ARDMORE BASIN SANITARY SEWER EVALUATION SURVEY AND REHABILITATION MASTER PLAN

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ABSTRACT

Like many municipalities, the Winston-Salem/Forsyth County City/County Utilities Commission (CCUC) has identified areas within its sewer collection system that need rehabilitation or repair due to increased maintenance requirements, overloaded pump stations and treatment plants, and sanitary sewer overflows (SSO's). One high priority area identified by CCUC was the Ardmore sewer basin. Ardmore is an older area that consists of large quantities of vitrified clay pipe (VCP) sewer mains and service laterals and brick manholes. This area has seen a high number of work orders and emergency repairs due to root intrusion, broken/collapsed pipes, sewer system overflows (SSO's) and blockages.

Hydrostructures was retained by CCUC in December 2007 to evaluate the sewer collection system in Ardmore and prepare a Rehabilitation Master Plan to guide CCUC in bringing the Ardmore infrastructure up to current design standards. Hydrostructures started the evaluation by completing a Sanitary Sewer Evaluation Survey (SSES) in 2009, which included locating collection system structures using GPS equipment, preparation of a map and geographic information system (GIS) database, manhole inspections, flow monitoring, pole-camera inspections, smoke testing, cleaning, and closed-circuit television (CCTV) inspection.

Hydrostructures divided the Ardmore basin into 13 sub-basins to pinpoint high priority areas, so that available funding could be focused on the most problematic areas. The Rehabilitation Master Plan prioritized the sub-basins to allow a phased approach for rehabilitation. Hydrostructures used a prioritization matrix system with eight weighted criteria: maintenance records, flow meter data, zoom camera inspections, smoke testing, manhole inspections, cleanout percentage, and water main age and diameter. This matrix ranked the sub-basins 1-13, with basins ranking the highest being the most in need of rehabilitation. These recommendations provided a “road map” for CCUC to incrementally upgrade the Ardmore infrastructure to current design standards while reducing maintenance costs.

The concept of “comprehensive sewer rehabilitation” (rehabilitating all sewer mains, manholes, and laterals within a particular area at the same time) has gained momentum because of its effectiveness in reducing maintenance requirements and eliminating overflows. CCUC has taken a proactive stance by identifying and prioritizing problem areas and implementing comprehensive sewer rehabilitation projects to correct the deficiencies, reduce maintenance costs, and comply with current design standards.

This paper outlines the background of the project, the methods of evaluation, our recommendations to the Winston-Salem/Forsyth County City/County Utilities (CCU), and provides a synopsis of the rehabilitation design and construction of the comprehensive sewer and water rehabilitation for the 13 sub-basins of Ardmore. Particular emphasis of this paper is placed upon the trenchless methods being used, including cured-in-place pipe (CIPP) lining and pipe bursting, general design considerations and specifications, and lessons learned thus far.

KEYWORDS

Sanitary Sewer Evaluation Survey, SSES, Comprehensive Sewer and Water Rehabilitation, CCTV Inspection, Manhole Inspections, Pole-mounted Zoom Camera, Flow Monitoring, Pipe Bursting, Cured-In-Place Pipe (CIPP) Lining, Basins, Prioritization Matrix, Phased Approach

INTRODUCTION

The Winston-Salem/Forsyth County Utilities Division's primary responsibility is to collect, treat, and distribute water, waste water, and solid waste for entire county of Forsyth, including Winston-Salem and all municipalities within Forsyth County. Their CCUC geographic area of responsibility can be seen in Figure 1.

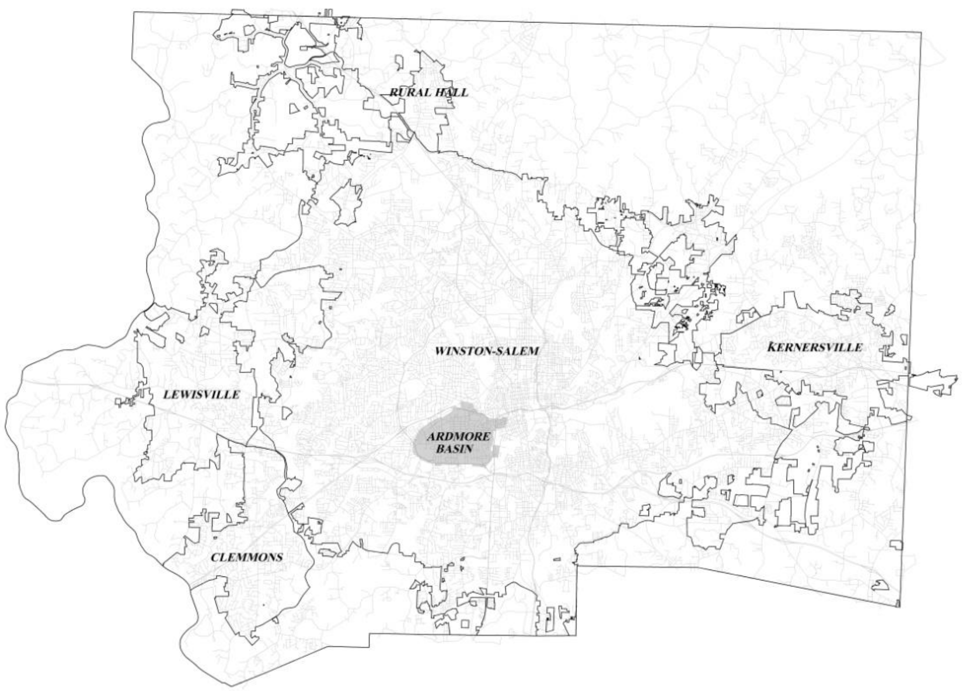

Figure 1
Winston-Salem, Forsyth County, NC

The Ardmore Basin is located just south of downtown Winston-Salem in Forsyth County, North Carolina. The Ardmore system, parts of which date back to the early 1900's, is a largely historic residential district composed of homes built mostly between 1920 and 1950. The Ardmore sewer basin includes over 1,300 manholes, approximately 325,000 LF of sewer mains, and over 300,000 LF of water mains. Most of the sewer mains in the area are vitrified clay pipe (VCP) installed between 1920 and 1940. Being one of the older portions of the CCU system, it includes large quantities of VCP mains, VCP service laterals and brick manholes. It is also subject to a high number of maintenance calls and emergency repairs due to root intrusion, collapsed pipe and sewer blockages. Most of the water mains in the area are older cast iron (CI) dating back to the 1920's through 1940's, with some smaller diameter galvanized mains installed during the 1950's and 1960's. The Ardmore basin is roughly bounded by 421/I-40 Business to the north, Peters Creek Parkway to the east, Silas Creek Parkway to the south, and Stratford Road to the west.

(see Figure 2 below).

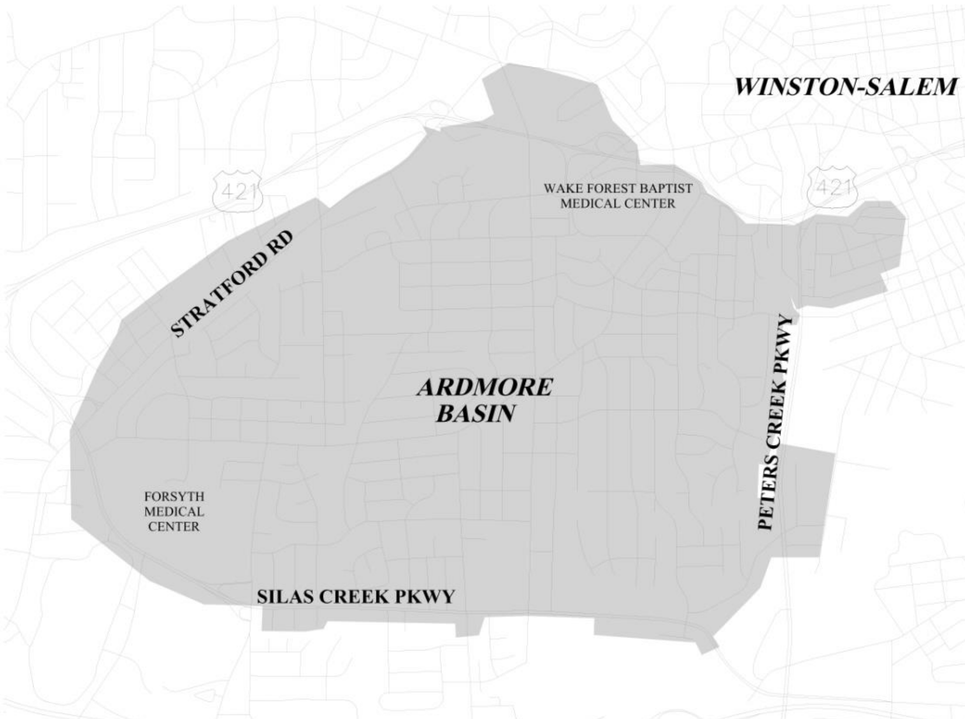

Figure 2
Ardmore Basin Area, Winston-Salem, NC

The Ardmore SSES and Master Rehabilitation Plan was completed in three phases. The first phase was obtaining accurate GIS mapping. The second phase of the project was extensive field evaluation, which included manholes inspections, smoke testing, pole-camera inspections, cleaning of sewer mains, and closed-circuit television (CCTV) inspection. The final phase of the project included the preparation of a rehabilitation master plan. This master plan divided the system into 13 sub-basins and prioritized them for rehabilitation using a prioritization matrix. This matrix used categories such as age, smoke test defects, number of maintenance calls, pipe and manhole condition ratings, percentage of undersized mains, flow meter data, and other data to rank the basins from worst condition to best condition, so that rehabilitation efforts could focus on the highest priority areas first. The City of Winston-Salem has used the Master Plan as a “roadmap” in its rehabilitation efforts, and to date, projects have been completed within the three highest priority basins, while the fourth basin is currently in the design phase, with a projected bid date of Spring 2015.

To date, CCUC has completed work in three sub-basins, with design currently underway in the fourth. CCUC plans to continue to address these priority areas according to the Rehabilitation Master Plan, as funding is available. This methodology, particularly the Prioritization Matrix, could be an effective tool for other municipalities that need to address their aging sewer and water infrastructure in a systematic manner.

METHODOLOGY

GIS Mapping

In the initial stage of the project, the existing GIS database was obtained & used as a base map for all field investigations. To ensure accuracy of the map and database, a total of more than

12,000 sewer manholes, cleanouts, water valves, fire hydrants, water meters, & storm water structures were located using real-time kinetic (RTK) GPS equipment.

Hydrostructures used Trimble R8 RTK (survey grade) GPS receivers to locate all manholes, cleanouts, water meters, water valves, fire hydrants, and storm structures within the Ardmore area. In areas where tree canopy prevented survey grade GPS, conventional survey methods were used to establish coordinates for sewer manholes. All survey data collected was referenced to the North Carolina State Plane Grid, US Survey foot, zone 3200 and horizontal datum NAD83. Vertical data is referenced to NAVD88.

The GPS points were used to correct the sewer geodatabase provided to Hydrostructures by the City. Over 11,500 GPS points were taken during the course of the GPS survey. Vertical coordinates from the GPS locations and depths from manhole inspections were used to establish pipe grades for all sewer mains. An updated geodatabase corrected with the results of field investigations and populated with approved codes from the GIS and Hansen work order system were provided to the City. Below is a GIS map generated showing the 13 sub-basins of the Ardmore Sewer Collection System.

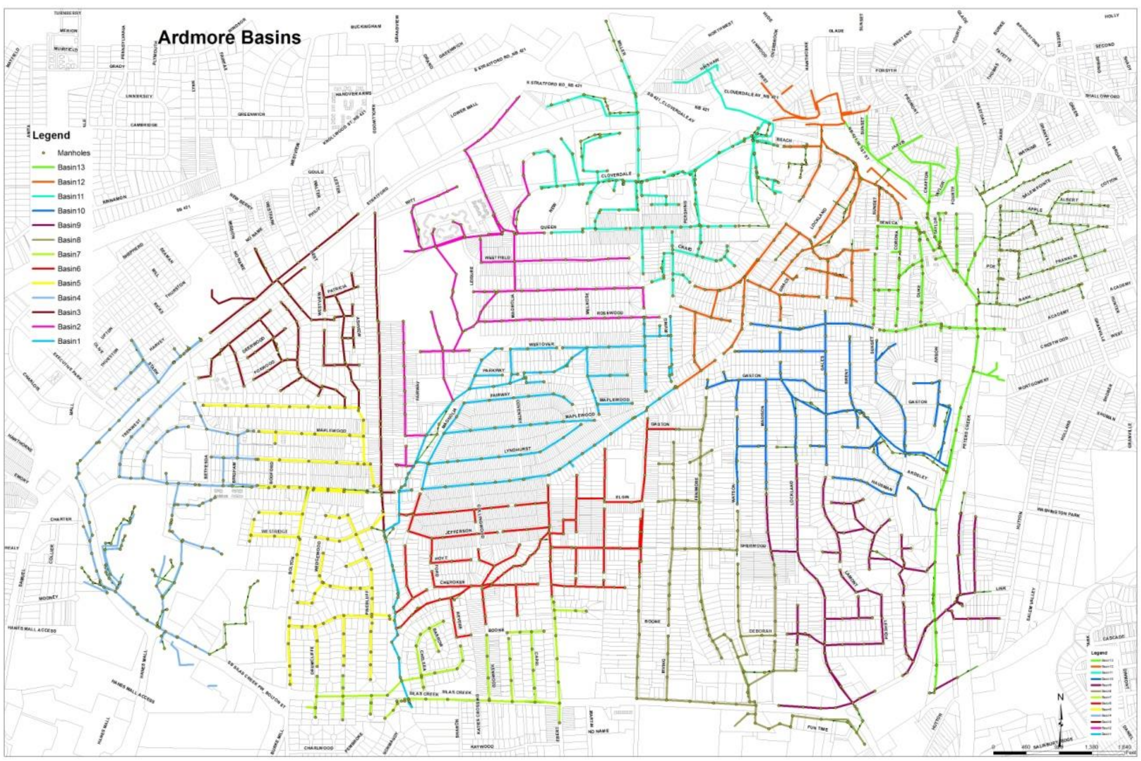

Figure 3
GIS Overall Site Map of the 13 Ardmore Sub-Basins

Data gathered during the various field investigations was used to update or populate the fields of the GIS database. This information included pipe diameters, pipe materials, section lengths, manhole depths and locations, valve locations, fire hydrant locations, etc. Using the GIS database, Hydrostructures was able to develop Material Location Maps and Diameter Location Maps in order to summarize the size, material, and footage of pipe in the Ardmore Sewer Basin. At the conclusion of the project, the entire GIS database was incorporated back into the City's GIS and Hansen work order system. This process was so successful that our contract was amended to include writing a protocol for a standard methodology to be used by all consultants working on similar projects. Table 1 below summarizes the sewer mains in the Ardmore Basin.

Pipe Size / Material	Total Footage
6" Clay	114,280’
6" Cast Iron	680’
6" PVC	1,730’
8" Clay	127,000’
8" Cast Iron	5,400’
8" PVC	690’
10" Clay	10,800’
10" Cast Iron	900’
12" Clay	5,780’
12" DIP	3,400’
15" Clay	4,650’
15" DIP	300’
18" Clay	9,340’
18" DIP	480’
18" RCP	110’
24" Clay	370’

Table 1 Summary of Ardmore Area Sewer Mains

Field Investigations

The second phase of the project included detailed field evaluations of the entire basin, including inspecting more than 1,470 manholes, using pole-mounted zoom cameras to identify defects, smoke testing of more than 325,000 LF of pipe, flow monitoring, cleaning of more than 325,000 LF of pipe, and main line CCTV inspection of more than 32,000 LF of pipe.

A total of 1,473 manholes were inspected as part of the SSES. The inspections were performed by two-man crews who located, opened and visually inspected each manhole. These field crews assessed the condition of each manhole and entered the following information into a manhole database, which includes the following data:

- Manhole number
- Basin and sub-basin name
- Physical location (street address)
- Invert depths of all pipes
- Material types (manhole and pipes)
- Physical condition (frame and cover, walls, bench, channel, etc.)
- Inflow/Infiltration entry points
- Defects descriptions, locations and severity

Each manhole was photographed using a digital camera in order to illustrate the ground cover surrounding each manhole, the overall condition of the manhole interior, and any defects noted. Based on our evaluations, each manhole was assigned a condition rating using the National Association of Sewer Service Companies’ (NASSCO) Manhole Assessment and Certification Program (MACP).

Smoke testing was also performed throughout the entire study area. Smoke testing was performed by forcing smoke through portions of the sewer collection system using a motorized blower. The smoke exits the system through defects in the system such as roof or storm drain connections, broken or missing clean-out caps, abandoned sewer connections, structural damage, leaking joints, etc.

During the smoke testing process, Hydrostructures, P.A. personnel walked each section of line being tested to locate any deficiencies in that section. Each deficiency was photographed and documented to show its location relative to the nearest manhole. This information was entered into Hydrostructures' Smoke Test Database and into the GIS system.

Hydrostructures provided a two man field crew to perform pole-mounted zoom camera inspections on 1,202 sewer mains in the Ardmore study area as part of the SSES. These Inspections were performed on the upstream and downstream ends of each sewer main, except for dead-in lines with no upstream access. The pole mounted zoom camera was positioned carefully at the mouth of each pipe to complete the inspection. The camera uses zoom technology to create the effect of traveling through the pipe. Inspections typically span from 30-100 feet of the pipe depending on pipe diameter, pipe alignment, presence of offset joints or other defects limiting visibility. The videos are numbered using a unique line identification number corresponding to our GIS and stored as MPEG files. The videos vary from 10 seconds to one minute in length. Inspections are limited because the camera only zooms in on its fixed view perspective and does not actually travel through the full length of the pipe as with a typical motorized CCTV camera unit. However, these inspections allow us to identify defects and provide us with a quick assessment of the current condition of the sewer main. Using the inspection videos, we prioritized the sewer mains from priority 3 through 1 based on our observations.

The final stage of the field investigation phase of the project included internally inspecting some of the highest priority mains using a self-propelled, tractor-mounted, CCTV inspection camera coupled with digital video inspection reporting software. These high priority areas were identified using maintenance records, manhole inspections, smoke testing and zoom camera pipe inspections. Other inspections were performed sporadically throughout the study area to allow us to get an idea of the conditions throughout the Ardmore study area. Approximately 38,170 linear feet of pipe (roughly 13% of the study area) was inspected as part of the project.

All sewer mains in the Ardmore area were cleaned using a high-velocity jet and vacuum truck in order to remove debris, grease, and roots. Since the lines were cleaned during the early stages of the study, they were not cleaned again simultaneously with the television inspection. For each line segment, an inspection log was prepared showing the location of any structural defects, offset or separated joints, points of infiltration, roots, etc. The log also shows the location of all service connections and indicates the depth of the sewer line at the upstream and downstream manholes. The complete inspection was also recorded on videotape and captured digitally, on MPEG files.

Flow monitoring was performed as part of the SSES in order to determine the relative severity of the inflow and infiltration (I/I) problem within the various meter basins in the study area. Nine electronic data logging flow meters placed in locations selected to adequately cover the Ardmore area were used during the monitoring process. These meters operate using the continuity equation, which states that the average velocity of a liquid passing through a pipe times the cross-sectional area of flow equals the rate of flow. The meters continuously gather the data, average it in 15-minute increments and store it in the meter. Field technicians periodically visited each site (approximately once per week or after every major rain event) to download the data and evaluate and/or calibrate the meters.

An electronic data logging rain gauge was installed simultaneously because inflow and rainfall-induced infiltration can only be analyzed in conjunction with recorded rain events. The rain gauge not only measures total rainfall, but also rainfall intensity. This is important because rainfall intensity has a direct impact on inflow. More intense episodes tend to increase flooding and ponding of water around manhole lids, cross-connected storm and roof drains, and broken clean-outs, which can cause large quantities of inflow to enter the collection system in a short period of time. Long sustained rain events of low intensity, on the other hand, tend to saturate the ground, raising the groundwater table and causing an increased amount of groundwater infiltration

Prioritization Matrix

Given the limited funding available for such a large project area and the length of time it takes to complete work in a single basin, it is extremely important that the City prioritize the basins so that the worst basins are completed first. Detailed field tests and inspections were performed on all sewer structures in the study area. To supplement this data, we also obtained the available work order history from CCU's Hanson computerized maintenance management system (CMMS). A prioritization matrix was developed using eight different categories that we felt gave the most accurate picture of the overall condition of the sewer and water infrastructure in a particular basin. These categories included maintenance records, flow meter data, pole-mounted zoom camera inspections, smoke testing, manhole inspections, clean-out percentage, age of water mains and percentage of small diameter (less than 6-inch) water mains.

Two matrices were developed using two different methods, a Ranking Method and a Point Method. In the Ranking Method matrix, the basins were ranked one to thirteen in each of the eight categories. The worst basin was assigned a score of thirteen, the next worse was assigned a score of twelve; continuing until the best basin was assigned a score of one. Each of the eight categories was weighted equally. The score for all eight categories was then totaled for each basin, and the basin with the highest score is in the worst condition and the highest priority for rehabilitation/repair. Table 2 shows the raw numbers scoring summary for each sub-basin.

Basin No.	Maint. Score	I/I Severity (gpdim)	Line Inspect Score	Smoke Test Score	MH Inspect Score	Clean Out Percent	Age of Water	Small Dia Water %
1	4.12	2,279	1.93	5.79	2.50	15.2	77.7	8.0
2	2.65	2,279	1.81	4.68	2.91	17.7	78.2	7.6
3	1.96	7,210	1.86	3.03	2.75	45.8	67.4	7.2
4	1.48	957	1.69	1.20	2.57	19.4	49.9	8.2
5	3.32	7,210	1.93	3.80	2.86	42.1	69.4	0.0
6	2.38	3,738	1.88	0.95	3.07	14.4	75.8	0.0
7	3.18	3,738	1.86	2.04	2.92	33.3	61.3	2.2
8	2.25	563	2.00	3.59	3.04	24.6	60.4	0.0
9	2.46	563	2.02	2.63	2.65	30.1	54.8	0.0
10	3.68	4,262	2.14	5.77	3.38	16.6	85.8	0.0
11	1.86	7,538	1.79	3.88	3.09	13.0	76.5	1.8
12	2.04	941	2.07	6.71	3.25	15.0	87.9	13.2
13	5.31	20,690	2.00	6.84	2.66	25.1	92.2	1.5

Table 2
Ardmore Sub-basin Scoring Summary

In the Point Method matrix, each basin was assigned a score between 1 and 10 in each category depending on the level of the data measured; with 10 being the worst score and 1 being the best

(A detailed breakdown of the scoring for each category is included with the point method matrix). If all 13 basins had a similar rating they were assigned a similar score for that category. Each of the eight categories was again weighted equally. The score for all eight categories was once again totaled for each basin, and the basin with the highest score is in the worst condition and the highest priority for rehabilitation/repair. Table 2 shows the results for each of the 13 sub-basins.

BASIN PRIORITIZATION MATRIX

Basin No.	Maint. Score	I/I Severity (gpdim)	Line Inspect Score	Smoke Test Score	MH Inspect Score	Clean Out Percent	**TOTAL**
1	12	6	8	11	1	11	**49**
2	8	6	3	9	8	8	42
3	3	11	5	5	5	1	30
4	1	4	1	2	3	7	18
5	10	11	8	7	8	2	46
6	6	8	6	1	11	12	44
7	9	8	5	3	8	3	36
8	5	2	10	6	9	6	38
9	7	2	11	4	3	4	31
10	11	9	13	10	13	9	**65**
11	2	12	2	8	11	13	**48**
12	4	3	12	12	12	11	54
13	13	13	9	13	4	6	**58**

Table 3
Summary of Ardmore Sub-basin Prioritization Matrix Point Method

RESULTS

The two methods resulted in similar priority rankings, but did differ slightly. Of the two methods, Hydrostructures concluded that the Point method gave a better representation of the condition of each basin relative to other basins. This reasoning resulted from the fact that points were given for a category being within a particular range instead of just being assigned based on rank. In the Point method, a large difference between the first and second place basins in a category would have a large difference in points, whereas in the Ranking method their difference is only one place (one point). The two methods resulted in similar priority rankings, but differed slightly. Therefore, Hydrostructures recommended using the Point method for determining priority ranking for future rehabilitation and repair.

Rehabilitation Master Plan

Given the large size of the Ardmore project study area, it was obvious that the needed improvements would need to be made over a number of years. Based on a review of recent sewer rehabilitation projects, both for CCU and in other nearby systems, we calculated that a typical comprehensive sewer rehabilitation project (including trenchless rehabilitation of mains, spray-applied cementitious lining/rehabilitation of manholes and typical excavation and replacement of service lateral connections) has a construction cost of approximately $105 per linear foot of sewer mains.

In recent sewer rehabilitation projects performed for CCU, aging water mains were replaced in conjunction with the sewer rehabilitation work. This work was typically conventional excavation and replacement, and was completed simultaneously to prevent areas from being disrupted multiple times by heavy construction projects. CCU plans to continue replacing old water mains in an area in conjunction with sewer rehabilitation work, so the water main cost must also be determined. When water main totals are unknown, we calculated that comprehensive water replacement project (including mains, valves, hydrants and services) has a construction cost of $120 per linear foot ***of sewer mains***. (Note: a portion of the extra cost for water replacement is based on the fact that there is typically an additional 5-10% more water mains than sewer mains in a particular area due to looping of the system). When water main totals are known, we used a construction cost of approximately $95 per linear foot of water mains. Therefore, the total construction cost including both trenchless sewer rehabilitation and water replacement (via exaction and replacement) is $200 per linear foot.

Given the overall budget for the Ardmore area project and the estimated construction cost of $200 per linear foot for sewer rehabilitation and water replacement, we divided the Ardmore Study area into individual basins of appropriate size that they could be completed within a 12 to 18 month construction period. We looked at the budget limitations of CCUC, in order to recommended that the priority rankings developed using the “Point” method be used to schedule the various basins for the construction/rehabilitation phase. This analysis resulted in basins with a typical size of 20-25,000 linear feet, and with a typical construction cost estimate of $4,000,000 to $4,500,000 per basin.

DISCUSSION

Since 2009, CCUC has rehabilitated three of the sub-basins in Ardmore: Basin 13, Basin 10, and Basin 11. Although Basin 12, scored the third highest, the rehabilitation of Basin 11 was completed early due to coordination with other projects. Particularly, major street improvement projects were going to be completed in Basin 11, and the City took a proactive approach by identifying future projects, so that streets would not have comprehensive sewer/water rehabilitation shortly after other improvements, such as resurfacing, new sidewalks, etc.

The next basin scheduled for rehabilitation is Basin 1. Below is a map generated from the GIS database which shows the sewer mains of Ardmore Basin 1.

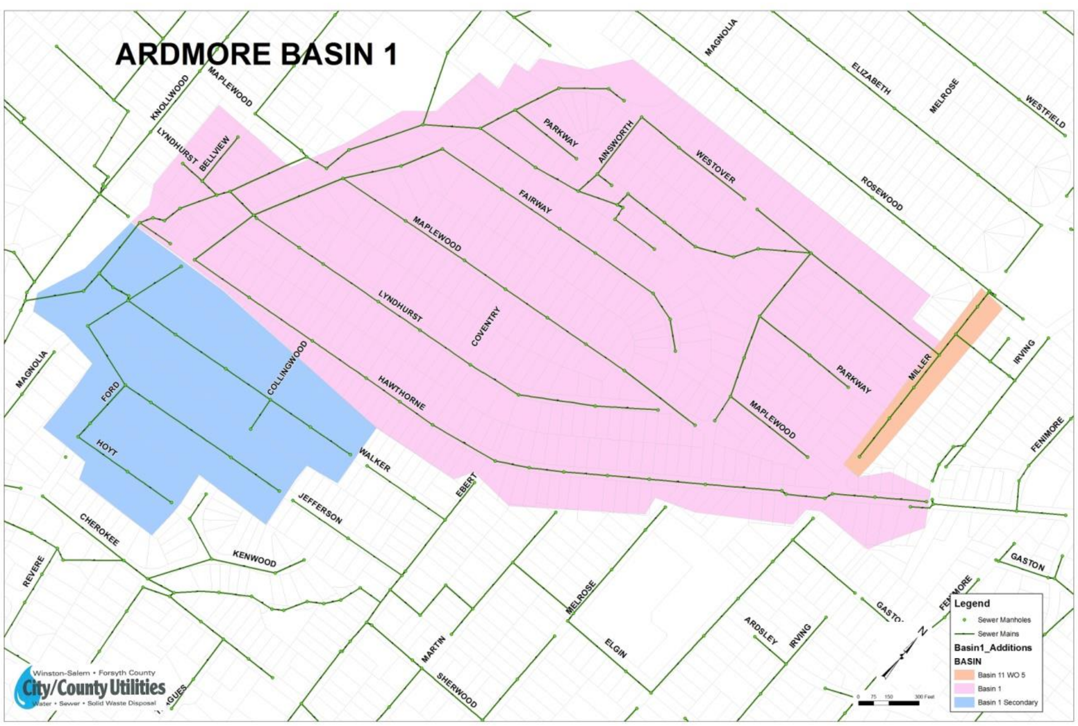

Figure 4
GIS Overall Site Map of the Ardmore Basin 1

Basin 1 is currently in the design phase and should be put out to bid in early 2015. Basin 1 is in the approximate center of the Ardmore Sewer Basin. The next basin following Basin 1 is scheduled to be Basin 12, which would return to the original prioritization matrix order.

In addition to the three basins having comprehensive sewer rehabilitation and water improvements, high-priority sewer repairs were completed during a Ardmore Basin-Wide Priority Sewer Repairs Project in 2010. These high priority areas which were scattered throughout all 13 basins were identified through CCTV inspections, and were repaired before they caused more costly repairs due to SSO's or other emergency repairs.

CONCLUSIONS

The Winston-Salem/Forsyth County City/County Utilities Commission (CCUC) has taken the first step toward meeting its goal of reducing maintenance and repair costs and eliminating Inflow and Infiltration from the Ardmore area by completing the SSES and Rehabilitation Master Plan in 2009. The CCUC is approximately one-third complete in the process of completing the construction/rehabilitation phases of the entire Ardmore Basin consisting of over 325,000 linear feet of sewer mains. The project has required a significant dedication of time and funding. However, the evaluation and prioritization of the sub-basins with Ardmore has allowed CCU to maximize the effectiveness of its funding, addressing the highest priority areas now, and then proceeding to the lower priority areas as additional funds become available in the future.

CCUC has been proactive with their rehabilitation efforts, having completed rehabilitation projects with the highest priority basins within the last 5 years. The CCUC has realized much of the water and sewer infrastructure in this area is approaching or has already exceeded its design life, and delaying repairs further will only allow the system to deteriorate further while the operation and maintenance and construction costs to increase.

ACKNOWLEDGEMENT

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Ardmore Area Sewer System Evaluation Study and Rehabilitation Master Plan – May 5, 2009