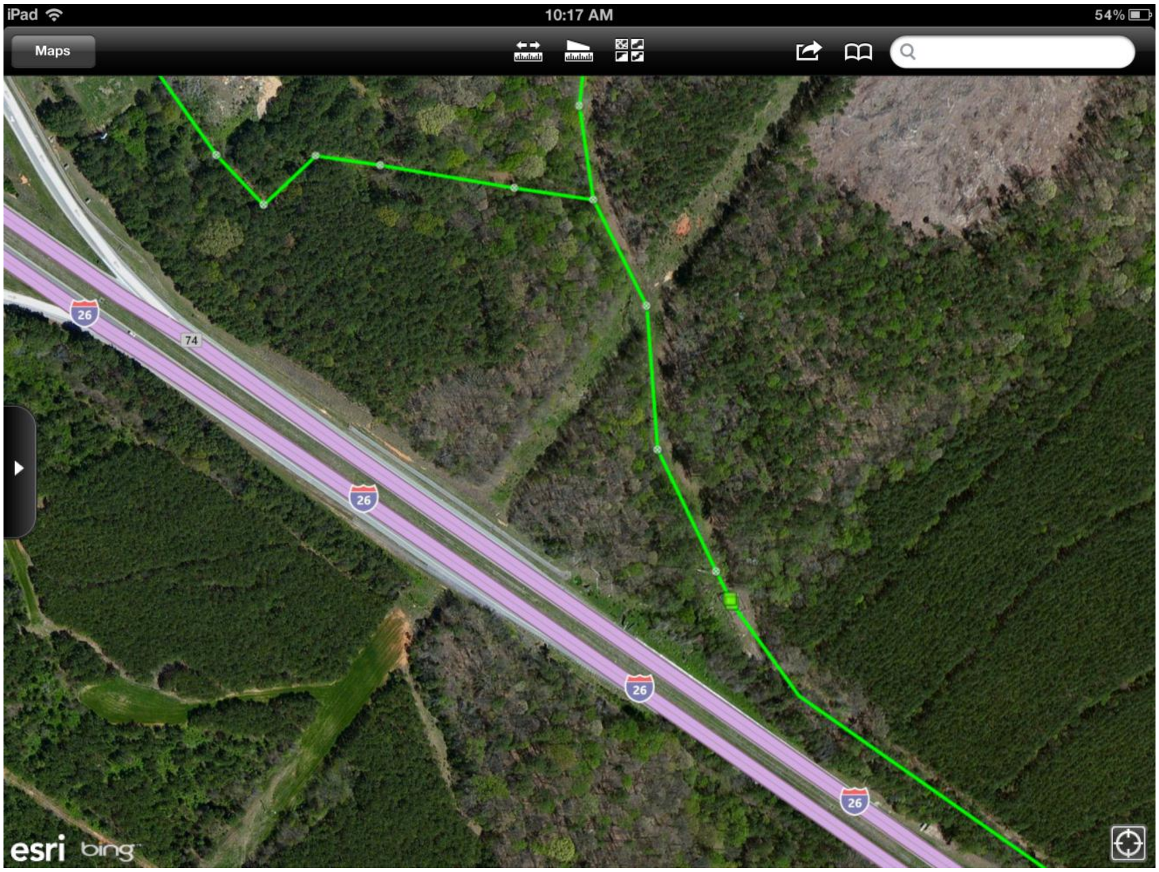

Figure 14 Screen Image Showing Zoomed in Section of Sewer Main and Sewer Manholes

CHAPTER 5 CONCLUSION

NCWSA spent a lot of money in the past with the engineering firm to create data and implement a GIS. NCWSA was disappointed with the progress of the implementation from the engineering firm, and in turn it made them skeptical of spending more money on GIS. They had reduced their yearly allocated budget for GIS and were not in the financial shape to increase it. They knew there was a need for GIS, but just did not know the best way to approach it. NCWSA realizes that they are not GIS experts, but through this project they have come to appreciate and understand their involvement during the planning and implementation process. This has given NCWSA a better understanding of the implementation process and how to better allocate their budget resources to continue to build their GIS. This thesis has helped bridge the gap between an unaffordable GIS and one that is functional for NCWSA. While their system is not complete and will not be for some time, they now know how to better plan and implement different pieces over time based on their needs. NCWSA continues to plan future advancements to the GIS. The biggest issues on the horizon include budget constraints, work order management system, field mobility and completing the system. With time and planning NCWSA will continue to reach their goals and implement a GIS one phase at a time.

This thesis involved the planning and implementation of a GIS for a small rural water company. While the implementation is not complete, there is a usable product in-house at the NCWSA office. This shows that even organizations with limited budgets can plan appropriately to implement a GIS. The implementation plan needs to be flexible, as goals, needs, and technology change. As more data products are produced, more services and applications will be available for NCWSA to use. It will take time and patience but eventually NCWSA will have a GIS that will meet all of their goals and needs.

There is a plan in place to continue to implement NCWSA GIS. In order to continue to build the GIS after this thesis project, Abraham Land Surveying will take the lead on the planning, maintenance, and implementation of the future phases of GIS. Abraham Land Surveying has the hardware and software needed to maintain and house the data for NCWSA. Abraham Land Surveying has been actively involved throughout the project in order to insure they could continue the project.

LIMITATIONS

As mentioned previously in this study, a major obstacle was the funding allocated to GIS implementation. NCWSA does not generate enough revenue to fully fund a full and quick GIS implementation. It was important in the planning process to identify the short term and long term goals of the NCWSA for their GIS. After identifying the goals, a plan was then developed to begin GIS implementation to meet their budget as mentioned previously. Involving NCWSA has been the key to helping them understand how to stretch their budget and determine which products are more important or needed currently. The previous contractor did not involve NCWSA as heavily and therefore missed their budget and their goals. Involving NCWSA also helped reduce their limitation on their knowledge of GIS. Being involved in the planning sessions, creation of data, and validation of data help them become more aware of the process and operation of GIS. While they still have much to learn, this has helped them become more prepared when planning for the next phases and determining their future goals of the GIS system. This plan also had to be flexible. As NCWSA learned more about GIS, their goals and GIS requests changed or altered a little. Being in constant communication with NCWSA has allowed the plan to be altered to meet their needs as they change.

NCWSA re-prioritized objectives throughout the project to meet their needs and demands as data was completed. At times this changed the scope of the project and pushed other objectives further down the priority list. The work order management system was high on NCWSA list when the project first began. However, during the first and second phases NCWSA changed their focus to completing the water and sewer infrastructure. While it was beneficial for NCWSA to re-prioritize objectives, it did change the planning and implementation of the GIS. When working with small utilities or organizations, there is a learning curve for the utility company and the party conducting the implementation. This study found that as NCWSA increased their knowledge of what GIS could do for them, their goals and objectives were revised. It was important to remain open to new ideas and objectives and work with NCWSA to implement those into their GIS.

FUTURE IMPROVEMENTS

Work order management is still a key objective for NCWSA; however, with their limited budget and increased focus on completing asset inventories, it has been delayed until a future phase. Prior to this study, NCWSA handled all their work orders through hand written notes. The goal with establishing a work order management system is to allow office staff as well as field staff to create work orders electronically that could be filed in GIS for all staff to view on a real-time basis. Additionally, the work order management system would allow maintenance crews to check out a work order ticket and document the procedures performed, materials used, and time allotted to complete the task.

NCWSA is continually looking ahead to improve their GIS system. They are focused on completing their data, but that does not mean they do not look ahead to see what else GIS can offer. They want GIS to be integrated into all of their daily operations, which involve maintenance schedules, critical decision making, managing accounts, managing real time data, and generating reports. Field mobility is another key issue for NCWSA. This would help crews efficiently find the nearest shut off valve, pipe type, and pipe diameter of a broken water line, for example. That is currently being done on a trial basis with the iPad, but it is still too early to tell if that will be the solution to the field mobility need. While NCWSA is focused on their yearly GIS budget and getting their most product for their dollar, they understand that GIS is a system that can continually grow and provide more services in the future.

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