EVALUATION OF SANITARY SEWER COLLECTION SYSTEM MANAGEMENT APPROACHES AND IMPACT ON WATER RESOURCES MANAGEMENT

Rob Bocarro[1], PhD, David Sample[2], PhD, P.E., Sean Kilpatrick[3], P.E.

AUTHORS: Supervising Engineer[1], Principal Water Resources Engineer[2] and Engineer III[3], Brown and Caldwell, 990 Hammond Drive, Suite 400, Atlanta, Georgia 30328.
REFERENCE: *Proceedings of the 2007 Georgia Water Resources Conference*, held March 27-29, 2007, at the University of Georgia.

Abstract. Management of sanitary sewer collection systems is a complex, multifaceted undertaking. Major and even smaller utilities can be responsible for the operation and maintenance of hundreds of miles of sanitary sewers, manholes and pump stations. Because of potential pollutant loading to receiving waters during wet weather events from Sanitary Sewer Overflows (SSOs), many utilities are now focusing on the management of their collection system in a comprehensive manner under so-called Capacity, Management, Operations, and Maintenance (CMOM) type programs. The primary goal of CMOM is to minimize SSOs. This is accomplished by a comprehensive management program, which includes an inventory and sewer system evaluation survey program for establishing the location and condition of the sewer, development of hydraulic models for determination of system capacity, development of Standard Operating Guidelines for better operation of the system, and ongoing repairs and maintenance. This paper describes experience of various programs undertaken within Fulton County, Georgia. A number of programs are evaluated in terms of the key elements and costs of the programs and reduction in impacts on the water resource system.

INTRODUCTION

In the Metropolitan North Georgia region, all of the larger and many smaller jurisdictions have developed programs or have programs under development to address the much anticipated federal Capacity Management, Operations and Maintenance (CMOM) regulations. The legislation is targeted at reducing the impact of sanitary sewer overflows from aging sanitary sewer systems, which ultimately improves the watershed water quality. In Georgia, jurisdictions can develop a CMOM plan in accordance with guidelines developed by the Georgia Association for Water Professionals (GAWP) and submit it to Georgia Environmental Protection Division (Georgia EPD) for approval. These plans typically need to show that the jurisdiction is committed to various elements including the preparation of detailed maps showing the location of existing sanitary sewer systems, the development of sewer models to identify capacity problems, the development of a sewer master plan to show current and future needs, conducting condition assessments of existing sewer systems to identify system defects, and finally developing capital improvement programs to upgrade and rehabilitate the sewer system. The CMOM plan is implemented by the jurisdiction and audited by EPD. If a County can demonstrate that it is committed to managing its sewer system through implementation of the CMOM plan, the jurisdiction will not be subjected to fines for minor spills by EPD.

One of the key benefits of developing these CMOM-type programs is to reduce the impact of inflow and infiltration (I/I) on the sanitary sewer system, which not only reduces the risk of watershed pollution through SSOs but can also potentially extend the permitted capacity of the wastewater reclamation facility. As the costs of developing new advanced wastewater treatment systems are highly significant (typically $5-$12 per gallon or higher), I/I correction in sewer systems can beneficially delay major investment in treatment plant expansions.

Many different approaches have been taken to reduce I/I. These approaches include various levels of inventory and sewer system evaluation, including comprehensive studies. The evaluations include manhole inspections as many sources of I/I are due to manhole defects. Defects in sewer lines are determined using closed circuit television, smoke testing and dye testing. However, such evaluation services can require significant resources and extensive sewer systems can take months to inspect and analyze.

This paper focuses on the 'Find-and-Fix' approach adopted by Fulton County to reduce I/I, which is based on setting initial budgets, prior to commencing the project; then identifying and prioritizing the main sewer defects; and finally developing and implementing repair-strategies to reduce I/I. There is less focus on engineering evaluation and analysis and more focus on repairs based upon the available budget. This paper details three projects undertaken using the 'Find-and-Fix' approach and presents the main results and findings. The reduction in I/I is documented in addition to the project costs and compares the costs of sewer repairs with the costs of developing additional wastewater treatment capacity.

BACKGROUND AND RELATED WORK

Brown and Caldwell has undertaken several I/I reduction projects on behalf of Fulton County, Georgia, as part of the County's CMOM program. In the south of Fulton County, there are two sewersheds: Morning Creek and Wolf Creek in which three I/I reduction projects have been completed. Under the Morning Creek I project, the sewer system included 30 miles of sewer ranging in diameter from 8-inch through 21-inch and over 800 manholes. The Morning Creek II project comprises the balance of the 23 square mile Morning Creek sewershed: 145 miles of sewer ranging in diameter from 8-inch through 42-inch and approximately 3,800 manholes. The 10 square mile Wolf Creek sewershed included 41 miles of sewer ranging in diameter from 6-inch through 30-inch and approximately 1,100 manholes. These sewersheds were given highest priority by the County, as historical flow data indicated these sewersheds as having the most significant I/I. These sewersheds also had the highest incidence of SSOs.

The I/I reduction projects were bid for and executed under three separate 'design-build' contracts awarded to Brown and Caldwell and its subcontractors over the period 2004-2006. Each contract had a 12-18 month duration. Under each contract, the services included the following engineering and construction activities: evaluation and identification of I/I defects; prioritize repairs; develop work orders for rehabilitation and repairs of the sewer system; execution of the work orders and finally document the I/I reduction and cost benefits.

METHODOLOGY

The 'Find-and-Fix' approach initially involves setting a not-to-exceed budget for the project. As Fulton County has an extensive sanitary sewer system, the County recognized that the costs of the I/I reduction program need to spread across all sewer watersheds with significant recorded I/I flows and/or SSO issues. Furthermore, it was considered as unrealistic to be able to eliminate all I/I in a sewershed without incurring unreasonable costs. Thus, realistic budgets were set with the intention of fixing the main sources of I/I in each sewershed. The budget set for the three sewer I/I reduction programs was: $0.9M for Morning Creek I, $4.9M for Morning Creek II and $3.0M for Wolf Creek.

The preliminary evaluation phase of each project required 2-3 months to complete. One of the initial evaluation tasks was to install additional sewage flow meters in virtually all the sub-basins of each sewershed. Thirteen flow meters were installed in the Morning Creek II sub-basins and three new flow meters were installed in the Wolf Creek sub-basin. All these flow meters were supplementary to the main flow meters previously installed by the County, which record the total flow in the sewershed. This measure was required to allow the sewer flows to be determined for each sub-basin, and thereby estimate the dry weather flows, dry weather infiltration and rainfall-induced I/I for the duration of the project. The flow meter readings were used to determine the sub-basins with the most significant I/I.

The evaluation phase included performing an initial 'windshield survey' of the sewer system. The purpose of this survey was to identify the sections of sewer and manholes with the highest potential for I/I. For example, the sections of sewer located adjacent to creeks, especially with manholes located at or below grade and with holes in the cover were considered high risk. Also, sewer maps showed some older sections of vitrified clay sewers and brick manholes which were considered as having a greater potential for I/I.

Based upon the findings of the 'windshield survey', the sewer manholes with the perceived highest risk of I/I were inspected. In the case of the Morning Creek II sewershed approximately 800 (21 percent) of the 3,800 manholes were inspected to identify sewer defects. Smoke testing was also conducted of some sections of sewers: over 170 manholes and some 41,500 feet of sewer were smoke tested in Morning Creek II sewershed.

Fulton County had previously conducted an inventory and survey to map the location of all sewer pipes and manholes, including the inverts, diameters and pipe materials of all sewers, which were made available to review. This information also included video inspection recordings of the all the main trunk and lateral sewers.

The sewer inspection videos were reviewed to determine the location of I/I defects in the main sewers and to estimate the I/I quantities in each section of sewer. Additional video inspections were conducted of trunk and lateral sewer sections previously not inspected by video.

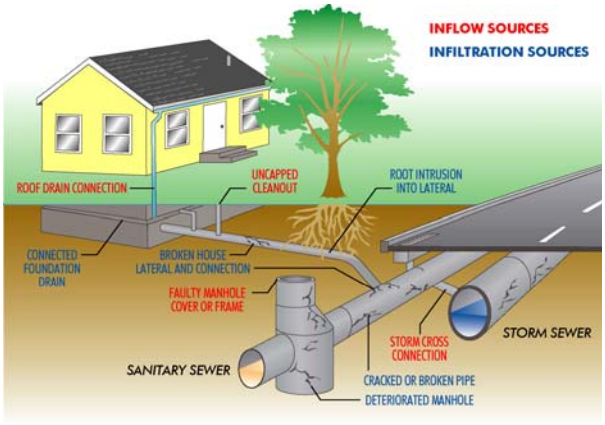
As the final stage in the evaluation process, a prioritization report was prepared. This included the findings of the evaluation, which included a tabulation of defects, estimated I/I quantities and costs to repair the defects. Prioritization strategies were developed which included:

- Repair of trunk lines in floodplain areas
- Raise/line manholes within floodplain
- Selected lining/spot repairs
- Repair of lateral sewers

Based upon the repair strategies, a series of work orders were developed in accordance with the available budget to rehabilitate the sewers and manholes, using unit rates established under the Contract. The work orders were then implemented to carry out the following types of sewer construction repairs and rehabilitation:

- Raising of manholes

Figure 1. I/I Sources



- Replacement of manhole covers and frames with monolithic waterproof covers and frames
- Cured-in-place pipe processes (CIPP) were used for epoxy lining of sewers and manholes
- Mechanical spot repairs of holes in the sewer
- External repairs
- Pipebursting to replace defective undersized sewers
- Improving access to the sewer easement to facilitate operation and maintenance.

During and after completion of the construction phase, the sewer flow meters were used to estimate the I/I reduction. This involved a thorough comparison of pre- and post-repair meter readings to analyze both dry weather flow and wet weather flow impacts following the sewer system repairs. Flow analysis considered both the effects of groundwater infiltration (GWI) and rainfall-induced I/I (RDII), as illustrated on Figure 1.

The data obtained from the program was used to determine the unit costs per repairs. The approximate reduction in I/I was used to determine a unit cost in terms of the costs of inspection and repairs per gallon of I/I reduced or saved. Finally, an assessment was made of additional work to further reduce I/I.

CONCLUSIONS

In this section, the conclusions of the largest of the three project are presented only, as similar results and findings occurred with Wolf Creek and Morning Creek I sewersheds.

Morning Creek II. As a consequence of the evaluation of the various Morning Creek II sub-sewersheds, approximately $3.65M in work orders were executed to address I/I defects determined from the evaluation.

The work orders included the following types of repairs and rehabilitation of the 145 miles of sewer and approximately 3,800 manholes:

- 65 manholes were raised out of the floodplain
- 87 frames and covers were replaced with monolithic frames and covers
- 110 manholes were epoxy lined
- Two mechanical spot repairs were installed
- One external repair was performed
- In one of the sub-basins, DC05, one manhole was demolished and the missing section replaced with a section of 36-inch ductile iron pipe to address a major source of I/I estimated at over 0.5 million gallons per day (mgd).
- 3,389 feet of 8-inch vitrified clay pipe was replaced with 10-inch HDPE via pipebursting
- 7,333 feet of medium and large diameter pipe (18-inch up to 36-inch) was epoxy lined

The results showed I/I reductions in all the sub-basins based upon limited post construction monitoring including:

- Sub-basins MC60 and MC61 had a combined peak flow RDII reduction of 1.5 mgd or 47 percent based upon a 24-hour rainfall event of approximately 1.3 inches as shown on Figure 2. A GWI reduction of 30,000 gallons per day (8 percent) was also achieved.
- Sub-basins MC50 and MC51 had a combined peak flow RDII reductions of approximately 0.7 mgd or 34 percent.
- At flow meter MC45, which captures the sewage flow from approximately two thirds of the Morning Creek sewershed, peak flow RDII reductions of 1.3 mgd or 22 percent were achieved and GWI reductions of 9 percent

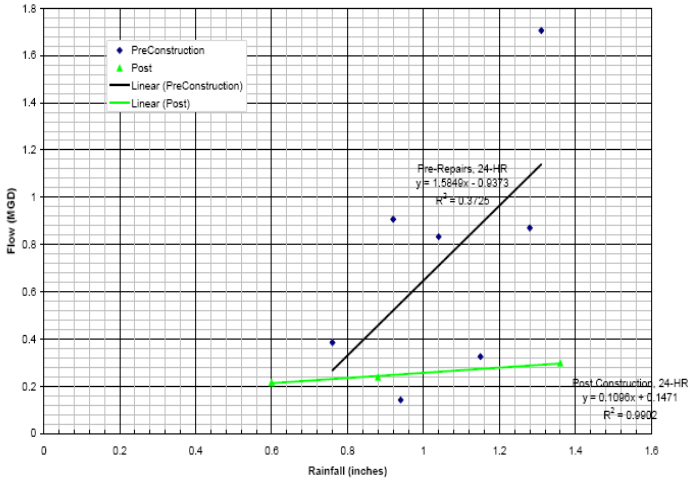


Figure 2. MC60 Wet Weather Analysis

Table 1. Breakdown of costs for Morning Creek II

Activity	Amount Spent ($M)	Estimate of Reduction in RDII (gpm)	Percent-age of Costs
Direct Reduction in I/I	**$2.13M**		**58%**
Manhole lining	$0.893M	993	24%
Manhole raising	$0.101M	1,180	3%
Pipe Lining	$0.668M	668	18%
Pipebursting	$0.427M	438	12%
Manhole demolition/repair	$0.040M	40	1%
Maintenance	**$0.130M**		**4%**
Replace frame & cover	$0.13M		4%
Other Associated Tasks	**$1.412M**		**38%**
Access	$0.314M		9%
Pump bypass	$0.854M		23%
CCTV/pipe cleaning	$0.135M		4%
Other	$0.109M		3%
TOTAL	**$3.672M**	**3,319**	
Estimated Total Cost / GPM - $1,106			

- In sub-basin DC05, after the manhole demolition and replacement with a section of ductile iron sewer, groundwater infiltration was reduced by approximately 0.5 mgd or 71 percent.

A summary of the work accomplished, costs and estimated reduction in RDII is given in Table 1. Table 1 showed that the total cost of the I/I reduction program was $1,106 per gallon per minute of I/I removed from the sewer system.

Table 2. Net cost benefit of program

Item	Cost
Costs of developing 1.0 mgd of additional treatment capacity (Assuming $6/gallon)	$6.00M
Costs of I/I program to reduce 1.0 mgd (Assuming $1,106 per gpm reduced)	$0.77M
Net cost benefit	$5.23M

In order to consider the cost effectiveness of the I/I reduction programs, Table 2 considers a comparison between the costs of reducing I/I in the system by 1.0 mgd with developing 1.0 mgd of additional wastewater treatment capacity.

It was assumed that the costs of developing new wastewater treatment capacity are in the region of $6 per gallon of developed capacity. Based upon reducing 1.0 mgd from the sewer system, Table 2 shows that the Morning Creek II project was not only successful in terms of reducing I/I, but the project has more than for paid for itself. The Camp Creek wastewater treatment facility, which treats the wastewater from the Morning Creek sewershed, has to treat significantly less flows especially after rainfall events. In effect the I/I reduction program has helped increase the available capacity for handling actual wastewater flow.

With the conclusion of the Morning Creek II project, further areas of the sewer system were identified which may have significant I/I. Fulton County may wish to revisit the sewershed for future I/I reduction using the 'Find-and-Fix' approach.

DISCUSSION AND RECOMMENDATIONS

This paper has shown that significant reductions in I/I can be achieved through the 'Find-and-Fix' approach. This approach recognizes that jurisdictions have finite budgets for collection repairs and that it is unrealistic and not cost effective to remove all I/I from the system.

The 'Find-and-Fix' approach is beneficial in terms of schedule, as the evaluation of the system is performed on a fast track basis to identify and prioritize I/I defects. The evaluation is followed immediately by repairs and rehabilitation of the system. Fulton County has found that the fast track approach is more efficient by dealing with one 'Design-Builder', who provides all the engineering and construction services under one Contract.

The illustrated projects achieved the goal of reducing I/I and the risk of SSOs. Furthermore, an I/I reduction program can pay for itself when compared to the costs of developing and permitting new wastewater treatment facilities.

It is noted that the analysis presented in this paper was based on limited rainfall data and sewer flow analysis following construction. The authors acknowledge that more detailed monitoring of rainfall data and corresponding sewer flows to confirm the estimated I/I flow and reductions presented in the pape

ACKNOWLEDGEMENTS

Permission to publish this paper by Fulton County is gratefully acknowledged