Challenges in Developing a City GIS Wastewater Geo Database System

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OVERVIEW

The City of Winfield Kansas recognized the need to fully utilize the capabilities of GIS technology to support the maintenance of its aging wastewater sewer and treatment system. The City currently utilizes a SDE SQL multi-versioned database for maintaining its base map layers and to support its gas, electric, storm water, and water utilities. The wastewater GIS system was absent of a user-interface and consisted of shape files that were originally built from inaccurate CAD data and drawings. To build a more accurate and functionally GIS system, RTK GPS was utilized , the database was re-designed, a user interface was built in the .NET framework, digital video was incorporated, and existing lines, spreadsheets, and log book information was migrated into a SDE SQL multi-versioned geo database. This paper discusses the field collection, database building, and challenges of building and implementing a GIS wastewater system for a city on a limited budget.

BACKGROUND

The City of Winfield Kansas is a full service city providing police and fire protection and public utilities and services including electric, natural gas, solid waste, water, and wastewater. In support of these utilities the city utilizes a GIS running ESRI software and a SQL SDE multi-versioned database for maintaining its base map layers, and for simultaneous editing of its utilities. As part of an effort to increase the use of GIS it is moving from using GIS as just a mapping resource to integrating it into daily operations with service and maintenance of its utilities. As part of this effort, it recognized that the wastewater GIS system needed to be upgraded to match other utilities ground accuracy, and to support the sufficient management of the wastewater utility.

Over the years, the City of Winfield wastewater system has been maintained in a number of different formats including the use of paper log books and maps, an Auto Cad system with map booklets, and a GIS shape file system. The GIS wastewater sewer system had never been utilized for the overall design, maintenance, and construction of the system, nor has the system been capable of generating reports and integrating data from other software applications and databases. It also had been created primarily from existing drawings, and lacked sufficient ground accuracy because of the absence of accurately surveyed or the use of GPS technology. It also had existed in a flat file or simple shape file system and not in a relational or geo database system. Previously no formalized attempt has been done to gather the needs of a wastewater GIS system from the field wastewater crews, supervisors, directors, and operational staff. As part of this project the first objective was to complete a user requirements needs analysis so that an understanding of what a GIS System could provide, and what the expectations are from the wastewater department.

Needs Analysis - Identifying components of the system

In order to fully identify the eventual use of the GIS wastewater system by field crews, operational and city staff, and the public, a needs analysis was completed. The wastewater collection department was interviewed, and existing paper documents, maps, computer systems and databases (including GIS, Access, laser fiche documents, and AS 400 applications) were examined. From the interviews and

analysis of the existing systems wastewater GIS layer and accuracy, functional system and database, and reporting and mapping capability requirements were generated. As part of these requirements, in order to keep costs at a reasonable level, it was assumed that the current GIS software and database system environments would be utilized which consist of ESRI Arc Map Arc Editor 9.3.1 for editing, ARCSDE 9.3.1 SQL 2005 for database, ARCIMS 9.3.1 for internet city-wide distribution, Arc Pad 8.0, and Trimble Geo XH equipment, Terra Synch, and Pathfinder software for field data collection, and Visual Studio 2005 C# and VBA for custom code development. The city maintains an Enterprise License Agreement (ELA) as a small municipality with ESRI for use of its GIS software, and has plans to migrate its ARCIMS sites to an ARC GIS server.

Results of the Needs Analysis

Wastewater GIS Layers Accuracy and Database attributes (Initial collection …. complete database)

Accuracy: Collect at sub-foot accuracy on the City's current standardized coordinate system (NAD 1983 State Plane Kansas South FIPS 1502, GCS North American 1983 Datum)

Manhole Layer – Manhole ID, material, diameter, GPS date, GPS method, notes …….
Section Number, depth, depth measured, Inspection date, structural date, structural condition, modification by, modification date, In-easement, work order, & status

Wastewater Line – Wastewater Line ID, diameter, material, length, collection date, collection method, notes…..Section Number, grade, collection, collection date, Built year, modification by, modification date, In-easement, work order, & status

Forced Mains – Forced Main ID, Size, material, length, collection date, collection method, notes……
Section Number, grade, collection, collection date, built year, modification by, Modification date, In-easement, work order, & status

Forced Main Relief and control valves – ID, material, GPS date, GPS method, notes…….
Section Number, depth, depth measured, Inspection date, structural date, structural condition, Modification by, modification date, In-easement, work order, & status

Clean Outs – Clean Out ID, material, diameter, GPS date, GPS method, notes……
Section Number, depth, depth measured, Inspection date, structural date, structural condition, modification by, modification date, In-easement, work order, & status

Lift Stations – Lift Station ID, material, description, GPS date, GPS method, notes……
Section Number, depth, depth measured, Inspection date, structural date, structural condition, modification by, modification date, In-easement, work order, & status

Future Collection and data integration

Video integration – Video ID, location, wastewater Line ID, video type, date, time, description

General Maintenance – Location, address, date, time, description, work performed……
Condition of manholes, operators, comments, & drawing

Blockage Information – Customer Name, date, time, address, blockage reason……
Description of line, operators, work hours manhole condition, comments, & drawing

Tap locations along lines – Tap ID, material, description, distance from manhole, method of collection, Collection date, built year, modification by, modification date, work order, & status

GIS Base Map Layers – address, streets, buildings, property lines, easements, curbs, county roads, city boundary, & aerial photo-image

Additional GIS Map Layers - City Owned properties, electric lines, electric service points, Gas Valves, Gas Lines, storm pipes, water meters, hydrants, & water lines

Functional system requirements

The functional requirements consisted of the GIS systems immediate ability to enter and maintain information on blockages, tap service line inspections, general maintenance and lift station maintenance, and secondary was the ability to maintain and display video along maintenance lines in a GIS environment.

Blockage – Provide a user interface in GIS and maintain database information on the location of a blockage including:

Name:	Name of the individual calling in the blockage
Date & Time:	Date and time that the blockage was called in
Address:	Location that the blockage is being reported by caller
Reason for blockage:	Reason for the blockage according the field crew
Operators:	Crew members completing work
Comments:	Comments and notes about the blockage and repair
Drawing:	Ability to create a drawing of the blockage.

Tap Service Line Inspection – Maintain information in a database on tap service line inspections and the locations in GIS where the service line inspection occurred including:

Location:	Where is the tap located along the service line
Address:	Address location of the tap request
Date & Time:	Retain date and time of the service line inspection
Distance:	Distance from uphill manhole to tap
Operators:	Crew members completing work
Notes:	Notes and comments from crew regarding the tap inspection
Type of Tap:	Tap types (pull down menu)
Angle of Tap:	Angle of tap off line (pull down menu)

General Maintenance – Provide a user interface in GIS to track maintenance in database for general line cleaning, manhole repair and other maintenance activities (excluding video):

Address:	General location of the maintenance
Date & Time:	Date and time of the maintenance
Line Description:	Description of line cleaned
Length of Cleaning:	Maintain the length of the line that is cleaned
Type of Work:	Keep track of what was cleaned
Condition of manholes:	Note the condition of the manholes if they are cleaned
Operators:	Crew members completing work
Comments:	Maintain comments on the maintenance work by crew members

Lift Station – Provide a user interface in GIS to keep track of ongoing maintenance of our lift stations and include the possibility of interfacing with the SCADA system.

Address:	General location of the lift station
Date & Time:	Date and time of the maintenance
Line Description:	Description of lift station maintenance performed
Operators:	Crew members or contractors completing work
Comments:	Maintain comments on the maintenance work by crew members

Video Integration – Provide a user interface that allows field personnel to view and select video in the GIS based on a wastewater line or manhole location that automatically comes up and plays as a video. Provide static images of piping view where video isn't available.

Integration of other data and applications in GIS

Laser fiche document imaging – GIS system should either have all the maintenance and tap information residing in the Laser fiche document imaging system migrated to the GIS system, or be provided in the form of data tables for viewing in GIS. System should provide data from the last 5 years if directly in GIS, or the entire document imaging system if linked or integrated. System should be developed for everyday usage by the wastewater field crews and operational staff. As the system evolves the document imaging needs to be linked up to the GIS and provided to users in an ARCIMS or Arc GIS server capability for city-wide access and future public usage.

Blockage Maintenance and Tracking – The GIS system should have the ability to link up to the AS 400 system maintaining the blockage customer call information, or the data should be migrated to a data base and linked up to the GIS for usage through a user interface.

Tap Service Line Inspections - All tap service line inspections that have been maintained in an Access database should be migrated or linked to the GIS for usage.

Report and Mapping Capabilities

General Maintenance Report – Provide the ability to generate a report for general maintenance based on a time frame, and provide for each maintenance event the address, location, date & time, manhole condition, manhole description, operators, and resulting work completed. The system should be able to provide it in a printed version, or provided as an image file, word file, or provided as an image for emails and document image integration. The report should include the option to print up a map containing the blockage locations accompanying the report and eventually be able to be integrated with the city's Laser fiche document imaging system.

Blockage Report – Provide the ability to generate a report for sewage blockages based on a beginning and ending time frame that provides for each blockage an address, customer name, date and time of blockage, manhole description, manhole condition, operators, and resulting work completed. The system should be able to provide it in a printed version, word file, or provided as an image file for emails and document image integration. This report should include the option to print up a map containing the blockage locations for the report and eventually be able to be integrated with the city's Laser fiche document imaging system.

Tap & Service Line Inspection Report - Provide the ability to generate a report for Tap & Service Line Inspections based on a beginning and ending time frame, or a customer name that provides for each an address, customer name, date and time of inspection, manhole description, manhole condition, operators, and resulting inspection that was completed. The system should be able to provide it in a printed version, word file, or provided as an image file for emails and document image integration. This

report should include the option to print up a map containing the tap and service line inspections for the report and eventually be able to be integrated with the city's Laser fiche document imaging system.

System Requirements – The system shall provide the Ability to be maintained by the wastewater field staff in an Arc Map 9.3.1 editing environment utilizing an ARCSDE multi-versioned SQL 2005. Provide layers in ARCIMS 9.3.1 so city operational and service personnel can utilize and view the layers. Training should be provided to the Wastewater field crew to sufficiently maintain the system in Arc Map.

STATUS OF SYSTEM DEVELOPMENT

GPS Field Collection

As of June of 2010, all of the wastewater manholes and cleanouts have been located in the field and collected using a Trimble Geo XH unit with the exception of 39 manholes and cleanouts. The remaining 39 are buried or are inaccessible and will be pinpointed with crews using metal detectors and probes and coordinates collected. From this effort and the use of other source materials including log books, engineering and construction drawings, Auto Cad DXF and DWG files, and other records wastewater lines have been connected between manholes, and flow direction has been assigned. See Figure

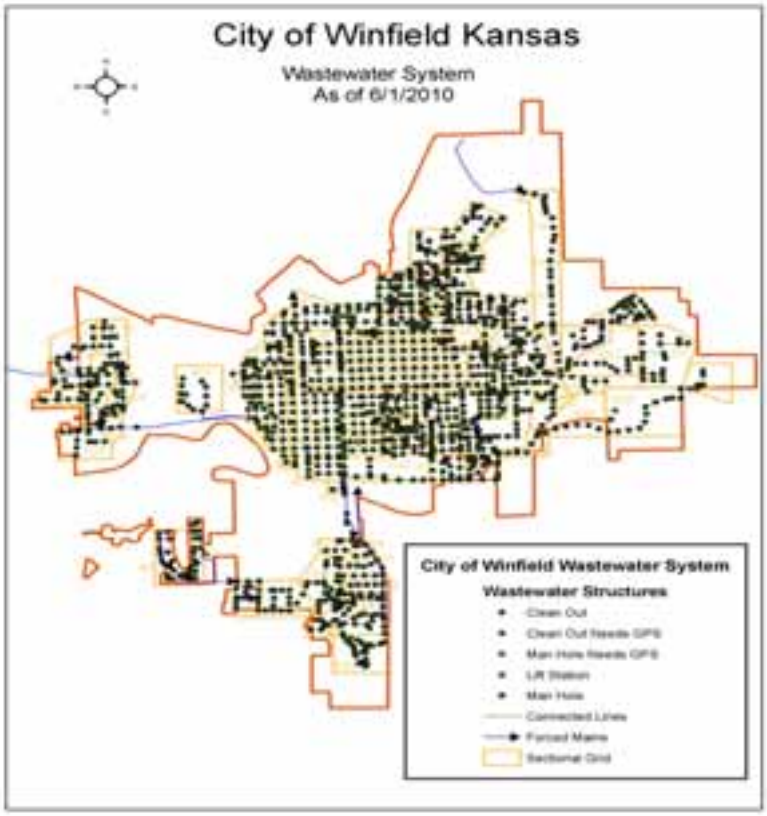

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Figure 1: City of Winfield Kansas Wastewater mapping system as of June 1st, 2010.

The remaining wastewater system components that need field GPS collection include the relief and check valves along our forced main lines, and a more extensive collection and data gathering effort for our lift stations. This would include collecting components with GPS, and collecting additional field information with PDAs or laptops including lines in and out of the lift stations, electric capacity and location, pump and depth characteristics of the lift stations, and other manholes in and around our lift stations.

Database Creation

After completing the GPS collection of the wastewater manholes and reviewing drawings and existing Auto cad files the wastewater lines were connected to the manholes using a snapping operation. From this effort database attributes were built in GIS for each layer identified in the user requirements. Attribute tables of the manholes, forced mains, cleanouts, and connected lines were updated from existing data residing in Auto Cad; GIS shape files, and spreadsheets. The remaining data fields are being populated from information that exists from construction and as-built drawings, log and map books, and discussions with field personnel.

User Interface & System

As part of the requirements of the system a database and maintenance logging system needed to be created with a user interface. To assist collection, database design, and logging of maintenance information the city was broken up into maintenance sections and unique ID numbers were created for all the manholes, and wastewater lines. The unique ID number is a seven coded number that was created to uniquely identify a manhole or sewer line within a section, and across the entire system. The ID number includes a system that accounts for the flow of the line to the termination of the section, and whether it branched off from right (even numbers) or left (odd numbers) from the main or another branch line within the section. The ID number also accommodates the ability to add or remove manholes as the numbering system increases by 100 along main lines, and by 10 in the branch lines. This numbering system (in addition to be used for identification in the field and future collection) will be used to link up the GIS and log databases for the maintenance system being developed in GIS.

As part of a test environment that is being reviewed by the wastewater department the system has been built with Visual Basic Application (VBA) code, and utilizes GIS shape files, Access databases, and MXD project files. Figure 2 is the user interface that was developed to allow the user to select whether they would be entering information into the GIS for a blockage, maintenance, tap service line inspection, lift station maintenance, or to generate reports from the system. Figure 3 provides the user interface that was built in Arc Map 9.3.1 for initially entering field maintenance information for a maintenance event – including start date, duration, work type, and crew members. The wastewater staff member first indicates which operation is going to be performed, and then based on that operation the code then directs the user to select the wastewater lines and/or manholes in Arc Edit. After the user has selected the lines or manholes in the GIS, the system generates a user form to gather all the pertinent information on a line call, line clean, line repair/rehab, manhole repair/rehab, or televise/Inspection log. The system records who is entering the information, the date and time, and automatically generates a job number (used to track in the log databases and GIS tables) and asks the user to enter all the pertinent information for that particular job. Figure 4 provides the user interface for gathering information following a line repair/rehabilitation.

Figure 2: User interface to select work once the person recording the information on the maintenance has been recorded along with the date of the work.

Figure 3: Initial user interface to record information on a work job before gathering in depth information on a blockage, general maintenance, and tap service line inspection work order through the Work Log Tabs.

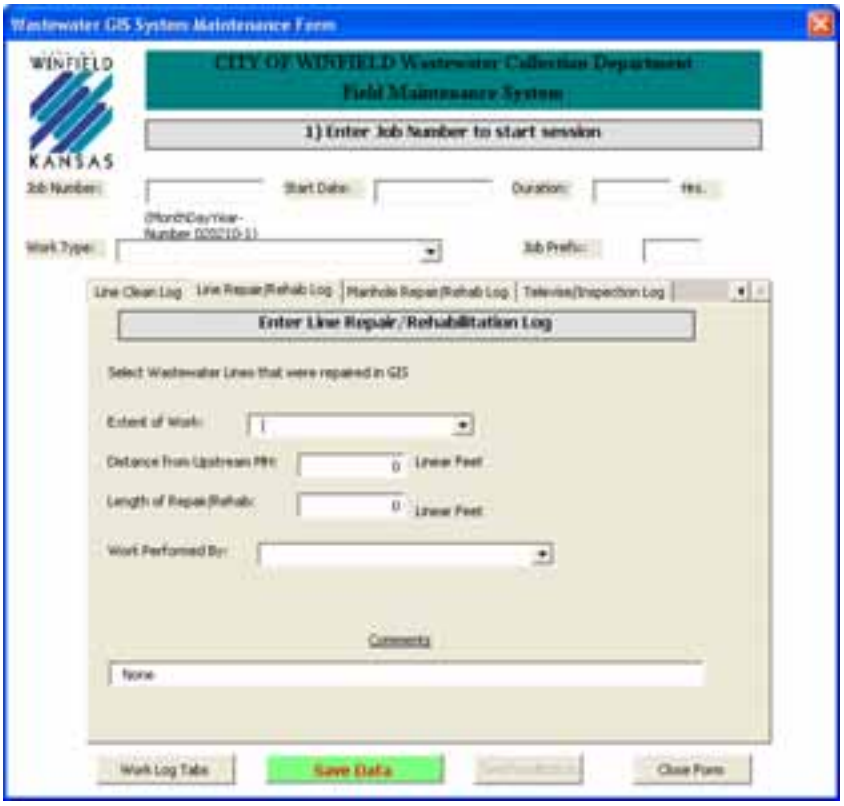

Figure 4: User form interface for gathering information on a wastewater line repair or rehabilitation.

The system was designed to have the GIS Engineering staff update the wastewater manholes, lines, forced mains, cleanouts, and lift station information for the wastewater department, or have the department do the edits once they are trained. The customized code developed for the system automatically updates the log tables once a wastewater manhole or line ID number is added, updated, or deleted from the system during editing in Arc Edit. Once this work is completed the system updates all GIS layers for current and future display in the MXD file and the log tables are updated.

The system currently has been developed with VBA code for a single user in a GIS shape file, access database, and MXD environment. Once the system is fully tested and accepted by the wastewater crews and operational staff, the GIS shape files will be migrated into SDE for a multi-versioned database and the VBA coding will be re-created in a .NET environment utilizing C # to create a system that can reside on multiple computers instead of the single user test MXD system. System log tables will be loaded into SQL or will reside in Access depending on access and privilege issues.

CHALLENGES OF DEVELOPING A WASTEWATER GIS SYSTEM

In developing a system that will be used by the wastewater field crews and operational staff for ongoing mapping and maintenance of a wastewater system has provided many challenges. A number of these have been solved, while others are still in the process of being addressed. One of the challenges was the need to swiftly collect the 1600 wastewater manholes and cleanouts identified in the for the initial collection phase. To accommodate this a Trimble Geo XH system with Terra synch and Pathfinder software was purchased, along with a Zephyr antenna. It was felt that this system of collection would meet the accuracy needs and could easily be transported and utilized quickly in the field with minimal training and setup. This was critical because it provided an accurate basis quickly to build the other

layers, including wastewater lines, forced mains, and lift stations. The initial collection was completed in the summer of 2009 by an Engineering Specialist and a summer intern. Follow up collection sessions were completed with the wastewater crews in the fall and spring of 2010 to locate and GPS man holes that weren't successfully identified by the collection staff. The only remaining challenge is to collect the 39 manholes and cleanouts that are either buried, in harsh terrain, or not able to be located while not impeding the current ongoing maintenance that the wastewater crews are undertaking. Also, though minimal, inconsistencies in data collection occurred depending on the time of day during collection, and the number and location of the base stations that were available during differential correction. This will have to be analyzed to insure that future collections are consistent especially before additional utilities are collected.

Another challenge involved the usage of the sewer blockage information currently residing in an AS400 database and integrating this data with our GIS data layers for use in the maintenance system. Currently the data has been migrated into an Access database, but a user front end needs to be developed for maintaining the records, while the GIS system is built. The database will need to be linked to the GIS so it can be utilized quickly and be used through a single interface instead of being maintained in a separate application. Another challenge will be to complete the migration of the GIS shape file data from the test environment into an SDE multi-versioned database and setup editing for the wastewater department and city-wide usage. To assist this effort Visual Studio 2005 C# coding and the Arc GIS Engine is being utilized for development. Portions of the code have been migrated to C#, but a remainder of the code will need to be developed and tested as the test phase developed in VBA of the project is finalized.

The other major challenge involves people and procedures. The proper training of the wastewater field crew to successfully utilize the GIS in the Arc Map 9.3.1 editing environment and to use the new user interface and maintenance system will be key to the systems overall success. This also involves making sure that the data entry and report generation is coordinated between the field crews, the operations desk staff, management, and the rest of the city. The reports that are generated out of the GIS from the maintenance system needs to meet the needs of the field crews, the directors, and questions that arise from the public. This will need to be evaluated and revised as the new wastewater system is utilized by staff and old ways of conducting business is replaced by a fully integrated GIS wastewater system.

Also as part of the project, it will be a challenge to development a video system library that can be accessed from the GIS system, ARCIMS, and other applications that can be used city-wide and not just within the wastewater department. Other challenges include the future integration of the GIS system and our Laser fiche document imaging system. The goal is to enable the wastewater GIS user to obtain historical wastewater work order documents out of the Laser fiche systems while working in GIS, and to enable counter and utility employees to have a corresponding map displayed while they are examining documents in Laser fiche. Other technological challenges will be setting up the ARCIMS site for the wastewater system for city-wide usage and the eventual public usage of our utility layers in an ARC GIS server public internet site.

SUMMARY & FUTURE PROJECTS

The Wastewater GIS system initial collection has been completed, including the GPS of all the manholes, cleanouts, and lift stations. The remaining field collection includes locating and getting GPS coordinates of our relief and check valves along our forced main piping. Wastewater piping has been connected to the manholes and the database attributes have been created. The City of Winfield is in the process of updating data attributes for all the wastewater manholes, lines, clean outs, lift stations, and forced

mains from drawings and other sources, for those that didn't have data from the migration from previous system. Field maintenance sections have been created and ID numbers have been established for those that will be used in the maintenance system. Components of the maintenance system has been developed in VBA using GIS shape files, access log tables, and coding connecting up all the functionality needed for the blockage, general maintenance, and tap service line inspections. The remainder of the system is being developed including the ability to generate needed reports, and the lift station and video line maintenance modules.

Once the remaining modules are completed and tested in VBA and wastewater approves the initial test system it will be migrated into an SDE multi-versioned SQL 2005 geo database utilizing the .NET 2.0 framework and C# coding. This will support a more robust maintenance system that can be used by multiple users simultaneously. In addition, future plans call for the use of SDE disconnected editing to allow the wastewater department to enter maintenance information into a laptop or PDA in the field to minimize paperwork and increase field data collection efficiency. Other efforts include the need to link up as-built image drawings of individual manholes, lift stations, and relief valves to the GIS for viewing and building and integrating the video library of lines that have been videotaped into GIS.

Once the GIS maintenance system is accepted and utilized, other projects on the horizon include setting up flow capacity modeling and network capabilities in the GIS wastewater piping system, and the examination of influent and effluent flow and discharge discrepancies. The linking of our Laser fiche document imaging system to the GIS wastewater system, integration of our Inhance utility billing system, and building an ARCIMS or ArcGIS server for city-wide access, and eventually making the system available to the public on a web-based public internet site.

For any questions regarding this project or other GIS related questions as it pertains to the City of Winfield please contact:

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