Chapter 3

Pilot Project SSES

Sanitary Sewer Evaluation Survey (SSES) work in each pilot basin was performed to help identify the specific pilot project work to be done, and to provide design information for the techniques to be tested. (Refer to Section 5.2.1 for a discussion of pilot basins.) The three major objectives for the SSES effort included:

- Identify specific I/I sources and system conditions within each pilot basin through the application of a variety of inspection techniques
- Apply a variety of inspection techniques in different locations in an effort to understand the effectiveness of each technique for identifying I/I sources on a program-wide basis
- Apply standardized coding to observed system defects in order to reflect their relative severity

3.1 Investigation Techniques

Investigation techniques for each pilot basin were determined based on flow monitoring data. The flow monitoring data provided flow response characteristics observed at the outlet of the basin. Refer to Section 2.3 for a discussion of flow responses.

The specific type of flow response may indicate the potential sources of I/I such as roof leaders or catch basins (inflow) or cracks in the sewer main (infiltration). Some inspection techniques are better suited for identifying specific sources of I/I. Figure 3-1 presents the approach to the selection of SSES inspection techniques based on the flow response I/I component. The SSES priority identified in the figure establishes the preferred SSES inspection techniques and the order of priority.

Six inspection techniques used in each of the pilot basins included:

- Mainline closed-circuit television (CCTV) inspection
- Smoke testing
- Lateral/side sewer CCTV inspection
- Manhole inspection
- Vacuum testing
- Focused electrode leak location (FELL) testing

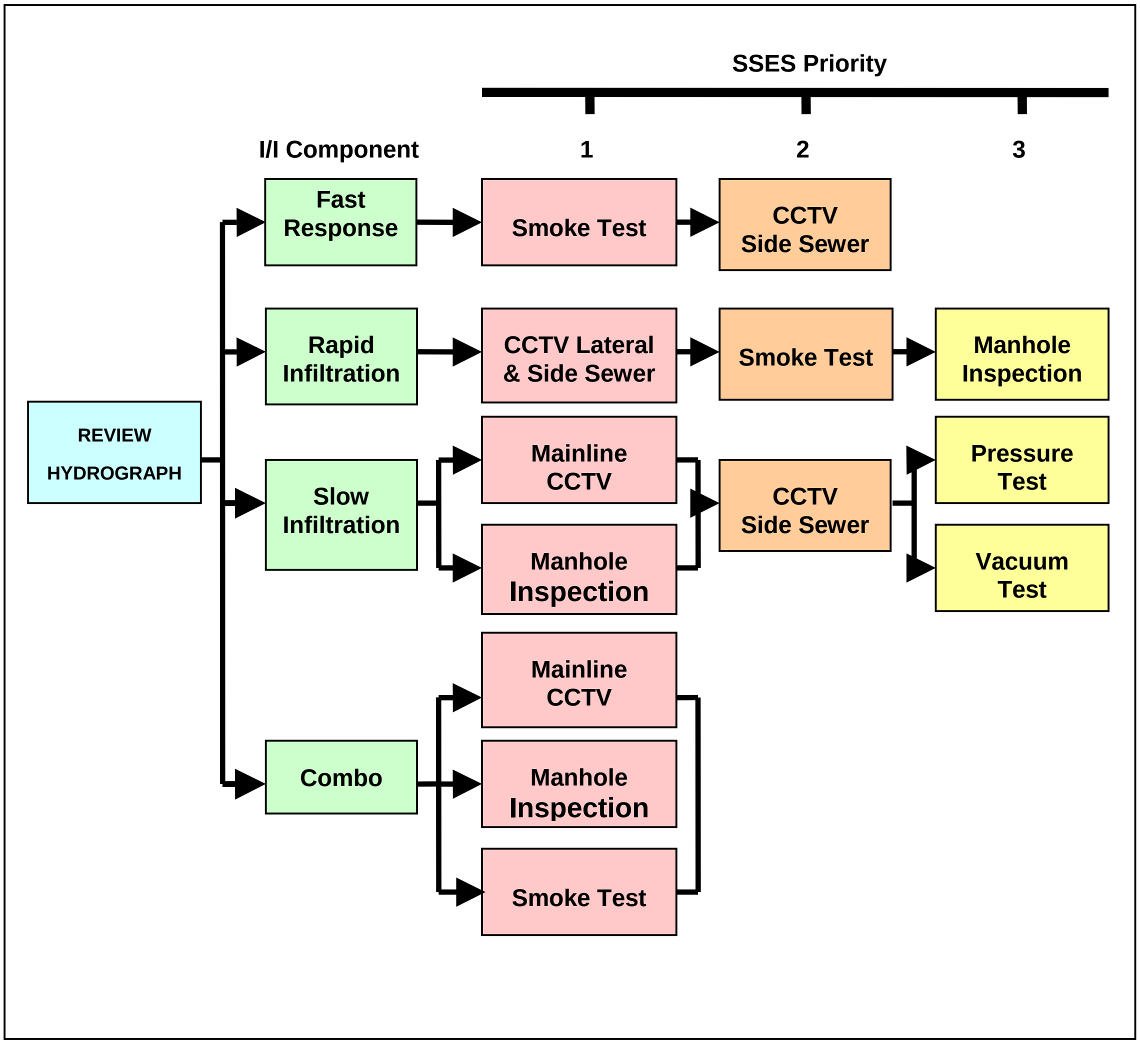

Figure 3-1. SSES Technique Selection Approach

3.1.1 Mainline CCTV Inspection

Visual inspection of the sewer lines, via remotely-operated video cameras, was performed to identify sources of infiltration and to some extent inflow. CCTV inspection also provided a means to identify undocumented connections, as well as the structural, construction, and operational defects present in the pipe. Fieldwork included hydraulic cleaning, root removal, and debris removal as required to facilitate CCTV inspection. Observations were recorded on videotape and as hand-written notes on inspection forms. The condition assessments were applied as one element in determining I/I severity, rehabilitation approach, and also served to determine the degree of system degradation during future condition assessments.

3.1.2 Smoke Testing

Smoke testing is often used to identify inflow sources, or direct connections, from roofs or from the ground surface to the sanitary sewer system. Typically, these connections are pipes from roof drains, cross connections from storm sewer systems, open cleanouts, holes in the sewer pipe that are connected to the ground surface, or submerged manholes. Smoke testing is done by blowing low-pressure, non-toxic, non-staining vapor or "smoke" into a section of the sewer line through the manholes. During the SSES, locations where smoke emerged were recorded as smoke "returns," including leak severity, leak type, leak source, and surface conditions. Digital photographs were taken of each "return".

3.1.3 Lateral/Side Sewer CCTV Inspection

Visual inspection of the laterals and side sewers, via remotely-operated video cameras, was performed to identify sources of rapid infiltration and to some extent inflow. CCTV inspection also provided a means to identify bad connections and joints. CCTV inspections were performed on laterals in the right-of-way and side sewers on private property. No pre-cleaning of the laterals/side sewers was performed. Work on private property was limited to basins where "rights-of-access" were obtainable. Two types of CCTV systems were used for lateral/side sewer work. Inspections using lateral launches from the mainline were restricted to about 80 feet up the lateral. Mini-cams launched from cleanouts on private property could inspect about 200 feet down the side sewer.

Lateral and side sewer defects were coded and condition grades assigned for application in determining I/I severity and rehabilitation approach, and also to serve as a quantifiable benchmark when determining the degree of lateral/side sewer degradation during future condition assessments. Property line locations were conducted using a built-in sonde unit (see Section 3.1.6) and surface locators. Observations were recorded on videotape and hand-written on inspection forms.

3.1.4 Manhole Inspection

Visual inspection of manholes was performed to identify sources of inflow, infiltration, and rapid infiltration. Visual inspection of manholes also provided a means to identify undocumented connections, as well as the structural, construction, and operational defects present in the structure. Manhole inspections were completed by entering the manholes with a safety harness, emergency retrieval equipment, gas detection, forced-air ventilators, digital cameras, and a global positioning system (GPS) computer for recording the inspection results in digital format. Digital photographs were taken of four different aspects of the manhole:

- The general area at the surface
- Looking down at the invert
- At specific moderate-to-severe defects identified during inspection
- Looking into the inlet and outlet pipes greater than 6 inches in diameter

Manhole defects were coded and condition grades assigned for application in determining I/I severity, rehabilitation approach, and also to serve as a quantifiable benchmark when determining the degree of manhole degradation during future condition assessments.

3.1.5 Vacuum Testing

Vacuum testing of three manholes was performed to determine the ability of this method to detect I/I defects compared to visual inspection. The test involves isolation of the manhole structure through placement of pipe plugs and application of a vacuum to the structure. Prior to vacuum testing, a soap solution is sprayed on the manhole interior so that a failure point is visible due to the presence of bubbles. Pictures can be taken or the area requiring rehabilitation can be marked. If a vacuum cannot be held for a specified period, defects in the structure allowing air or water to pass are found to be present.

3.1.6 Focused Electrode Leak Location (FELL) Testing

The Focused Electrode Leak Location (FELL) system was applied to selected pipelines to determine the ability of this method to detect I/I defects compared to CCTV inspection of mainlines and laterals. The FELL test system uses a specially constructed electrode called a “sonde” that generates an electric field. The electric field is focused into a narrow disc that is perpendicular to the longitudinal axis of the sonde. A surface electrode (usually a metal stake) is put into the ground at the surface. When the sonde is placed in a non-conducting pipe that contains sewage, the electric current flow between the sonde and the surface electrode is very small. Defects in the pipe that would allow a flow of fluid either into or out of the pipe usually provide an electrical pathway from the sonde through the defect in the wall of the non-conducting pipe, then through the ground to the surface electrode. When the sonde is moving through the pipe and passes close to such a defect, the current between the sonde and the surface electrode increases.

3.1.7 Dye Testing

Dye testing was not used for this SSES work because smoke testing previously identified suspect connections. Dye testing is typically used to confirm surface connections or cross connections that may not be identifiable by smoke testing. A liquid dye is introduced at the upstream point of suspected inflow, such as a roof leader, catch basin, abandoned building connection, or tank. A downstream point, usually a manhole, is monitored to see if the dye is detected.

3.2 Selection of SSES Contractor

Six contractors experienced in collection system investigations were invited by Earth Tech, the prime consultant, to submit proposals for performing the SSES fieldwork. A key issue in the selection of SSES contractors was that they meet minimum standards for inspection equipment and procedures, and reporting, as well as for traffic control. The minimum information to be included in the proposal included team organization, methodology, inventory of equipment, samples of reporting and investigation forms, unit rates for six categories of work, and related experience.

The candidate SSES contractors were provided with the following information:

- Narrative description of the Regional Infiltration and Inflow Control Program and the SSES task and objectives
- Maps of the proposed pilot projects with pipe and terrain data, as available, from King County's geographic information system (GIS)
- Flow data to allow contractors to form some idea of flow depths at various times of the day and under wet weather conditions
- Technical specifications and report forms for cleaning and inspection documentation of defects and pipe condition
- Schedule of estimated quantities per pilot basin, including acreage, length, diameter and material of pipes, number and range of manhole depths, and number of parcels within each pilot basin
- Proposal form listing key tasks, unit rates, and estimated quantities for each pilot basin. Contractors were requested to identify the threshold quantities under each task for which their unit rate would either increase or decrease.

The final selection of the contractor was based on evaluation of the quality of the proposed approach, available resources, adaptability of the contractor to project conditions, and estimated costs.

3.3 Documentation of Defects

A standardized coding system for defects provided a quantitative method of describing the type and severity of a defect and a means of relating information to a location on a specific pipe segment. Coding was easily incorporated into an electronic database that provided a tool for summarizing, querying, or reporting the data (for example, the computation and sorting of the overall condition of a component pipe, lateral, or manhole based on type, severity, and frequency of specific defects).

The North American Association of Pipeline Inspectors (NAAPI) standards and protocol were adapted for use on the project to code defects identified during inspection and testing. The NAAPI codes were incorporated into a condition assessment process used to evaluate the overall condition of pipelines. While there are NAAPI codes that address I/I defects, the system is not specifically tailored for I/I condition assessment. However, the types of defects and conditions that are addressed (cracked pipes, separated joints and connections, root intrusion, staining, and encrustation) are valuable indicators of I/I.

3.3.1 Data Management

All SSES data was stored based on the type of information collected in the field. Contractors submitted field inspection and testing data in an electronic format suitable for incorporation into a computerized database. Each mainline pipe section, lateral pipe section, manhole, and smoke test defect was a single record in a database table.

All tables were integrated into a Relational Database Management System (RDBMS). This allowed linking (relationally) to data outside or within the database, and access through links or interfaces that were specifically designed for the project. Outside the database, linking to the corresponding record in GIS allowed the results to be viewed graphically. Within the database, the RDBMS allowed linking to other database tables containing additional information, such as the defect scoring or condition code, or linking a lateral connection to the corresponding detail on the mainline record. The main RDBMS was in an Oracle® format and the main method of viewing, extracting/retrieval, and reporting of data was performed using a Microsoft Access™ interface.

The types of SSES data collected and the formats available for retrieval of the data from the database are listed in Table 3-1.

Table 3-1. Summary of SSES Data Collected and Retrieval Formats

Type of Data	Format Received	Retrieval Format
CCTV - Mainline	Paper Reports Electronic - database Videotapes	Paper Reports Electronic - database - PDF[1] - GIS Link Videotapes
CCTV - Lateral	Paper Reports Electronic - database Videotapes	Paper Reports Electronic - database - PDF Videotapes
Manhole Inspection	Paper Reports Electronic - database Diskette - Photos	Paper Reports Electronic - database - PDF - GIS Link - Photos with Link Diskette - Photos
Smoke Testing	Paper Reports Electronic - database embedded photos	Paper Reports Electronic - database embedded photos - PDF - GIS Link

[1]portable document format (file extension)

3.4 SSES Results

CCTV inspection of mainlines revealed structural and non-structural defects to varying degrees of severity within seven pilot basins. These included the cities of Auburn, Brier, Kent, Kirkland, Lake Forest Park, Mercer Island, and Redmond. Condition grades for the system components inspected by CCTV, manhole inspection, and smoke testing are summarized in Figure 3-2 and Figure 3-3. Condition Grades from 1 to 5 represent a rising scale of defect severity. Items with Condition Grades 3 and higher have defect severity levels which may indicate potential I/I sources requiring repair. As shown in these figures, 17 percent of mainlines, 10 percent of laterals/side sewers, and 47 percent of manholes tested showed potential need for I/I-related repair.

Inspection of manholes indicated that a significant proportion of the structures have moderate to very serious problems within 11 pilot basins. These included the Coal Creek Utility District, Northshore Utility District, Val Vue Sewer District, Skyway Water and Sewer District, and the cities of Auburn, Brier, Kent, Kirkland, Lake Forest Park, Mercer Island, and Redmond.

Smoke testing revealed relatively few connections to the sewer system within nine pilot basins. These included the Coal Creek Utility District, Northshore Utility District, Val Vue Sewer District, and the cities of Auburn, Brier, Kent, Kirkland, Lake Forest Park, and Mercer Island.

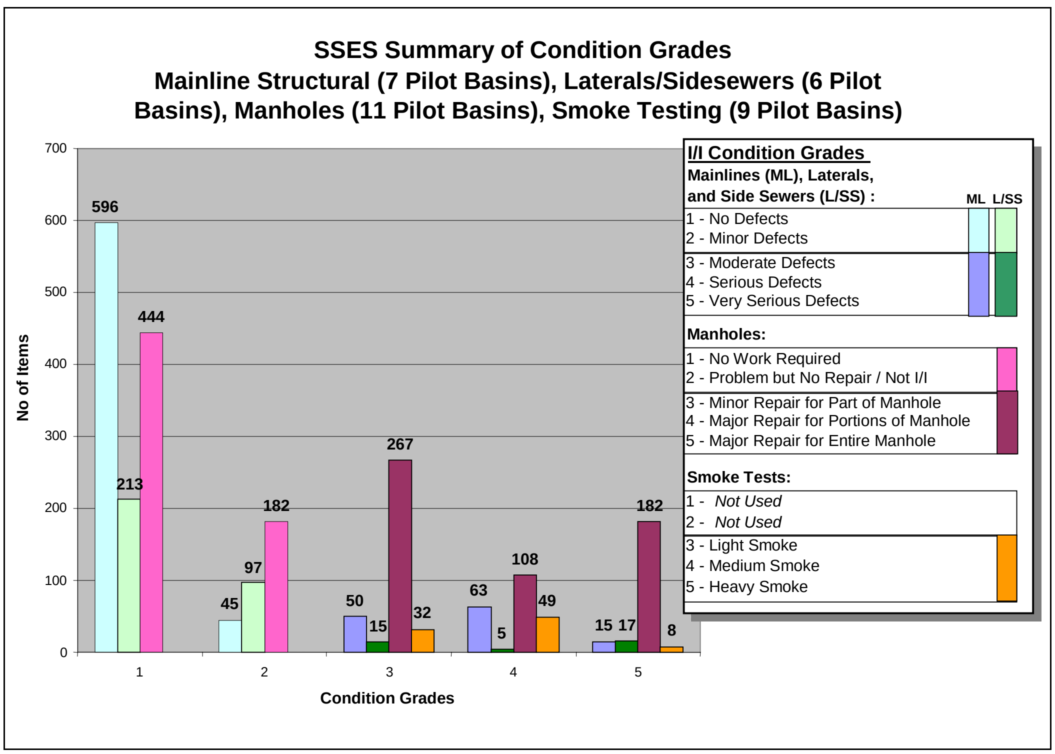

Figure 3-2. SSES Structural Defects Summary

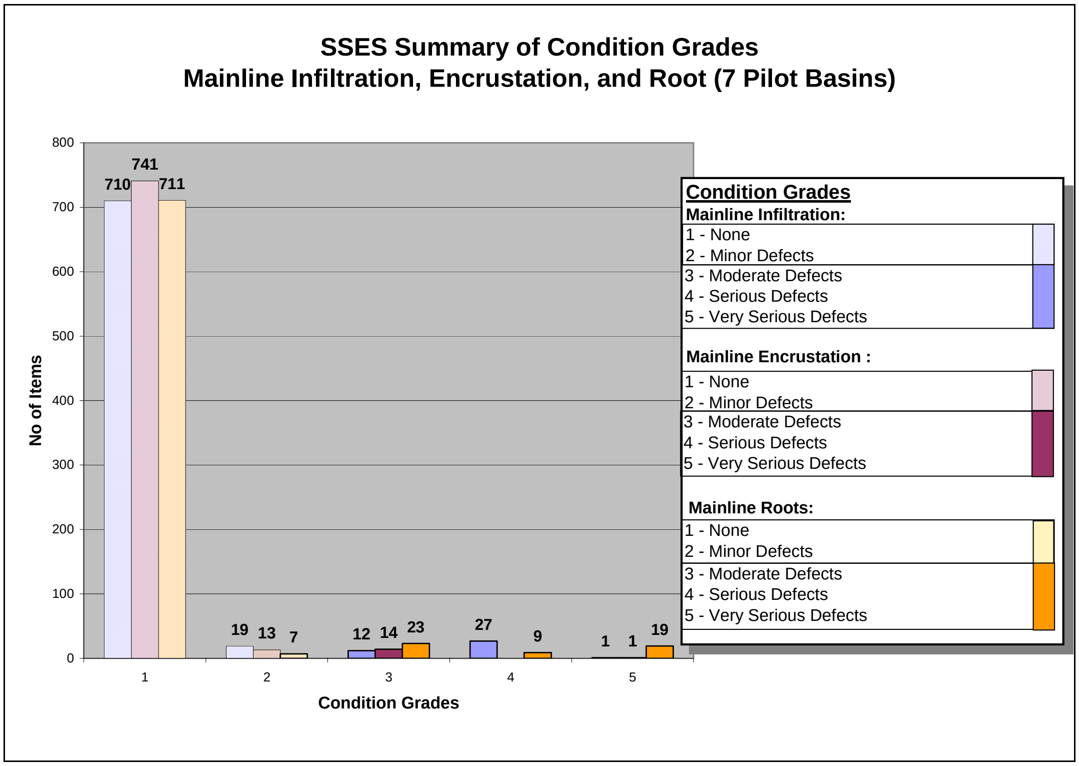

Figure 3-3. SSES Non-Structural Defects Summary

Vacuum testing of the manholes proved to be effective in locating defects in the manhole structures that were otherwise not detected by visual inspection.

FELL testing proved to be effective in locating defects not detected by the CCTV inspection, particularly at pipe joints where potential I/I pathways were detected.

3.5 SSES Costs

The contracted costs incurred to complete the SSES work for all pilot basins, excluding King County and local agency administrative and management time, are summarized in Table 3-2. Overall, the SSES effort cost approximately $1.2 million. Not all the costs can be converted to a unit cost because some of the costs, such as force account work, have no direct dependency on the linear footage of pipe or number of manholes in the system.

Table 3-2. Summary SSES Unit Costs

Task	Quantity	Cost	Unit Cost
Administration (King County, Local Agencies, and Earth Tech Team)	---	$434,000	
General SSES contractor costs (mobilization/demobilization, insurance, permitting, traffic control, project management, documentation/report)	---	$114,000	
Mainline cleaning, CCTV, and coding	141,358 lf[a]	$246,000[b]	$1.74/lf
Laterals and side sewers (CCTV, locates, cleanout installation)	475[c]	$169,000	$356 each
Manhole inspection	1,179	$104,000	$88 each
Smoke testing	209,236 lf	$68,000	$0.32/lf
Force account (unanticipated non-specific SSES work)	---	$86,000	

[a] linear feet
[b] No costs for coding Kent CCTV data included—City provided CCTV data
[c] Number of laterals and side sewers inspected

3.6 Public Involvement

SSES tasks were conducted in both public rights-of-way and on private property. Some activities, such as smoke testing, may be alarming to unprepared citizens or to fire and police departments. Cleaning and inspection operations may be temporarily noisy and disruptive to traffic. In some cases, access to and excavation work on private property was necessary and rights-of-entry needed to be obtained. Therefore, residents, appropriate officials of the local agencies, and local fire departments were informed of the location, timing, and nature of the SSES work. Appropriate agency and County staff were also involved in various aspects of public notification and SSES tasks.

3.6.1 Preliminary Orientation Meetings with Local Agencies

Prior to beginning any fieldwork, orientation meetings were arranged with each local agency. The meetings typically included public works operations staff and traffic control staff. In areas where a sewer district overlapped municipal jurisdictions, appropriate representatives from each jurisdiction were invited to attend the meeting to coordinate public notification, traffic control, and police and fire services, where necessary. The objectives of the orientation meetings were as follows:

- Review the anticipated scope of work and potential impact on community
  - Manhole inspection - traffic control
  - Smoke testing - traffic control and property access
  - CCTV - traffic control and property access

- Identify local requirements
  - Special event days on which to avoid work - for example, Seafair, street carnivals, etc.
  - Traffic control - identify any unique local requirements and ask local agency representatives to facilitate acquisition of any required permits

- Identify contact personnel - identify a chain of responsibility for notification requirements; identify appropriate agency staff, contractor, and County representatives and provide their phone numbers
  - Police - provide notification of location and time of smoke testing and other inspection work
  - Fire - provide notification of location and time of smoke testing
  - Public works or collection system staff - provide notification of location and time of inspection work, coordinate with cleaning and maintenance schedules, obtain assistance in locating and opening difficult manholes

- Identify public notice requirements and format preferences
  - Draft forms
  - Neighborhood block or committee meetings
  - Medium for notification - mailing, media release, door hanger, day-of-event smoke testing signs, County I/I program Web site
  - Schedule for notification

- Determine rights-of-entry requirements
  - Review draft form
  - Determine which staff will get signed rights-of-entry - County or local agency
  - Need for current owner addresses and exact boundaries for notification
  - Determine schedule for completion

- Answer local agency questions

3.6.2 Rights-of-Entry

Rights-of-entry (ROE) were obtained for properties in those pilot projects where side sewer CCTV inspection was performed. As a precaution, pins were placed to mark the location of critical features such as wyes or changes in pipe direction, and in case it became necessary to excavate to retrieve a jammed camera head or to install a cleanout. Typically, the local agency was responsible for obtaining ROEs. King County reviewed the forms used to ensure that the forms covered the County’s needs. Some CCTV work on private property was not performed specifically because the ROE could not be signed in a timely manner.

3.6.3 Public Notification

Several forms of public notification were used for the SSES, depending on the type of investigation being conducted.

- CCTV (mains and laterals) and manhole inspections were preceded by a media release about 2 weeks in advance of the work.
- Prior to smoke testing in an area, the residents, businesses, and city officials received written notification from King County. The notification included one document highlighting the Regional Infiltration and Inflow Program, and another document identifying the elements of the study and providing contact information for local agency and King County staff. These notices carried both the local agency and County logos to show partnership in this program. Two days prior to smoke testing, crews delivered notices to each residence or building. At apartment or condominium buildings, the crews notified the site manager and provided enough notices to post either within the building or to distribute to each unit.

  In addition, King County issued media releases for each project area and sent the same information to local community or business organizations. To help notify "pass-through" traffic, several wooden A-frame signs were placed in the area ahead of the crews. These signs identified the program and provided a contact telephone number. The day smoke testing occurred, crews attached a red sign saying "smoke testing in progress". In the City of Kirkland, the public works crews offered the use of their construction light sign to help notify motorists and pedestrians on the smoke testing day. Police and fire departments and local agency contacts received daily schedules of the streets to be smoke tested within their jurisdictions.
- Designated local agency contact representatives were notified at the completion of SSES investigations and informed of any significant preliminary findings.

3.7 SSES Conclusions

Only visual identification of clear water entering the pipes through a specific defect or inappropriate connection can positively identify a source of I/I. Even during seasons of wet weather, it is often difficult to see or videotape a site at exactly the right time and conditions to record actual inflow of clear water. In addition, the amount of I/I varies from one rainfall event to the next. Consequently, identification of I/I sources is generally accomplished through compilation of circumstantial evidence pointing to a given defect, connection, or system condition as a “probable” source of I/I.

SSES investigations for the pilot projects successfully identified actual and potential I/I sources using a variety of inspection and testing techniques. Pilot project areas were selected based on pre-SSES flow monitoring results indicative of high I/I levels. In all pilot basins except the City of Auburn (ABN002) and City of Mercer Island (MRC012), the type and extent of defects and system conditions identified during the SSES were consistent with the observed patterns of the flow monitoring results. For pilot basins ABN002 and MRC012, SSES results did not identify actual or potential I/I sources that were consistent with the flow monitoring results. As a result, a more in-depth assessment was required to determine the source and nature of the excess measured flow.

In MRC012, an inability to identify I/I sources for what appeared to be a high inflow (a sharp spike in the flow) on the metering hydrograph led to re-evaluation of the flow records and further field testing. This revealed hydraulic anomalies at the metering site rather than actual inflow conditions, leading to the conclusion that there was no significant inflow contribution from the basin.

In ABN002, the initial SSES investigations looked beyond the narrow limits of the specific tests being performed (for example, CCTV and smoke testing), resulting in identification of a run of manholes set below the flow line in a drainage swale. In addition, re-evaluation of pre-SSES flow data from the basin meter indicated that the magnitude of recorded peaks was influenced by site conditions, thus impacting the accuracy of the readings.

The application of a variety of inspection techniques in different basins provided a greater understanding of the degree to which these techniques identified potential I/I sources so that they could be applied on a system-wide basis. Of the conventional inspection techniques applied to the pilot basins (CCTV of mainlines, side sewers, and laterals; manhole inspections; and smoke testing), CCTV provided the most complete and definitive data on probable I/I sources. While performing inspections during rain events might be more successful in spotting actual leaks, flows would be higher, resulting in either less pipe exposed for inspection or higher costs for bypassing flows.

FELL was very effective and economical in detecting the watertight properties of the pipe. It was especially effective in detecting leaky pipe joints where none could be identified by standard CCTV methods. The FELL technique does not give information on pipe surface condition and other non-penetrating defects. The FELL equipment and tests are simple to apply and can be readily and economically incorporated into the cleaning phase of pipe inspection work. FELL testing can be a valuable complement to CCTV inspection for general pipe condition assessment. If the objective is solely to identify existing breaks and leaky joints, FELL testing could be used instead of CCTV.

Manhole inspections also provided valuable information, particularly when these inspections were performed during rain events after antecedent rainfall had saturated the surrounding soils. As previously described, vacuum testing in manholes was very successful and economical in identifying small potential leaks at joints and for holes not otherwise apparent upon visual inspection. This is a test that could be applied more often where manholes are thought to be sources of I/I.

Smoke testing did not, for the most part, identify as many significant sources of inflow as expected, although several open connections were located. In most basins, peak I/I flow response was a combination of inflow and rapid infiltration. The relatively small number of returns on the smoke testing suggests that rapid infiltration may be the dominant contributor, or potential interferences (such as sags and debris dams) exist within the pipe and prevent the smoke from escaping.

The application of standardized coding to the observed system defects to reflect the relative severity and location of defects provided a way to consistently characterize defects and to quickly identify severe defects requiring corrective design work. SSES work identifying the location, types, and severity of system defects and overall pipe condition provides specific information to designers so that they may effectively determine appropriate types of rehabilitation and the limits of application.