Advancing Water Utility Capabilities and Efficiencies

Transitioning from Autodesk to ESRI's ArcGIS Server

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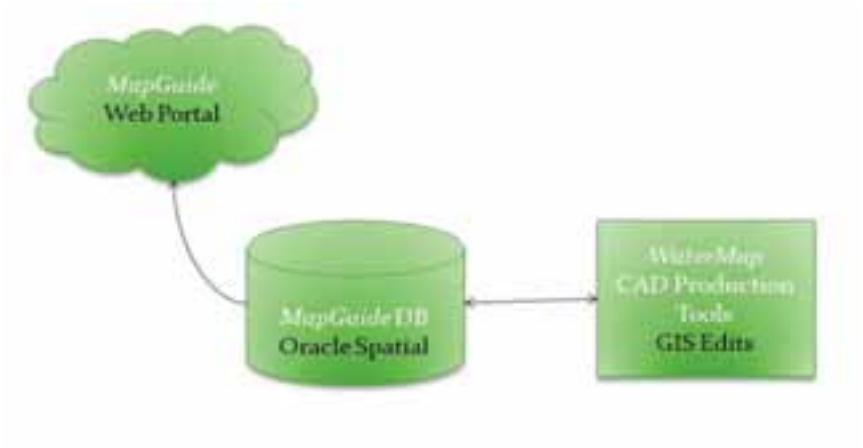
Overview

The Prince William County Service Authority (SA) is a forward-thinking water utility in the northern Virginia area, providing wastewater and water services to a population of approximately 360,000 people. The SA has been in the process of upgrading its technological infrastructure since early 2009 as part of a large-scale *Information Technology Master Plan* (ITMP). One of the cornerstones of the plan includes the development of an Enterprise Geographic Information System (EGIS) to deliver a robust versioned data production environment, a sophisticated geodatabase design capable of integration with other SA systems, an advanced ArcGIS Web Portal, and upgrade of all other ancillary geospatial systems under the ESRI umbrella (GPS and routing applications).

The SA's prior GIS environment was constructed around an Autodesk Computer Aided Design (CAD)-based application known as *MapGuide* Enterprise (version 6.5). *MapGuide* included functionality to edit GIS data in a CAD based environment and then provide that data via the SA's intranet to users throughout the company. *MapGuide* provided stable service of GIS data to the users within the company, however it lacked modern GIS capabilities, preventing the SA from meeting its GIS vision for the future.



The ambitious plan to transition from Autodesk to ESRI and develop greatly expanded GIS functionality within the organization is based on an aggressive twelve month schedule. Within that time-frame, the SA set-out to complete the following tasks: (1) needs analysis and discovery; (2) review and refinement of internal workflows; (3) establish recommendations and solution paths; (4) generate internal buy-in; (5) configure, develop and test solutions; (6) implement new systems; and (7) train employees on the use of new software applications. Internally, the project was labeled the *GIS Transition Project*.

GIS Background

The SA employs a GIS Group consisting of five full-time GIS analysts providing a range of tasks including GIS database edits, map corrections, data analysis, and cartographic map production. The GIS Group has used the *MapGuide* system for approximately ten years and has performed all GIS database edits in a CAD environment. An application known as WaterMap was employed to write database edits to an Oracle Spatial (10g) back-end – effectively writing data to a GIS database. The WaterMap application had been heavily customized over the years in order to provide basic editing capabilities that are common in today's suite of ESRI ArcGIS editing tools. The Oracle Spatial data was served to the *MapGuide* Web Portal where internal users could view and query the data

and perform minor edits to GIS information. In the past, the *MapGuide* portal was very stable and effective at serving GIS information to the SA and providing basic tools for network analysis, reporting, and access to scanned documents (engineering plans and field notations). However, true topological relationships could not exist in *MapGuide* and were instead defined through brute-force methods of attribution amongst the varying layers. For example, each sewer main line segment required fields to define the upstream and downstream manholes. Through use of a lengthy querying process, *MapGuide* could eventually produce a representation of networked flow. Additionally, *MapGuide* lacked modern GIS functionalities for system integration, advanced data querying, symbolization, and data analysis.

GIS Vision

The SA team envisions GIS as the cornerstone of an integrated information technology environment and the enabler for advanced asset analysis and service delivery. By coupling GIS data along with no-spatial data from other SA systems, the SA seeks the ability to provide faster, more accurate and efficient services to its external and internal customers. At the same time, the SA plans to enhance the ability of its employees to be more efficient through use of a common data source of spatial and non-spatial data. The EGIS will not only allow for access of spatial and non-spatial data from a common interface, but it will also facilitate the combined analysis of that data in a way that had not been done before – revealing hidden spatial patterns in information that were not known in the past. Utilizing GIS as the central point between the various systems will also allow the SA's full technology suite to be utilized in every aspect of its operations. This vision changes the GIS from a silo system within the organization into an operational requirement and a key component in the way the SA conducts business.

Review and Planning

The SA team understood the utility's situation with its existing GIS/CAD technology before beginning the *GIS Transition Project* and realized that the GIS vision of the company could not be met with the *MapGuide* tools in use. However, a clear understanding of where the SA stood in terms of GIS data quality as well as effective and ineffective workflows was not known. Understanding this information was critical to the planning phase and beginning the GIS Transition from Autodesk to ESRI's ArcGIS Server technology. This project provided an opportunity for the SA to: (1) evaluate its existing workflows and data quality; (2) create a foundation for improvements in the way data was collected, stored, and linked to other systems, and (3) ultimately provide a path for advanced asset management through spatial and tabular data analysis.

A series of internal workshops were held to discuss the existing GIS system – specifically focusing on data quality and efficacy and the existing database schema. Workshops were conducted in several groups. Each group represented a different department within the SA and consisted of those who currently use the GIS system heavily and those who may potentially be new users of the EGIS system. The groups included representatives from Engineering, Operations and Maintenance (O&M), Information Technology (IT), and Customer Service (CS). Discussion did not only focus on the GIS system, but reviewed data and workflow's within O&M's Computerized Maintenance Management System (CMMS) and Customer Service's Customer Information System (CIS). While tedious and time-consuming, these workshops provided an invaluable opportunity to discuss four key questions necessary to the development of a proper GIS database schema designed to meet the SA's GIS Vision:

- *What existing data do we have that is useful?*
- *What existing data do we have that is not useful?*
- *What data do we <u>not</u> have that is needed or could be needed in the future?*
- *What functionality would help you perform your job better*?

Additionally, workshops were geared around the discussion of existing workflows within each department and how those workflows are related to one another. Some database procedures were in use to move data between GIS, CMMS and CIS; however, much of the SA's existing workflows were within silos relegated to each

department. The existence of these silos is not uncommon when enterprise systems are absent. However, as the SA planned to move to an EGIS environment, it was crucial to discuss how data originated within the organization and passed from one department (or one system) to another. Several essential questions were asked, including:

- *Where does the data we have originate?*
- *How is the data transformed in a particular process?*
- *Is the data ever transferred to another system, and if so, how does that data change over time?*
- *How many copies of a particular piece of data exist and in which systems?*

Detailed discussions of these topics shed light on how processes and workflows could be improved and integrated with one another, either as part of this project or at a later stage.

As systems integrate, data must be managed in a different manner. Part of the discovery process revealed that some similar asset attribute information was being stored in GIS and CMMS. At times, the attributes for a particular asset differed from one system to another. For example, a water main pipe diameter attribute may exist in GIS as 8" but the same asset had a recorded pipe diameter of 6" in CMMS. In these scenarios, the SA team had to determine which system was correct, which business rules were used in the varying systems for that attribute, and how that attribute should be handled in the future. Additionally, the team discovered that while the GIS lacked several key attributes essential to proper asset management, those attributes existed in CMMS with adequate business rules in place to properly add and update those attributes.

Since the SA is moving to an EGIS, it does not make sense to store similar information in two or three different systems. All stakeholders agreed that a piece of information should only exist in the system with the most appropriate business rules for maintenance of that piece of information. Therefore, several decisions were made on where particular attributes would be stored and updated in the future (CMMS, CIS or GIS). Through system integration, the information will still be available for users via the ArcGIS Web Portal, data maintenance will be simplified, confusion on conflicting attributes will be reduced, and access to the information will become more simplified.

For example, the older *MapGuide* GIS system had over fifteen attribute fields for water meters (date of installation, meter type, material, serial number, etc.) but almost no attributes were populated for the GIS water meter features. The CIS system had up-to-date and accurate information related to each water meter and substantial business rules were in place within the Customer Service Department to maintain that information. The SA team decided to develop the new water meter GIS layer with one key attribute – serial number. The serial number field could be utilized to link to CIS and 'pull' all related water meter information and serve that data via the ArcGIS Web Portal to users.

The process of guiding these workshops into constructive dialogue and recording the information gathered from discussion proved invaluable for future development tasks. While some information and requests had to be set aside for development 'down the road', the knowledge that certain functionality may be needed in the future helped determine the best way to develop the database schema and plan for future functionality.

Hardware and Software Review

Development of a new EGIS requires a thorough evaluation of your existing hardware and software environment. As in the case of this project, a review of the GIS Group's software needs and the IT hardware needs was paramount. The existing server space was not adequate to serve a growing pool of ArcGIS Web Portal users or the volume of data that would be pushed to those users due to the planned integration of GIS with CIS and CMMS systems. The SA contacted ESRI to discuss planned uses of the system and capacity estimations, existing hardware, planned software for implementation, database storage options, and recommended solutions. ESRI worked with the SA's IT Department and provided a recommendation for a server that worked with the SA team's choice for ArcGIS Server version 10, Oracle 10g, and existing network infrastructure.

Database Design and Development

Database design and development can be a challenging task involving two fundamental steps:

1. The development and articulation of a logical data model
2. The physical implementation of the database schema

Development of the data model for the SA revolved around three key sets of information: (1) the existing GIS database design and GIS data; (2) GIS attribute workshop discussion reports, and (3) workflow workshop reports.

The old GIS database design had not been developed properly and was in need of a series of fundamental alterations. Of note, the existing database design utilized text fields for numerical ID attributes, had limited use of domain values, and had no functional way to utilize subtype classifications or topological relationships amongst varying features. These issues were relatively easily identified and corrected in the data model. For example, the old GIS used a text/string type field to hold construction date information for all of the water and sewer assets. Furthermore, there were no constraints on how that textual information could be entered by users. As a result, the construction date information in the old GIS was entered in a wide variety of formations. The date of May, 2005, for example, was able to be entered as any of the following: (1) *05/2005; (2) May 2005; (3) 05-01-2005*; and (4) *May 05'*. This makes analysis of the date information cumbersome and complicates movement of that information into a properly formatted date field.

Additionally, in order to properly develop a data model, the SA team had to consider how the EGIS would interact with other SA systems, which information would be stored in GIS versus CMMS, and how that information would be used in the future. To answer these questions, the SA team consolidated the comments and information collected during the GIS system and workflow workshops.

The SA team also identified all data in the GIS that was also stored in other systems such as CMMS and CIS. If similar data was stored in two or more systems, one system was identified as the appropriate container for that information and linkages/relationships from GIS to the other system(s) were defined. For example, manufacturer information for water and sewer mains existed in CMMS and GIS. CMMS contained accurate manufacturer information and had functional business rules in place for continued manufacturer attribute edits. The GIS system manufacturer information was not well maintained and there were no existing business rules to properly address that information. The SA team decided to eliminate manufacturer fields in GIS and 'pull' that information from CMMS via use of an IDOBJECT attribute field common to both systems. Additionally, the team decided to eliminate certain attribute fields that were no longer in use or fields that had been added in the past but never used.

The SA team then identified GIS layers that could be merged into a single GIS feature class and subdivided via use of feature Subtypes. Subtypes are a subset of features in a feature class that have similar attribute fields. The SA team's treatment of water valve data provides an example of the use of Subtypes. The SA's old GIS system had several GIS layers for water valves, including water fitting valves, water main valves, and water hydrant valves. The new GIS conglomerated these valve layers into a single water valve layer which was then subdivided through use of geodatabase Subtypes. The SA utilized subtypes in its database model as an efficient means to categorize and simplify the storage of data, increased performance, set default values for the varying subtypes and apply connectivity rules between other subtypes and feature classes to maintain the integrity of its geometric network.

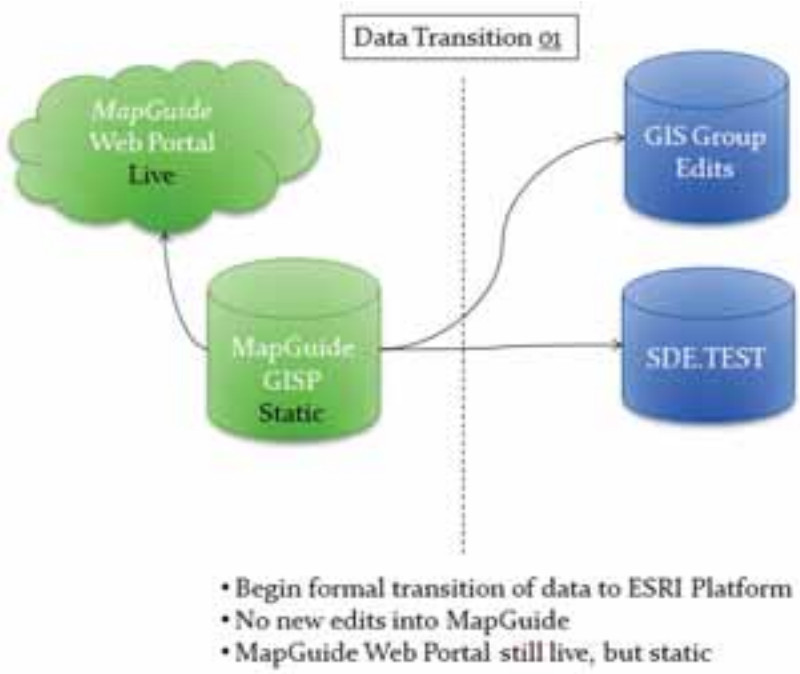
Next, the SA identified information to be collected in the future as part of an expanding desire to refine and develop asset management capabilities. The team carefully evaluated which attributes would not only be useful in the future, but could also be feasibly collected and maintained.

Upon completion, review and approval of the data model, work began on the development of the physical database. The SA utilized ESRI's SDE database model for development. SDE was chosen for two primary reasons. The first reason is that the SA planned to implement versioned data editing as part of its GIS Group production environment,. The second is that SDE provides superior performance when serving GIS information to web portals. The initial development database was named SDE.TEST and the later production database named SDE.PROD.

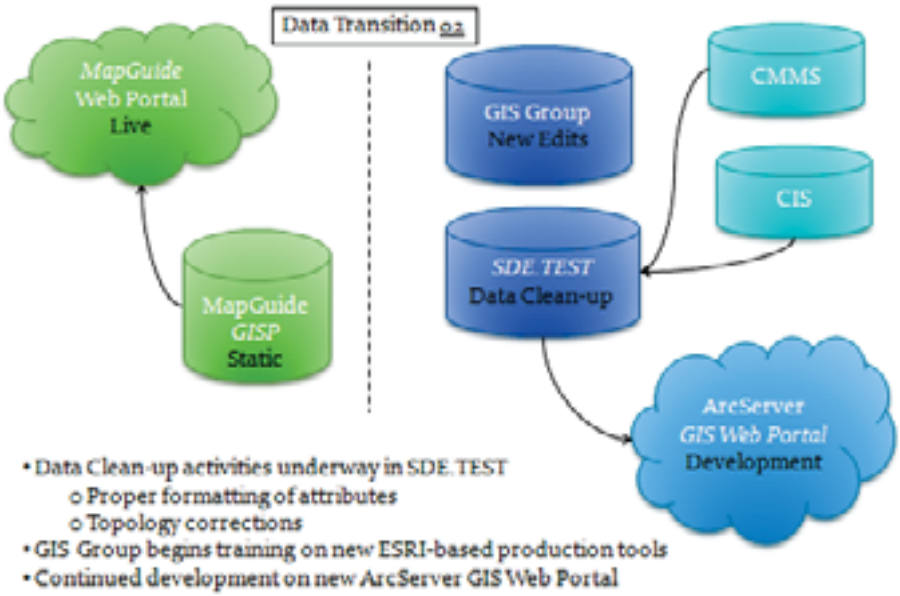
Data Transition and 'Go-Live'

Data transition from one system to another is a critical step in the project's life cycle. This step involves the formal transition of data from the Autodesk environment to ESRI. Any future editing to the Autodesk system is suspended, new production tools are rolled out, in-depth training for the GIS Group commences, and the challenging task of moving data from an outdated database to a more sophisticated database schema begins.

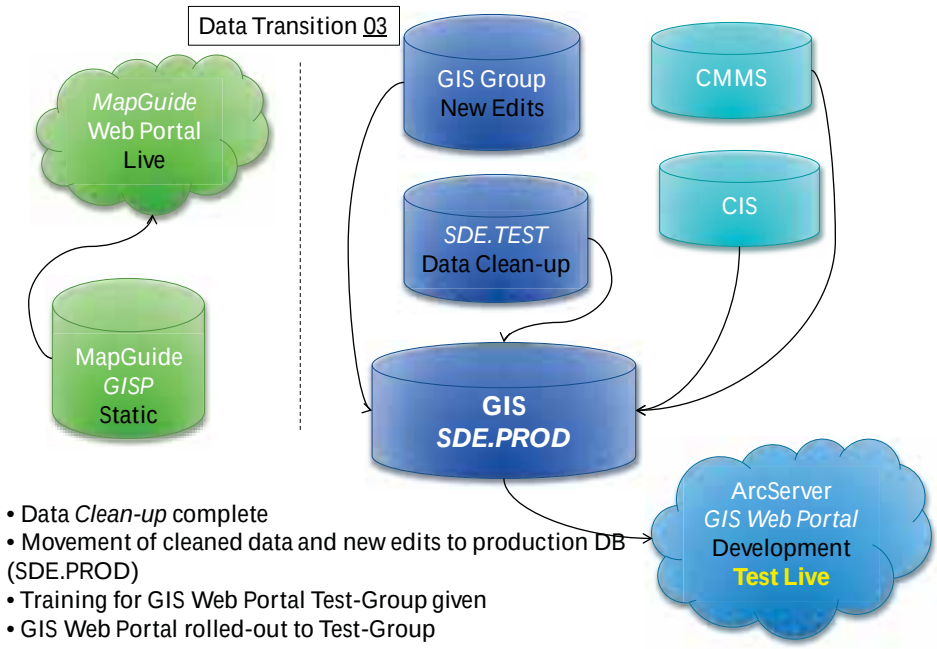
On the initial day of the transition, the SA team suspended new edits to *MapGuide* and prepared a database dump of the Oracle Spatial database. The new database schema (SDE.TEST) includes a variety of changes from *MapGuide* related to how GIS information is stored, which GIS layers that information is stored in, and in which fields; therefore, only geometry could be automatically loaded from *MapGuide* to SDE.TEST. Data clean-up activities are scheduled to begin on the following step to address topological corrections and attribute corrections. These corrections took approximately 4 weeks. Within that 4 week window, the GIS Group was able to continue GIS production work on a separate GIS database which acted as a copy of SDE.TEST. New edits within this database were acceptable, but not changes to existing data. At a later date, the new edits would be rolled-into the production database prior to 'go-live.' The *MapGuide* Web Portal remains live at this point, but contains static GIS data.



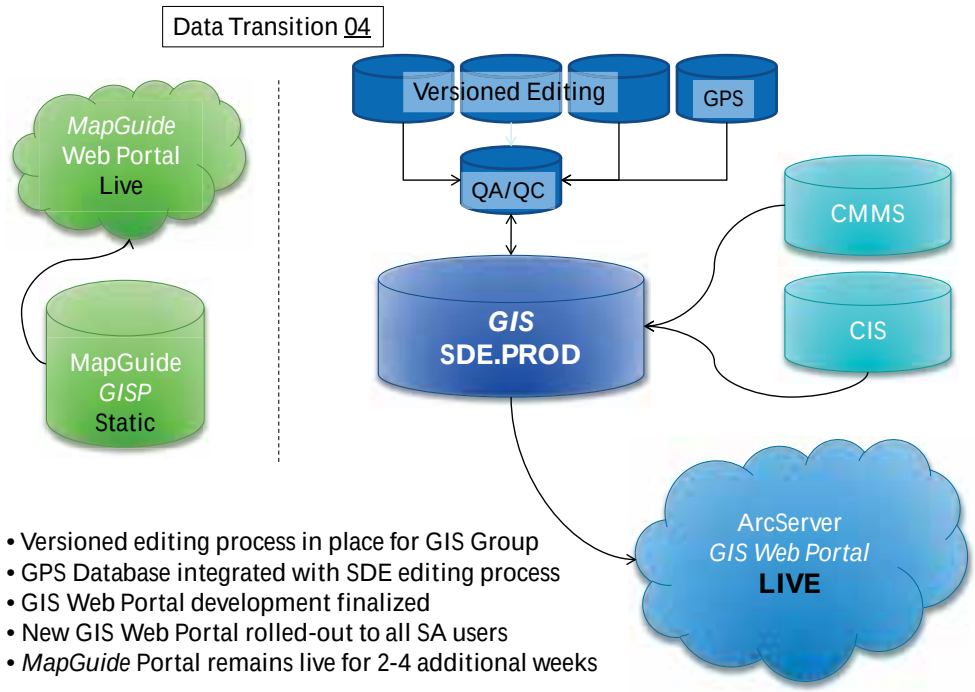
The second phase of the data transition involved the integration of CMMS and CIS to SDE.TEST and data clean-up activities. The integration relationships had been developed in prior activities, but up to this point integration testing was performed on sample data tables from CMMS and CIS, rather than on the live systems themselves. The ArcGIS Web Portal still under development was now running on live systems, rather than static testing databases.



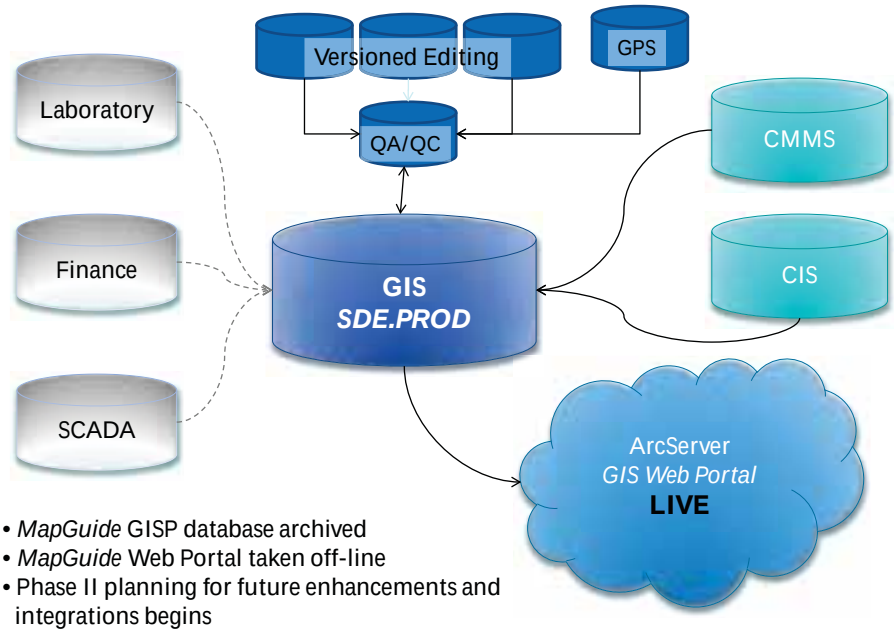
Upon completion of data clean-up activities and a QA/QC review of data mapping activities, the data from SDE.TEST and the GIS Group's production database was loaded into the final GIS production database (SDE.PROD). Integrations from CMMS and CIS were transferred from SDE.TEST to SDE.PROD and the ArcGIS Web Portal was linked to the new GIS production database. At this point, the new GIS database (SDE.PROD) includes all GIS data from the *MapGuide* environment plus any new edits created by the GIS Group over the subsequent 4 weeks, additionally, data from CMMS and CIS is viewable in the ArcGIS Web Portal. The ArcGIS Web Portal was rolled-out to a test group for review and analysis before went live to the entire SA. Training was performed for the test group and they were given instructions on how to review and document any comments they may have related to the portal. Comments from the test group provided essential user feedback for final configuration of the ArcGIS Web Portal.



Final configuration to the ArcGIS Web Portal was completed as step four of the transition process enabling it for 'go-live' to the rest of the SA. *MapGuide* remains live for another 3 weeks while SA personnel transition their workflows from one system to another. The versioned database editing environment is active for the GIS Group and system integrations with CMMS and CIS are finalized.



The final step of the transition process involves archival of the *MapGuide* system, including Oracle Spatial database, editing tools, and web portal. Planning for future enhancements begins – in this case, the SA has begun planning for possible GIS integration with Laboratory management systems, SCADA, and Financial information.



ArcGIS Web Portal Design and Development

The existing *MapGuide* Web Portal had been a stable and trusted source for geographic information related to the SA's sewer and water network but its functionality was rather out-dated and lacked fundamental capabilities related to system integration, data analysis, and data visualization that are common in ESRI's ArcGIS Server tools. As part of the *GIS Transition Project*, the SA decided to develop and implement a new ArcGIS Web Portal giving SA personnel access to not only the GIS information it was accustomed to, but related information from CMMS and CIS.

ArcGIS Web Portal design began early in the project life cycle as part of the workshop discussions. Information from various SA departments was garnered from discussions related to what functionalities would be available to the SA with ArcGIS Server technology. Internal personnel quickly realized the capabilities and began providing feedback related to how they could effectively use information from their tabular database systems in a spatial context.

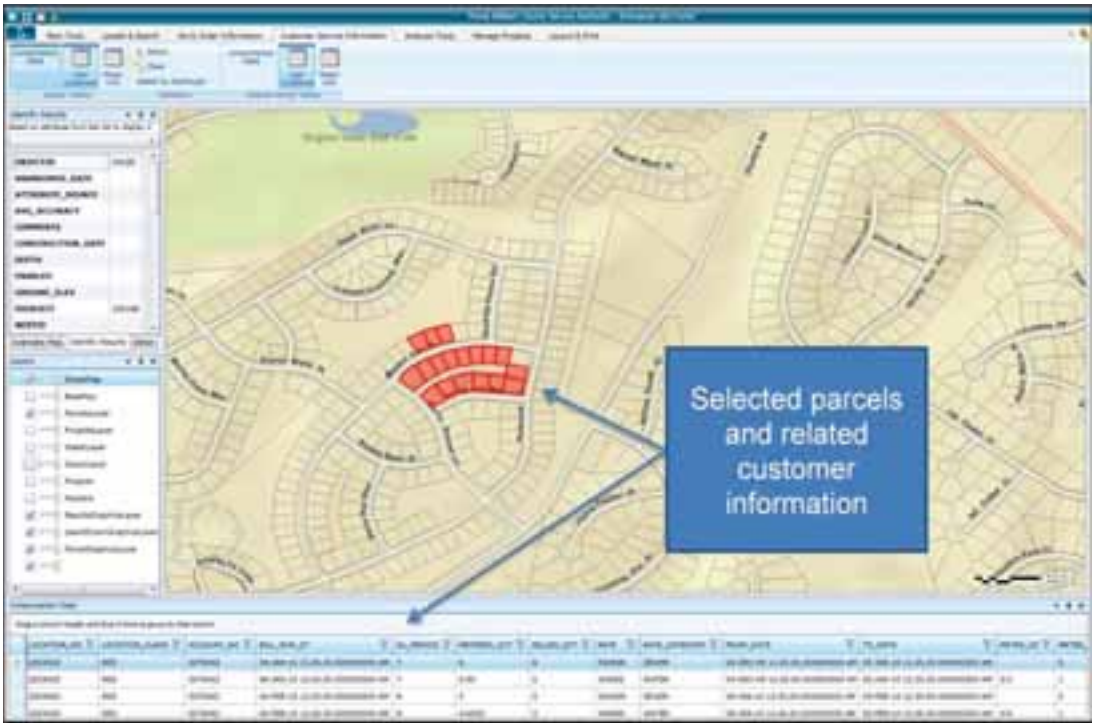
Operations & Maintenance had always been heavy users of *MapGuide* in the past. Existing O&M workflows revolved around field personnel looking up asset information in *MapGuide* such as pipe diameters, asset ID's, and valve and line locations. They also needed access to CMMS for work order information and manufacturer information. Furthermore, they often needed to look up customer information from CIS at a job site and determine the name and contact information for a particular account and if there were any critical remarks on the customer's account such as no-cutoff restrictions. It was discovered that O&M personnel routinely used CMMS, CIS and GIS throughout their daily routines to complete their tasks.

Customer Service personnel had never been users of *MapGuide* in the past and relied solely on tabular database information. Customer Service personnel relied on their CIS database to provide crucial account information to customers when they called in to discuss billing inquires or other account issues. Customer Service personnel reported that it was challenging to navigate the numerous modules of the CIS to collect the information they needed to adequately deal with customer inquiries. Data such as consumption history, billing amount, liens on properties and cutoff restrictions were all located in different parts of CIS and were time consuming to navigate. Customer Service personnel were not aware of the locations of most work orders being completed by O&M nor did they have a way to determine the spatial context of customer calls throughout the day.

The Engineering Department had always been the 'power' users of *MapGuide* and relied on it to provide simple network analysis, project management information, document hyperlinks for plans and records, as well as overall asset attributes related to the water and sewer network.

ArcGIS Web Portal design focused on integration of information that is commonly used by SA personnel in a spatial context accessibly via a single web interface. Web Portal planning for O&M and CIS focused on combining the information they routinely need from GIS, CIS, and CMMS.

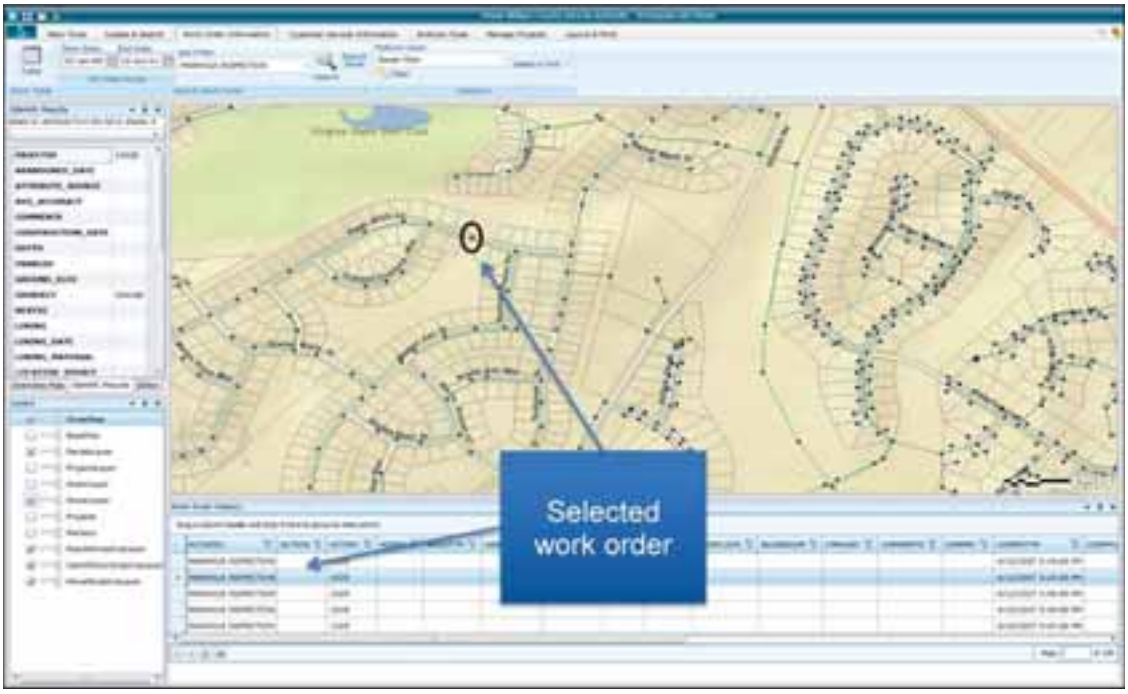
By integrating GIS with CIS, O&M and Customer Service personnel would not need to log into CIS to look-up customer information. Integration relationships between the GIS parcel layer and the CIS database provided a linkage between the two systems. SA personnel are now able to search for a particular parcel address or customer name and zoom to that location, then access the CIS information for that account that via a database view established in SDE from CIS. This saves O&M time because they no longer need to log-in to a separate system and it saves Customer Service personnel time because they do not need to navigate several CIS modules to find the information they need.



CMMS integration was focused on the 'mapping' of work orders in the GIS. The SA's CMMS system contains over 300,000 work orders that have been performed over the last several years. Most of these work orders are either tied to a particular asset, such as a water valve or manhole, or they are tied to a particular address. Work orders tied to assets are relatively easily linked to a GIS record; therefore, by integrating GIS with CMMS, users can view those work orders spatially. Likewise, work orders tied to an address can be linked to the GIS parcel layer via use of an address ID number, further enabling additional work order mapping.

For the first time, the SA is now able to view and analyze where work is being performed. By associating work order codes the SA can also identify what type of work is being done is certain areas and in what time frames. Similarly, the Customer Service personnel can view where work orders are taking place and provide up-to-date information to customers as they call in – identifying issues and communicating response times to customers in a way that was not possible in the past.

Furthermore, the ArcGIS Web Portal was designed to include improved data analysis features and search capabilities. The SA relied on .NET controls that give users the ability to create simple and/or complicated search queries on attribute information from GIS, CMMS and CIS. For example, Customer Service users can create a query to search for all properties with late payments and refine the search based on street name, select a particular record from the attribute table, then zoom to that property. O&M personnel can open the work order table from CMMS, categorize all work orders by type, such as manhole repairs, then further refine the search by a date range. Once the user finds the work order(s) they are interested in they can easily zoom to that location for further review. Or, they can simply spatially select an area and retrieve work orders done in that area for a given date range.



The new ArcGIS Web Portal has given SA personnel access to information in a way that was not possible in the past. Users have greatly expanded power to create their own tabular queries and spatial view that data, analyze information from across multiple systems rather than from silos of information, and discover patterns in information that was hidden in the past.

Conclusion

To date, the *GIS Transition Project* has been a success for the SA. It has enabled the SA to access information in a spatial context that was not possible with prior applications. Additionally, it expands the role of spatial information within the company and lays the foundation for continued tool development and system integrations. While the newly developed applications are still in their infancy at the SA, they are being met with positive feedback. Project possibilities enabled by the new ArcGIS Server environment, some of which are already under development, include: (1) GIS integrations with water and sewer modeling software; (2) system integration with SCADA systems for real-time reporting of SCADA data from the ArcGIS Web Portal; (3) mapping of financial information throughout the county for a spatial view of where SA money is being spent and on what activities; (4) density analysis and mapping of chlorine residuals: and (5) mapping and spatial analysis of customer complaints. The *GIS Transition Project* has enabled the SA to make excellent progress toward meeting its GIS vision.

Contact Information

The sheer volume of lessons learned in this project makes follow-up discussions critical to fully understand the individual parts of each task of this project. Please feel free to contact me and I will be happy to discuss any questions you may have. My contact information is below:

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