Chapter 9

I/I Rehabilitation Project Costs and Lessons Learned

This chapter provides an overview of the overall infiltration and inflow (I/I) rehabilitation pilot project costs and the primary lessons learned during execution of the projects. The lessons learned relate to such issues as project selection, rehabilitation approaches, and documentation of a project's effectiveness. This chapter's purpose is to summarize useful information as guidance to the ongoing King County I/I Control Program. It may also be helpful to individuals involved in other I/I programs.

Lessons learned as presented in this chapter are not prioritized in any order of importance. The lesson is stated in bold and supporting comments follow. The relevance of these lessons to other programs varies depending upon the nature of the specific program. Note that the 10 pilot projects represent only a small cross section of the basins included in King County's I/I Control Program, and the construction rehabilitation methods and products utilized were limited by funds and time. Hence, it is difficult to draw broad conclusions about I/I rehabilitation based on these pilot projects alone.

9.1 I/I Rehabilitation Project Costs

The final construction cost for the 10 pilot projects, including local sales tax, was $7.80 million. Local agencies contributed $0.67 million and King County contributed $7.13 million.

In addition to construction costs, the total pilot project costs include the Sewer System Evaluation Survey (SSES), design, pre- and post-rehabilitation flow monitoring, construction management, and modeling and analysis. Table 9-1 summarizes each project's costs.

Table 9-1. Summary of Pilot Project Costs

	Auburn	Brier	Kent	Kirkland	Lake Forest Park	Manhole Project	Mercer Island	Redmond	Ronald	Skyway	TOTAL
SSES	$173,800	$163,600	$75,400	$117,300	$122,100	$124,800	$129,100	$134,300	$110,200	$70,000	$1,220,600
Design	$96,100	$145,700	$177,900	$154,700	$186,600	$222,300	$132,600	$193,800	$145,000	$238,400	$1,693,100
Pre-Rehabilitation Flow Monitoring	$9,000	$9,000	$9,000	$9,000	$9,000	$27,000	$9,000	$9,000	$9,000	$9,000	$108,000
Construction	$384,700	$372,700	$1,080,700	$838,200	$790,400	$200,800	$815,800	$840,100	$1,077,300	$1,395,200	$7,795,900
Construction Management	$72,200	$115,800	$90,300	$57,600	$107,200	$44,600	$118,500	$82,600	$176,300	$157,700	$1,022,800
Post-Rehabilitation Flow Monitoring	$8,500	$8,500	$8,500	$8,500	$8,500	$25,400	$8,500	$8,500	$8,500	$8,500	$101,900
Modeling / Reporting	$5,100	$5,100	$5,100	$5,100	$5,100	$15,300	$5,100	$5,100	$5,100	$5,100	$61,200
TOTAL	$749,400	$820,400	$1,446,900	$1,190,400	$1,228,900	$660,200	$1,218,600	$1,273,400	$1,531,400	$1,883,900	$12,003,500

9.2 Success of Reducing I/I

Service basins with I/I can be identified through comprehensive wet-weather flow monitoring programs and in many cases, I/I can be successfully reduced through rehabilitation of the sewer collection system.

Regional flow monitoring was conducted throughout the winters of 2000/2001 and 2001/2002 within mini-basins. This flow monitoring, coupled with the data interpretation program, identified service basins with relatively high I/I. The information was subsequently used as one factor in the selection of suitable pilot projects.

Rehabilitation methodologies used in the pilot basins were selected, designed, and constructed based on flow data and the SSES investigations.

Rehabilitation efforts reduced I/I in 7 of the 10 pilot projects. In one pilot project basin, a maximum reduction of 87 percent was achieved through a complete system replacement. The pilot projects demonstrate that monitoring and rehabilitation of sewer collection systems can successfully identify, target, and reduce I/I.

9.3 Lateral and Side Sewer Sources of I/I

There is a strong indication that in many service basins, a high percentage of I/I originates in laterals and side sewers.

In the Kent and Ronald pilot projects, the focus of system rehabilitation was laterals and side sewers only. An I/I reduction effectiveness of approximately 75 percent in each indicates that in these cases, the majority of I/I originated in laterals and side sewers.

In the Manhole Project, manhole rehabilitation resulted in very little I/I reduction. This signifies that I/I sources in the basin are from other sewer system components.

In the Mercer Island pilot project, which included only sewer main rehabilitation, a 37-percent reduction in I/I indicates that a high percentage of I/I originates in other system components, most likely laterals and side sewers.

However, in Lake Forest Park, I/I was reduced by 69 percent by rehabilitating sewer mains and manholes only. Therefore, while laterals and side sewers may be highly suspect sources of I/I, it is necessary to evaluate flow data, review the results of SSES investigations, and possibly use pre-rehabilitation system modeling to identify likely sources of I/I.

9.4 Sanitary Sewer Evaluation Survey (SSES) Effectiveness

The extent and need for SSES work (videotaping sewer mains, laterals, and side sewers with a closed circuit television [CCTV] camera; smoke testing; dye testing; and performing manhole inspections) depends on the rehabilitation work to be performed. In order to identify the most appropriate method of rehabilitating a collection system component, some level of SSES work must be completed. However, SSES alone will not always identify all sources of I/I or the extent to which I/I is entering collection system components.

SSES investigations to identify sources of infiltration are most effective during the wet weather season.

SSES investigations, including pipe videotapes and manhole inspections, identified several defects and the general condition of system components in each project; however, there was no clear correlation between identified defects and the extent of I/I known to occur in the system. A factor contributing to this was that most SSES investigations were completed during the relatively dry summer months when many infiltration sources were inactive.

Several sources of infiltration that eluded detection during SSES investigations were identified during pilot project construction work completed during the wet season, and through the post-rehabilitation inspection also performed during the wet season. For example, the Mercer Island post-rehabilitation CCTV inspection of sewer mains identified several laterals with small but continuous flows of clear water, suggesting an infiltration source in the lateral or side sewer. During construction in the wet season, infiltration that had eluded detection during the summer SSES investigations was identified at several manholes.

While SSES work (primarily CCTV data) completed in the wet season may identify more sources of infiltration, it will probably remain difficult to establish a good correlation between identified defects and the I/I known to occur in a basin. Ideally, inspection should be completed during or immediately after a storm. This may not be feasible due to the infrequency of storm events that activate the sources of I/I. Also, during storm events, the high flow rate in sewer pipes may prevent effective CCTV inspection. In the interest of increasing the percentage of I/I sources identified through SSES work, these investigations should be completed during the wet season when I/I sources are most likely to be active. Smoke testing for direct connections and defects is still presumed to be most effective in the dry weather months, however, due to the lower likelihood of smoke being inhibited by water in the pipes, p-traps, and soil.

SSES investigations may not be effective at identifying all sources of I/I.

A number of SSES techniques were used for the pilot projects, including manhole inspections; CCTV inspection of sewer mains, laterals, and side sewers; and smoke testing. As previously discussed, many sources of I/I eluded detection because the SSES work was completed in the summer. In addition, some I/I sources were not identified because of deficiencies in the SSES technique. For example, smoke testing identified only a small number of inflow sources in the pilot projects. This could have been because obstructions in the sewer pipes prevented migration of smoke, or there simply may have been very few inflow connections. In some cases, I/I sources were part of the building plumbing and could not be easily removed. Also, smoke testing does not identify many rapid sources of I/I such as sump pumps, foundation drains, or inflow connection pipes with water traps that are filled with water. Because of the small number of inflow sources identified through smoke testing, very few inflow removal improvements were implemented as part of the pilot projects. In a proposed I/I rehabilitation project where flow data indicates an extremely fast response, smoke testing should be considered. In a number of cases, such as in basins where the response to storm events is less immediate, the cost and time required to conduct smoke testing may not be justified.

CCTV inspections of laterals and side sewers did not effectively identify all sources of I/I in these pipes. CCTV inspection methods involve either pushing a camera through an access point such as a cleanout, or using a side-launch camera from the sewer main. A majority of homes in pilot project areas had no cleanouts on the side sewer; therefore, using a conventional push camera was not an option unless a new cleanout was installed. Even when access is available, there may be inactive sources of I/I at the time of inspection. In addition, side sewer branches that cannot be observed during the inspection may include sources of I/I.

In a number of instances, a side launch camera inspection was terminated because the camera encountered a wye, a sharp bend, or a defect that prevented advance of the camera head. This prevented comprehensive investigation of the entire run of piping. Additionally, at the time of the SSES investigations, the use of side-launch cameras was limited to a length of approximately 80 feet; longer side sewer runs were not completely accessible.

When side-launch camera inspections were successful, they provided some data that was subsequently used to focus design efforts. In the Ronald project, the side-launch CCTV inspection was fairly successful; it identified the fact that about 20 percent of laterals and 66 percent of side sewers had defects. This was the basis of focusing the Ronald project primarily on side sewers. The other benefit of the side-launch camera inspection was that it provided an opportunity to locate the side sewer at the right-of-way line on the ground surface above the pipe using a locating transmitter attached to the camera head. This provided a horizontal location where the contractor could excavate a pit. Generally, the side-launch CCTV inspection was successful in laterals that were in reasonably good condition and did not have complicated piping configurations.

SSES should also include an assessment of the number of residences or businesses with sump pumps in the crawl space or basement that discharge to the sanitary sewer. Sump pumps that cannot be disconnected may limit the I/I removal effectiveness of an I/I rehabilitation project. SSES investigations should also extend to the foundations of the house to ensure that no foundation drain connections are overlooked.

9.5 Selection of System Components to Rehabilitate

When developing a lateral and side sewer I/I rehabilitation project, it is important to consider the cost of also rehabilitating sewer mains.

While the pilot project results suggest that a high percentage of I/I originates from laterals and side sewers, consideration should be given to the marginal additional cost of including sewer mains when developing a lateral and side sewer I/I rehabilitation project. In Skyway, work in the project area was bid in 1998 as primarily a lateral and side sewer project with a bid price of $0.9 million; however, a construction contract was never awarded. For the King County I/I pilot project, the work was expanded to also include bursting 9,500 linear feet of sewer mains and replacing 38 manholes, with a successful low bid of $1.3 million. The difference in the bid prices suggests that adding the sewer mains and manholes to the project was quite economical. During execution of the Kent project, the contractor proposed expanding the project scope to include sewer mains and manholes for a relatively small additional cost. The economy of rehabilitating sewer mains at the same time as laterals and side sewers was also confirmed by many of the contractors bidding on the pilot projects.

Adding the sewer mains and manholes to a lateral and side sewer rehabilitation project can be cost effective for a number of reasons:

- For pipe bursting projects such as Skyway and Kent, excavating a pit at the sewer main to reconnect the lateral to the sewer main is common to pipe bursting the sewer main and pipe bursting the lateral. Pipe bursting both mains and laterals under the same project may be economically attractive because performing the sewer main and manhole work adds the cost of pipe and manhole materials, but adds few additional pulling and insertion excavations.
- The contractor has already mobilized for the project.

The decision to include sewer mains and manholes in a lateral and side sewer rehabilitation project should be investigated from the perspective of long-term asset management as well as for providing additional I/I control.

9.6 Determining I/I Reduction Effectiveness

Accurate flow data collected during significant rainfall events and computer simulation modeling is required to quantify I/I reduction resulting from rehabilitation projects.

Collection of pre- and post-rehabilitation flow data is a critical part of determining the effectiveness of I/I reduction projects. Collecting open-channel flow data in small-diameter (8- to 12-inch) sewers is very challenging. However, by dedicating staff and resources to flow monitoring and by performing routine maintenance and field verifications on flow meters, flow data was successfully recorded for more than 95 percent of the monitoring period.

In order to collect accurate data, the team recognized the following factors that complicate flow monitoring:

- Wide ranges of flows, from low flows (less than 10 gallons per minute [gpm]) and low depths of flow (less than 1 inch in an 8-inch-diameter pipe), are difficult for meters to accurately measure.
- High flows and velocities with frequent debris accumulation on flow meter equipment can result in inaccurate data and require frequent maintenance.

The flow monitoring staff used area velocity meters that measure depth of flow, which can be used to calculate the cross sectional area of flow and an average velocity across the area of flow. It is difficult to measure flows with portable area velocity flow meters under low flow conditions because minor changes may not be accurately measured. Additionally, developing a reliable flow data record is complex given meter malfunctions, unique hydraulic anomalies at some sites, and erratic flow patterns that prevent establishment of normal dry weather sanitary sewer flow patterns. I/I reduction analysis also requires flow measurements from periods before and after the rehabilitation work. This may necessitate removing and then reinstalling a flow meter at a later date, which can result in data inconsistencies between monitoring periods due to installation and calibration differences.

The flow monitoring program for pilot projects should emphasize selection of flow monitoring sites and flow meter technology that will provide reliable results and consistent data, particularly if the flow meter will be installed for one season, removed, and then reinstalled for another monitoring season. Consideration should also be given to installing fixed monitoring equipment that will remain in place from one season to the next and provide consistent results between flow monitoring periods. Confidence in flow data increases as the flow rate increases (depth measurements at higher flows are more accurate than those for low flows). As pilot basin size increases, larger flows can be monitored and the I/I flows reduced as a result of rehabilitation can be more accurately quantified.

Three methods to quantify I/I reduction are as follows:

- Compare the flow response to storms before and after rehabilitation
- Evaluate the changes in flow response in a control basin and a rehabilitation basin
- Model by computer simulation

The first method was not used for this program because of the unique nature of storm events and the differences in antecedent (ground/trench) conditions at the beginning of a storm. The second and third methods were both evaluated as part of this program and computer simulation modeling was selected as the preferred method. Using a control basin (a similar basin without rehabilitation) provided reasonable estimates of the effectiveness of rehabilitation work; however, a number of issues can contribute to inaccuracies, including the difference in flow response between the control basin and the rehabilitation basin. Computer simulation modeling calibrated with the rehabilitation basin flow data provided the most reliable method of representing the actual system response to storm events and ultimately the I/I reduction achieved.

9.7 Working on Private Property

Maintaining a good working relationship among the contractor, contracting agency, and private property owners is imperative to performing successful I/I rehabilitation work on private property.

The approximately 75-percent I/I reduction achieved in the Kent and Ronald pilot projects demonstrates that lateral and side sewer rehabilitation is effective for I/I control. However, there were and continue to be significant concerns over performing work on private property due in part to the required interaction between agencies and property owners.

Factors that contributed to successful private property pilot projects included coordination and communication between all parties, advance public information and education, dedicated staffing for the project by the agencies and contractor, property owner incentives, and active local agency participation. Advance public education gained support for and understanding of the project from Ronald, Skyway, and Kent property owners. Therefore, a high percentage of property owners were engaged in the projects; property owners understood how they could participate, such as helping to locate cleanouts and refraining from using the sewer while construction was in progress. Active local agency participation was also extremely important for maintaining communication; the contractual relationship for sewer service is between the property owner and the local agency.

9.8 Successful Pilot Project Implementation

A collaborative process between King County and the local agencies resulted in pilot project success. The collaborative process was used to establish selection criteria, select project locations, establish intergovernmental agreements (IGA), and to coordinate during design and construction of the projects.

The 34 local agencies served by King County selected the pilot projects for the I/I Control Program. This was a consensus-based process that required the input and concurrence of these agencies. The collaborative process received praise and positive support from local agencies and helped keep them engaged in the program. King County considers this process very successful and it is being considered as a model for other implementation efforts. Any future program that requires the involvement of multiple stakeholders must establish processes that incorporate input from all parties.

Significant time and resources were necessary for administering construction of 10 concurrent pilot projects.

Simultaneous construction of 10 pilot projects required considerable time and resources to administer due to the duplicate administrative efforts required for multiple contracts. Options to reduce this impact include expanding the scope of individual projects or sequencing the contracts.

9.9 Rehabilitation Construction

Establishing minimum contractor experience requirements in the bidding documents helped ensure that qualified contractors were awarded the pilot project construction contracts.

During pilot project design, minimum experience requirements were established in the contract specifications for the variety of technologies applied to the projects. Pilot project objectives included demonstrating proven rehabilitation techniques and establishing the necessary experience requirements for ensuring that products would be installed correctly.

The trenchless sewer rehabilitation industry is unique in that a limited number of contractors in the local area are qualified to perform the work. For these pilot projects, two contractors were ultimately responsible for 8 of the 10 contracts. This limited representation of contractors on the pilot projects may not reflect the experiences anticipated on future rehabilitation projects.

When developing I/I rehabilitation construction contracts, consider the suitability of selected technology combinations and the combinations of contractors and subcontractors required for the work.

During pilot project design, there was interest in combining trenchless rehabilitation techniques and technologies to suit the needs of a specific project, and also to test a large cross section of techniques and products. This approach was somewhat incompatible with current practices of the contractors that perform trenchless sewer rehabilitation, and resulted in conflicts between contractors in a number of cases. No contractors submitted bids the first time the Manhole Project was issued for bid. For this project, a number of competing manhole rehabilitation products were included under a single contract and the response from potential bidders was that there was no interest in working cooperatively with manufacturers and installers of competing technologies.

The Ronald project was primarily a pipe bursting project, but also included several laterals to be rehabilitated using a cured-in-place lateral lining system. The laterals to be rehabilitated were very deep, and it was thought that the necessary excavations at these locations for pipe bursting would be prohibitively expensive. During construction the contractor proposed and was allowed to pipe burst these laterals because of the difficulty of mobilizing and coordinating the cured-in-place pipe (CIPP) contractor for these few laterals.