Challenges in Developing and Managing a Regional Stormwater GIS
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Overview

The Northeast Ohio Regional Sewer District (District) is the agency responsible for the collection, conveyance and treatment of wastewater in the Greater Cleveland Metropolitan Area. Recently, the District embarked on the implementation of regional Stormwater Management Program (SMP) – to provide comprehensive stream system and watershed management activities across the District's Service Area, which encompasses all or part of 61 communities in 4 counties. To help ensure successful SMP implementation, a considerable amount of data and spatial analysis requirements need to be met. Prioritizing data collection (from potentially over a hundred sources) and GIS application development while effectively managing costs, resources and end-user expectations has proven to be an extremely challenging undertaking. Additionally, integration of the developing SMP GIS with the existing enterprise wastewater GIS, without diminishing existing level of service and limited staff resources, presents an additional series of administrative and economic challenges.

This paper will provide details regarding some of the various GIS-related challenges in developing and managing a GIS to support the implementation of the District's regional Stormwater Management Program. The paper is organized in the following sections:

- **Background** – Provides an overview of the District and the various proposed roles associated the SMP.

- **Challenges in Defining SMP GIS Requirements –** Provides details regarding the GIS-related requirements to support the successful implementation of the SMP. Also, for various challenges, a brief summary of how these challenges were dealt with and the benefits and lessons learned throughout the SMP GIS implementation are also provided.

- **Challenges in SMP Billing Program Development (GIS Perspective) –** Provides a brief summary listing of the various GIS-related challenges facing the District in the ongoing development and implementation of the SMP Billing components.

- **Summary and Next Steps –** Provide an overview of the next steps in the SMP GIS implementation effort.

Background

In 1972, the Northeast Ohio Regional Sewer District (NEORSD) was created as the regional agency responsible for wastewater treatment collection and conveyance (i.e. plants and interceptor sewers) in the Greater Cleveland Metropolitan Area. This Service Area encompasses the City of Cleveland and all or portions of 60 suburban municipalities in Cuyahoga, Summit, Lake and Lorain Counties (See ***Figure 1 – District Service Area***).

The District's Service Area encompasses approximately 370 square miles and serves approximately 1 million customers (approximately 350,000 residential and non-residential billing accounts). The tributary wastewater conveyance system includes approximately 3,500 miles of locally owned sewer lines, approximately 250 miles of District-owned large-diameter interceptor and intercommunity relief sewers and three major wastewater treatment plants.

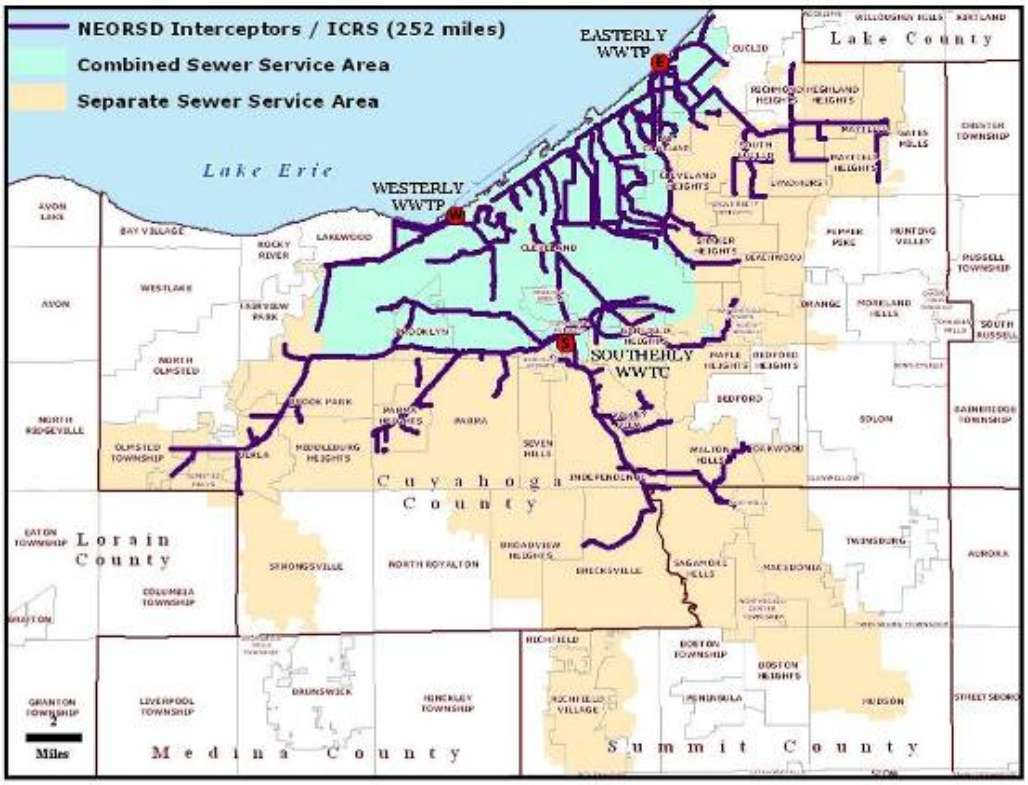


Figure 1 – District Service Area

The District is also responsible for controlling combined sewer overflows throughout the Greater Cleveland area. Furthermore, the District conducts environmental monitoring to identify opportunities within the tributary collection system that have the potential to be enhanced through pollution prevention, green infrastructure and other best management practices. Other District activities include watershed protection, facilities planning and coordinating with local communities and other agencies to ensure that small streams and tributaries are properly maintained. Through these programs, the District minimizes the amount of pollution entering Lake Erie and the Cuyahoga River.

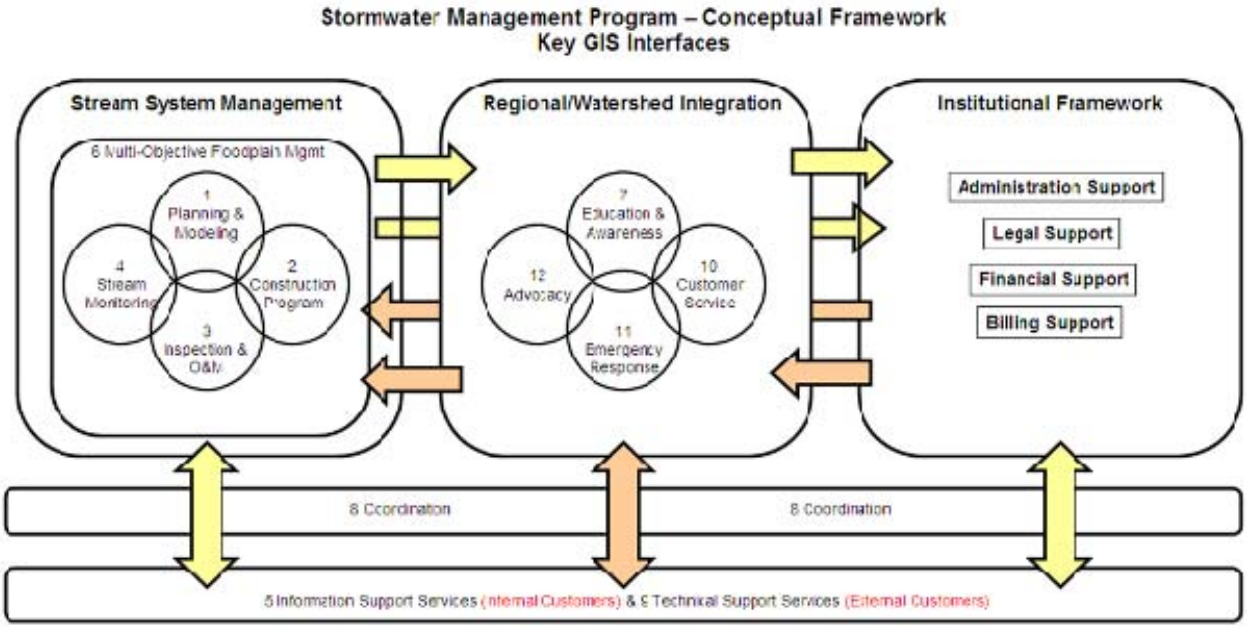
Several planning studies have shown that stormwater problems (e.g. flooding and erosion) are increasing and unresolved. Also, the region's great natural resources (i.e. Lake Erie, Cuyahoga River and the tributary rivers and streams) are facing ongoing water quality issues. Also, in the northeast Ohio region, there is no single agency or entity responsible for regional stormwater management activities. Solving these storm drainage problems can not be done by the individual communities – a regional, multi-jurisdictional approach is necessary. The District has always taken pride in being an environmental-based organization whose focus revolves around clean-water and protecting the health and environment of the District's customers. Additionally, the District feels it has the experience and track-record as a regional agency to be able to provide regional stormwater management services.

As a result, the District embarked on the development and implementation of a regional Stormwater Management Program. The proposed Stormwater Management Program (SMP) will include two key roles and the associated institutional/administrative support roles. The two key program roles are:

- Stream System Management – Focusing on the "Regional" Storm Drainage System
- Regional/Watershed Integration – Coordinating with stakeholders to maximize benefits

These two key proposed SMP roles have various components, or activities, anticipated to be provided. These roles and components are shown in ***Figure 2***.

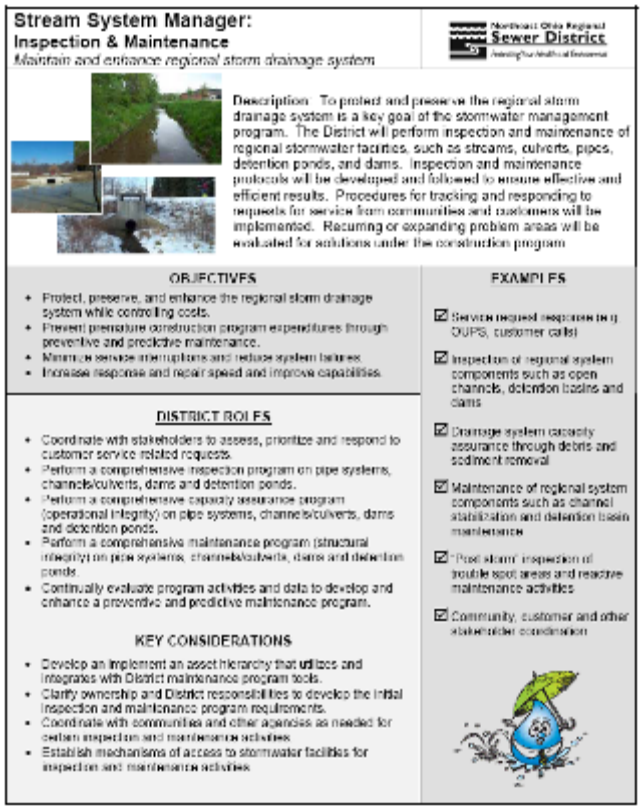
Figure 2: Stormwater Management Program Roles - Interrelationships



The District recognizes that to ensure successful SMP implementation, a robust GIS program will be necessary. The GIS would support or interface with many of the program components, such as Planning & Modeling, Inspection & O&M, Customer Service, Floodplain Management and Emergency Response. Additionally, various GIS analytical tools are being used for Billing Support – to create the SMP Billing Database – which is being developed utilizing parcel data, impervious coverages and various geocoded account and related landbase datasets.

Challenges in Defining SMP Program GIS Requirements

Defining the various activities, and the data and GIS requirements, for each of the SMP roles proved to be a very challenging – and ongoing – effort. The District conducted many internal workshops to help frame the activities that should be performed as part of the SMP. In addition, two rounds of meetings with the District's communities (approximately 100 meetings in all) were conducted to gather input for the District's SMP development. This effort resulted in a comprehensive series of program summary documents – outlining component objectives, District roles and Key Considerations (See right - ***Figure 3 – Inspection & Maintenance Program Summary***).



From these SMP Summary documents, the various datasets and initial GIS requirements were identified. However, identifying and prioritizing the GIS data and application requirements was not an easy effort – as many challenges were discovered along the way.

One of the key challenges that needed to be addressed was - ***What is the Regional Storm Drainage System***? In other words – which facilities (storm sewers, streams, detention basins, etc.) would the District be responsible for as part of the SMP? It was necessary to answer this question first – in order to help identify and define the other SMP GIS Requirements.

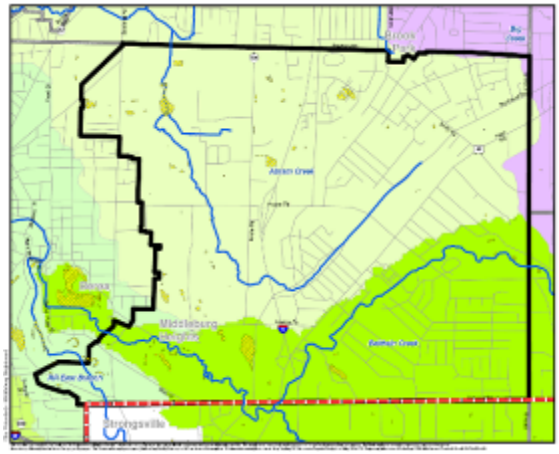
Defining the Regional Storm Drainage System

One aspect of the regional approach to managing stormwater is defining the extent of the storm drainage system that is considered the local system (whereby the local communities are responsible for their operation and maintenance) and the extent that is considered to be regional system (whereby the District would be responsible for the operation and maintenance). The Court Order that created the District originally defined much of the current regional wastewater conveyance system, but the Court Order did not include a similar definition for the regional storm drainage system. Therefore, defining the regional storm drainage system was one of the initial GIS-related tasks conducted as part of the SMP implementation effort.

The biggest challenge to defining a regional storm drainage network was finding an equitable and defensible methodology that addressed the amalgamated needs of District and its customers as well as the needs of 61 member communities including the City of Cleveland, 4 county governments, a national park, and numerous other agencies and watershed groups. After

considering several definitions, including ones based on whether or not streams crossed 3 or more jurisdictional boundaries, the following definition was concluded to be possible, maintainable, practical, and legally defensible:

> *"The system of open channels and closed systems that commences from a point where the accumulated drainage area is approximately three hundred acres and runs lengthwise downstream along the centerline of the drainage until it either reaches Lake Erie or flows out of the District's service area for stormwater management."*



Using GIS software, the preliminary regional stormwater system was delineated utilizing various data sources and by utilizing a combination of both automated and manual processes. The starting point was a GIS layer called RP3Link (from a previous regional drainage study) that identified major drainage features in the District Service Area and some outlying regions. This data layer served as a baseline dataset for the SMP drainage system layer as it already contained reasonably spatially-accurate representations for most of the major drainage features in the region. However, the RP3Link dataset did not offer any supporting attribution to establish whether or not a drainage reach was regional according to the 300-acre drainage rule discussed above. An approach was devised to use the available topology and stormwater feature GIS-data to generate a polyline layer delineating theoretical surface drainage features draining 300+ acres by a process of automated flow accumulation.

The flow accumulation process began with "burning in" the culverted streams from the existing drainage layer into a terrain dataset built from elevation data ensure that water drains under the road at the culvert location. Flow direction and flow accumulation grids were built from the DEM, and a vector layer of theoretical surface drainage features draining 300 acres or more was derived from the flow accumulation grid. The nature of the processing produced a layer that itself was not spatially-accurate enough to serve as the end product drainage system layer to support the SMP, but it was satisfactory to use as a general guideline for where a surface drainage feature existed, and to indicate how far up into the drainage system the regional classification needed to be applied to pick up 300 acres of drainage.

Using the 300-acre flow accumulation polyline as a guide, corresponding reaches in the RP3Link drainage dataset were manually attributed as being "regional" in ArcGIS 9.2. SWMM Model delineated catchments generated during a previous drainage study were referenced to verify the acreage being drained by a drainage feature. In areas without RP3Link coverage, the regional drainage network was digitized using hydrology datasets supplied by the local County governments. While this process helped to generally define the overall extent of the regional drainage system, the specific termination points along each reach where the system transitioned from regional to local needed further refinement.

To be practical with overall O&M, field inspection, and physical references, regional stormwater system termination points should occur at locations that are identifiable in the field by a maintenance crew (e.g., at a road crossing rather than at a mathematically-derived location identifiable only by a latitude and longitude coordinate). The upper end of each drainage reach flagged as regional by the 300-acre rule was visually inspected in GIS, and extended or truncated to a nearby landmark that would be field-identifiable and easily interpreted. These features included:

- Transitions from open channel to culvert at road crossings.
- A fence post or other human-constructed landmark if no road crossing was nearby.
- The confluence of two streams or pipes.
- A drainage basin.

The end result of the regional drainage definition effort was a defined regional drainage system of approximately 550 miles of streams, culverts, storm sewers and other drainage features. ***Figure 4*** shows the regional drainage system that was the end result of this process.

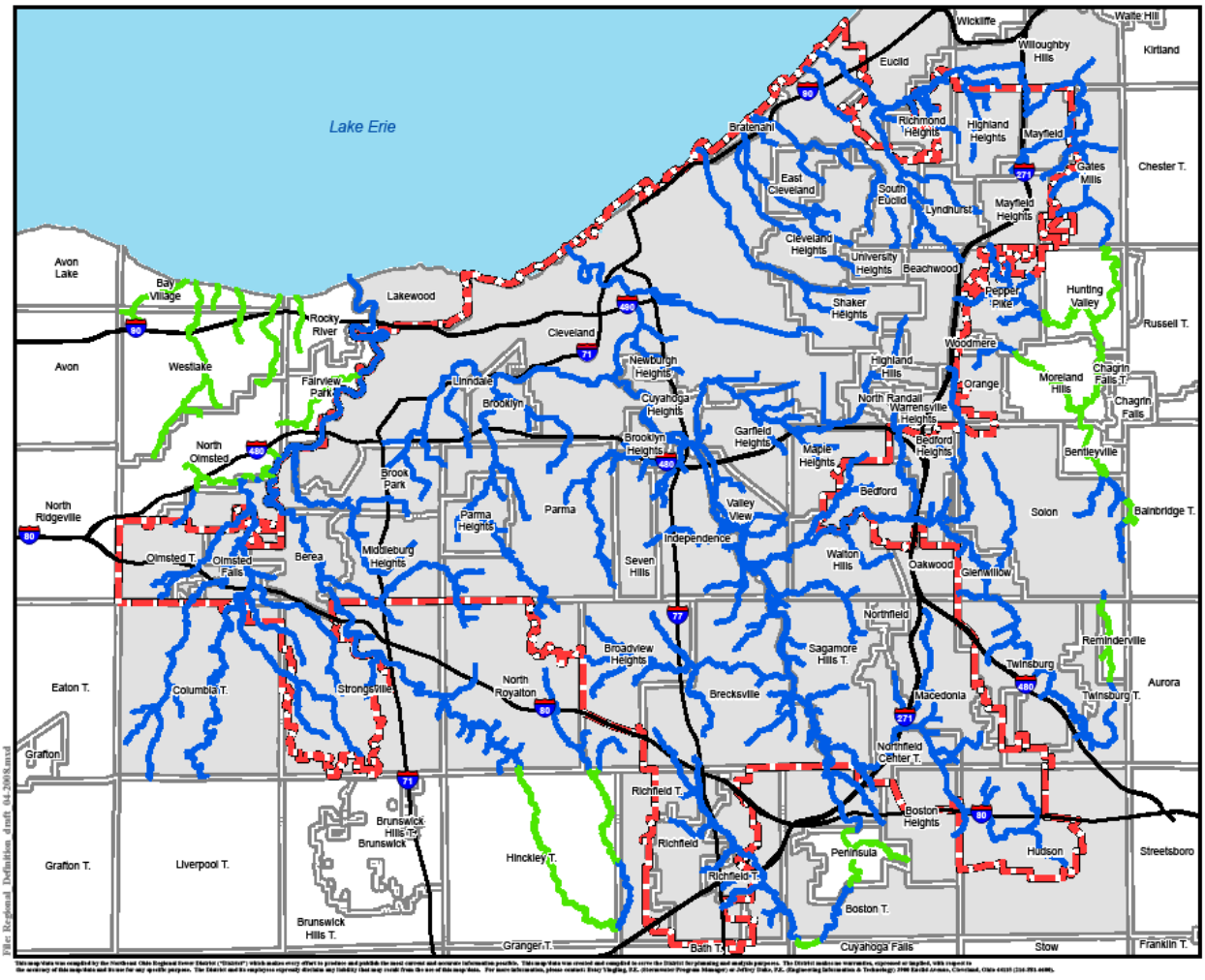


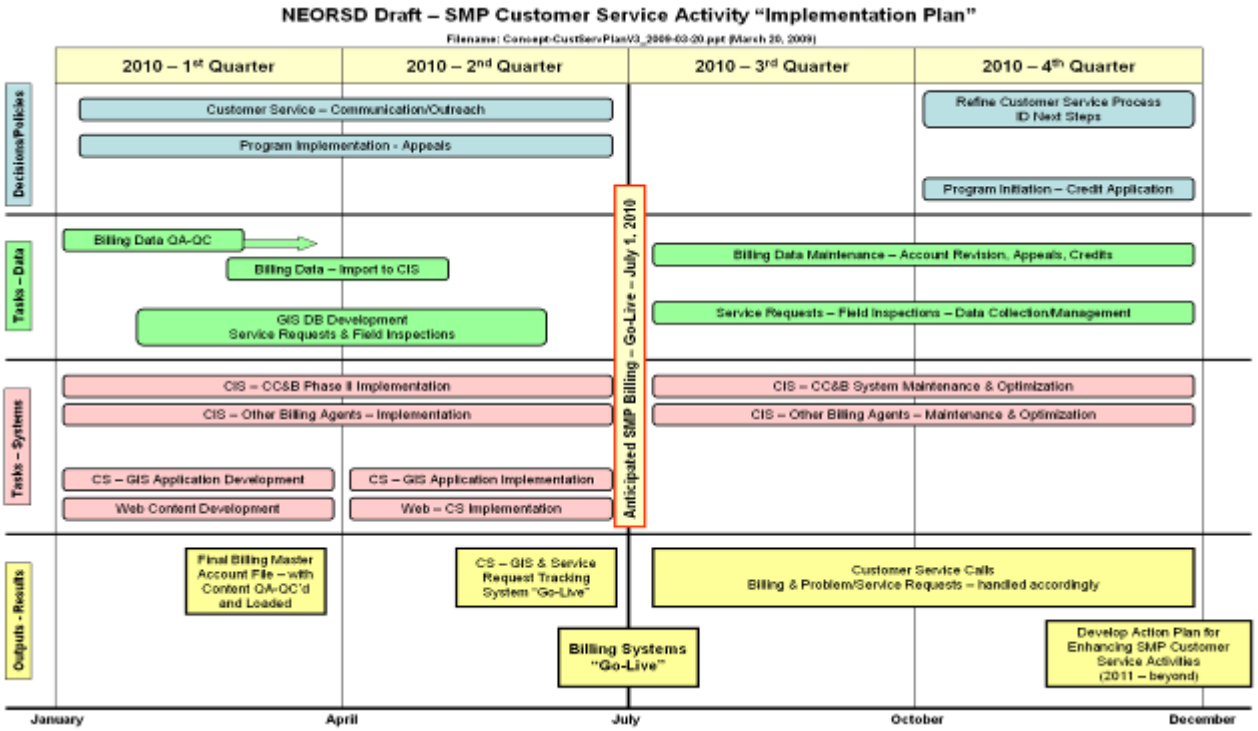
Figure 4 - Regional Storm Drainage System Overview

Defining Stormwater Program Activity – Specific GIS Requirements

To support successful implementation of the SMP, a tremendous amount of data was identified as needed for the various program activities. These various datasets would come from a wide variety of local, regional, state or federal sources. To help manage the collection and administration of this data, a Data Collection and Management Plan (DCMP) was compiled to serve as a roadmap for creating a comprehensive regional stormwater program dataset that supports the SMP.

Each of the 12 SMP program components has ramp-up activities scheduled over the first six years of the Stormwater Management Program. Many of these ramp-up activities will include detailed needs assessments of the specific program components' anticipated processes and data needs (See *Figure 5 - Example Customer Service Ramp-up Schedule*). As such, the initial iteration of the SMP Data Collection and Management Plan focused on identifying the anticipated GIS data needs to support the SMP start-up activities in the first 2 years of the program (Years 0 and 1). As various ramp-up activities are performed and the data needs are defined in more detail, District staff will add that improved information to the DCMP.

Figure 5 - Regional Storm Drainage System Overview



The data needs have been documented under thematic categories as follows:

Administrative	Billing
Cultural Interest	Elevation
Imagery	Landbase
Monitoring and Inspection	Time-Series
Water	

Each category contains a series of discrete GIS datasets grouped by the year in which that data layer is first needed or will be collected or generated.

- Year 0 – For datasets needed in Year 0, a data capture plan is listed that includes details on anticipated attributes & ID schemes required to support the SMP components.
- Year 1 – For datasets needed in Year 1, less detail is provided about the structure of the data as these details are often scheduled to be established during Year 0 ramp-up activities.
- Years 2-5 – For datasets in Years 2-5, general discussions are provided without dataset specifics.

The SMP DCMP will be used to guide the construction of the SMP GIS data model, which will be implemented in the NEORSD Enterprise ArcGIS Server geodatabase. The DCMP includes a detailed schedule for dataset acquisition/creation activities to help ensure that all data is in place as it is needed during the SMP ramp-up activities.

Miscellaneous Challenges – For Consideration

As stated previously, many challenges were discovered along the way in identifying the GIS requirements to support the SMP activities. However, each of these challenges cannot be explored in detail in this paper. Some of the key challenges that were encountered are described below:

- **Lack of defined "To-Be" Business Processes –** The SMP has identified many of the objectives, roles and key considerations for each of the program activities. However detailed "To-Be" Business Processes were not defined as anticipated. Without "To-Be" business processes driving the data requirements, GIS staff had to focus on data inventorying and trying to define data and application needs rather than SMP GIS data modeling. It was difficult to develop data needs for a new business that is unfamiliar to GIS staff.

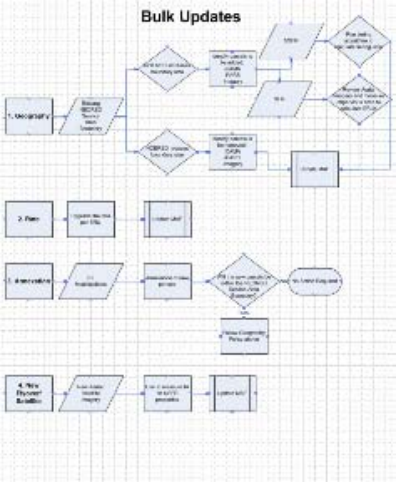
- **Data Collection Priorities (Year 0, 1, 2-5 Process) –** Because there were many different stakeholders involved in defining the SMP activities, it proved to be difficult to objectively define "GIS-related data & application needs" with a group. Many stakeholder showed the tendency to want everything now/soon "just in case". Initial draft requirements were for essentially all data to be available in Year 0 – which is not realistic or cost-effective. Additionally, many data layers need to be collected from many sources which are proving to be a logistical and administrative issue.
- **Multiple Sources – Accuracies – Details –** Every dataset that is recommended to be collected or created needs a data maintenance plan. That is a significant time investment to create and maintain given the sheer number of datasets involved with the SMP. Also, it has proven difficult to compile a cohesive regional drainage network from so many sources of varying accuracy.

- **Program Components – Competing/Conflicting Needs –** It has proven difficult to define a regional drainage system geometric network structure that will meet all program component needs – including planning & modeling, mapping, inspection/O&M, and jurisdictional reporting needs all at once. Also, due to organizational business requirements, it was difficult to define a regional drainage dataset schema without knowing how the asset hierarchy will be structured in the District's Computerized Maintenance Management System (CMMS) for O&M purposes.
- **Cultural-Regional Challenge -** The State of Ohio is a strong "home-rule" state – where communities have a lot of power. This has led to a lot of parochial thinking – where collaboration across municipal and county boundaries is often difficult. This has resulted in delays in developing and implementing regional GIS data sharing and application development. The greater Cleveland-Cuyahoga County area does not have the mature regional GIS infrastructure of similar cities (Louisville – LOJIC, Cincinnati – CAGIS, etc.).

Anticipated Challenges – The Road Ahead

Additionally, many GIS-related challenges are anticipated to be facing the District as the SMP implementation continues. Some of these challenges are summarized below:

- **Data Maintenance**
  - Implementing new data maintenance activities and processes with limited resources
  - Defining the District's role in data maintenance activities – regional or decentralized? Will other stakeholders buy into the District as a central data repository
  - Defining data maintenance plans for various data layers that accommodate internal and external stakeholders' maintenance of similar data - will be a huge coordination effort.



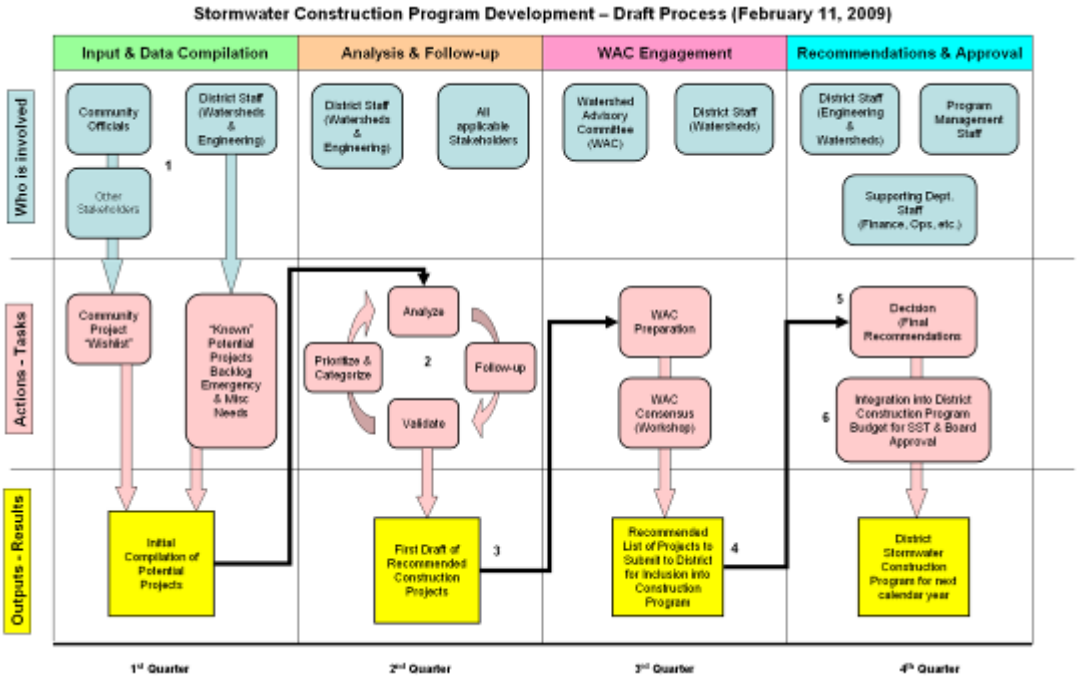
- **Data Access**
  - Need to develop data sharing and updating agreements.
  - Can the District's IT infrastructure support many stakeholders accessing information from external agencies?
- **GIS Application(s)**
  - Defining functional requirements for internal needs and external users
  - Development, rollout and ongoing administration of various GIS applications – including web-based map portals, mobile GIS data collection and map and report production.
- **Customer Service - Service Requests (Stormwater Problem Response)**
  - Defining Customer Service Program Needs – Need to define data access and GIS application needs for Customer Service representatives. Due to unfamiliarity with SMP and GIS – will need to keep simple/user-friendly and provide significant training.
  - Potential integration of Customer Service – GIS application with other District information systems.

For additional information on any of these challenges and how they are being addressed, please feel free to contact the authors (contact information at end of this paper).

Benefits & Lessons Learned – Points for Consideration

As the implementation of the District's SMP GIS database progresses, many lessons were learned throughout the current efforts that have proven to beneficial in ongoing SMP GIS implementation. Some of these benefits and lessons learned are described below:

- **Leverage Available Knowledge/Resources –** The District recognized that utilizing industry contacts would help with identification of GIS database and application development needs. Stormwater management business processes have been defined before – there are over 1000 stormwater utilities nationwide. GIS professionals from other utilities have provided the District valuable input in developing the District's SMP.
- **Define Business Processes** – Developing detailed business processes/workflows help defines many data needs and potential GIS application functional requirements. A lack of detailed business process/workflows makes decision-making and prioritization very difficult. Business processes clarify/define direction for data modeling and application/functional requirements. See graphic below for an example of Construction Program-related Business Process. The District now can use this as a roadmap to identify data needs throughout the process.



- **Identify Driving Forces** – It is important to understand and agree on what are the driving forces for developing a new program. Do the program requirements drive data & application needs (even if it means more costs/resources) or does the available resources – data, application, personnel – drive what services can be provided? In the District's case the SMP requirements drove the prioritization of the GIS Data Collection & Management Plan (DCMP).
- **Stakeholder Buy-In –** Spend the time coordinating and communicating with external stakeholders to maximize meeting user needs without significant extension of available resources.

- **Clarification of "NEEDS" vs. "WANTS" –** It was identified early on that users "***needs***" resulted in unrealistic prioritization for data collection and GIS application development (i.e. These "needs" were actually "***wants***"). It was necessary to make sure there was consistent understanding of *when* data is needed and *how* it could be accessed.
- **Data Inventory –** Perform a comprehensive data inventory (knowns & unknowns, sources). This exercise is recommended at the beginning of any major GIS implementation effort. This helped to bridge gaps from lack of clearly defined To-Be Business Processes. A benefit to the District is that this inventory will help streamline ongoing data collection efforts.
- **Managing User Expectations –** *Data accessibility and Application "User-friendliness"* – Users are very used to very intuitive, user-friendly applications (e.g. Google-Earth) – and want to have data available at fingertips and applications able to be used with minimal training.
- **GIS Application Development Strategy –** Previously, the District's GIS application philosophy was more of "1 STOP SHOP". Now, with ArcGIS Server 9.3 being implemented – the District anticipates a suite of "light-weight" business process-specific applications.

Challenges in SMP Billing Program Development (GIS Perspective)

In addition to the various SMP components requiring a tremendous amount of GIS data and application development, the development of the SMP Billing Program relies very heavily on GIS for various activities. GIS has been predominantly used in the development of the SMP Billing Program database – providing key assistance in calculating the appropriate stormwater charge for each applicable parcel. The stormwater charge was based on impervious area for each parcel – which was either derived from satellite imagery or digitized from recent digital orthophotography.

Due to many factors, the SMP Billing Database has not been finalized at this time. Many challenges and issues have been encountered to date. These challenges are briefly summarized below:

- **Billing Database Development**
  - Multiple data sources and formats have caused some increased data conversion and data modeling efforts.
  - Various policies had to be established to provide direction on various digitization activities. Some key policies that needed to be established included:
    - Impervious Feature Definition
    - Minimum Mapping Unit
    - Minimum Width for Digitization
    - Parcels with Common Areas
    - Public and Private Road contribution to Impervious Area Calculation
    - Charge Structure (e.g. Residential Tiers and Non-Residential Equivalent Resident Unit value)

- **Assignment of Stormwater Charges**
  - Parcel Aggregation – Thousands of contiguous parcels have the same owner - and the District has decided to provide a SMP charge/bill on an aggregated basis rather than an individual parcel basis. Several parcel aggregation scenarios have been identified for data rectification.
  - Parcel – Account Matching – Current billing systems are account/address based – and not parcel based. It is necessary to assign parcels to accounts to ensure proper stormwater billing.
  - Billing Program Policies – Undefined programs for Credits (i.e. fee reduction for good stormwater management practices) and billing appeals (i.e. review of impervious calculation to ensure proper charges are assigned) prevent finalization of database design and billing/customer service GIS application development.
- **Data Maintenance Workflows –** Conceptual data maintenance workflows have been established. However, these workflows cannot be implemented until decisions on billing agents/billing systems are final.
- **Billing Agent/Billing System Coordination**
  - Finalizing the various Billing Agent Options (e.g. Bill internally/outsource or user wastewater billing agents or a combination of both?)
  - Billing System requirements and limitations – especially related to Customer Service program support.

It is important to note that the SMP Billing Database is still in development (as of time of submittal of this paper – May 22, 2009). Key activities at this time include defining the workflows for parcel aggregation and account matching across pilot areas. Additionally, final decisions regarding selecting billing agent(s) and billing system(s) is still not complete. This will not decided until approximately September 2009. The delay in making this decision could impact the finalization of the SMP Billing Data and eventual implementation of the stormwater charge.

The authors intend that as the SMP Billing Database is finalized – a follow-up paper/presentation will be developed to identify how all these various SMP Billing-related challenges were handled to help ensure successful implementation of the program.

Summary – Next Steps

The District originally intended to "go-live" with the Regional Stormwater Management Program in April 2009. However, due to many political and logistical factors, the primary being final approval and overall billing agent acceptance/billing system readiness, the comprehensive program is now anticipated to "go-live" July 1, 2010. This revision of the program "go-live" essentially allows for more GIS data collection, business process/procedure development and GIS application development – which will ultimately result in increased accuracy (e.g. stormwater billing) and enhanced SMP services.

The SMP GIS has two major activities ongoing at this time – Billing System Development and Program Component GIS Database Development. The Program Component GIS Database Development has a detailed Data Collection and Management Plan (DCMP) that includes routine milestones, which have been prioritized to meet the needs of the implementation tasks identified for each of the SMP components. The SMP DCMP is updated routinely – based on changing priorities and other factors.

The SMP Billing System Development is essentially in full production mode – with key activities of Parcel Aggregation and Parcel-Account Matching ongoing. The District anticipates implementing the SMP component into the appropriate billing agent billing systems in October 2009 – to ensure a July 1, 2010 "go-live date".

Also anticipated to start in the fall of 2009 is the development of the various GIS applications to support key SMP activities. It is anticipated that the SMP Inspection & Maintenance Program and the SMP Customer Service Program will require GIS applications to support effective and efficient services. The District anticipates leveraging their existing web-based ArcGIS Server application – entitled DV2 (District Infrastructure Viewer Version 2) to streamline design, development and implementation of new GIS applications. The DV2 application is currently being upgraded from ArcGIS Server 9.2 to ArcGIS Server 9.3 – and that upgrade is scheduled for completion and rollout in 4th Quarter of 2009. The District anticipates that new SMP applications will be built utilizing ArcGIS Server 9.3+. Additionally, the District is investigating GIS hardware infrastructure upgrades and the implementation of ImageServer and/or cached map services – to help meet the increasing demand for users to access multiple series of imagery, and multiple datasets that cross several county and watershed boundaries.

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