3.0 SEWER SYSTEM EVALUATION

The pressing question for the sewer connection engineer is: whether to rehabilitate or not to rehabilitate. The answer to this question depends on whether it is more cost effective to rehabilitate the defective sewer or to continue maintenance of the sewer. For example, when the maintenance crew ends up spending extensive amounts of time in preventing stoppages in a few defective sewers at the expense of the rest of the system, it is clearly obvious that those portions of the collection system should be rehabilitated.

According to Parcher (1998), sewers have a design life of about 100 years, however, they will not last that long due to structural defects, wear and tear, overloading, corrosion, and deterioration. He further elaborates that any rehabilitation programme is often considered a 50-year fix.

When evaluating a typical sewer system or network, both experience and literature (America Public Works Association, 1977, and Existing Sewer System Evaluation and Rehabilitation, 1983) indicate that the following steps have to be generally covered:

1. Physical survey
2. Cleaning of the sewer
3. Internal Inspection
3.1 Physical Survey

A physical survey is performed to isolate the problem areas and to determine the general physical conditions of the sewer sections to be selected for rehabilitation works. The following tasks are normally included in a physical survey (American Public Works Association, 1997):

1. *Aboveground inspection* – Investigation of general conditions of the study area such as topography, streets, access to manholes will be conducted. Should there be any potential problem areas such as waterways, river crossings, natural ponding areas, notes will be made. Key manholes are identified for additional flow measurements and groundwater monitoring. Manhole access problems, such as easement, access, buried structures, traffic interferences, should also be noted. During the aboveground inspection, the accuracy and completeness of the sewer maps should be verified.

2. *Flow monitoring* – Flow monitoring should be conducted to identify the flow fluxes in the sewer. This will enable identification of areas where I/I (Inflow/Infiltration) exists. Flow monitoring should be conducted during the highest groundwater conditions to identify the maximum infiltration flow, while monitoring for inflow should be done during heavy rainfall or storm conditions. As a comparison, dry weather and wet weather flow should also be monitored.
3. **Flow measurement** – Flow in the sewer system consists of three types of flow: base flow, infiltration and inflow, therefore the primary aim of flow measurement is quantification of these components of flow. Flow measurement of the sewers will provide a clear understanding of the variations of the three flow components with time. There are many techniques for the measurement of flows and the choice selected depends on the resources available, the degree of precision required and the physical conditions within the sewer. Some of the available techniques are:


- Automatic flow measurement – depth and velocity measurement using electromagnetic or Doppler meters, orifice/nozzle and Venturi meters.

4. **Manhole and sewer inspection** – This is an important task which determines the actual condition of the sewer system. During inspection, each manhole should be numbered and its physical condition noted in log sheets. Safety precautions should be taken at all times before entering the manholes. An inventory of the length, size, type, depth and the general conditions of the sewer pipes provides a basis for the estimation of work required for the preparatory cleaning and internal inspection. The depth of flow in the sewers provides a rough indication of the capacity of the sewer and whether or not I/I is present in the particular section of sewer. All the observations made during the manhole and sewer pipe inspection should be recorded in field log sheets and correlated with the sewer maps.
5. *Rainfall simulation* – rainfall simulation allows the identification of I/I conditions during rainfall events. Not all sewer evaluation exercises require rainfall simulation to be carried out. To determine whether rainfall simulation is required, a careful study of the sewer maps and review of any current or previous I/I analysis, smoke test results and the physical survey results have to be made.

6. *Smoke testing* – smoke testing is an inexpensive and quick method of identifying inflow sources in sewer systems. Typical inflow sources are roof leaders, yard and area drains, foundation drains, faulty connections, illegal connections, structural damages and leaking joints.

7. *Dyed water testing* – this method is used primarily to detect infiltration. It can also be used to verify the results of smoke testing, however, this method of testing is more expensive and time consuming in comparison to smoke testing and requires large quantities of water.

3.2 **Cleaning of the Sewer**

Preparatory cleaning of the sewer is essential for any further internal examination of the sewer. The predominant reason for cleaning the sewer is to ensure that the pipe walls are sufficiently clean for the camera used in the internal inspection to discover structural defects, misalignments and I/I sources (American Public Works Association, 1997). The procedure should
ensure the cleaning of sludge, mud, sand, gravel, rocks, bricks, grease and roots from the sewer line. Typical equipment required for cleaning are:

- Rodding machines, bucket machines, high velocity water machines and other hydraulically propelled devices;
- Debris removal equipment, such as vacuum machines and trash pumps;
- Debris transport vehicles; and
- A proper debris disposal site.

Factors to be considered during cleaning are: access and condition of manholes, depth of the sewer, size of the sewer, depth and type of solid materials to be removed, degree of root intrusion, amount of flow, structural integrity of pipe, availability of hydrant water and the degree of cleanliness required.

3.3 Internal Inspection

In Section 2.3 it was mentioned that the structural grading of the existing sewer and its hydraulic capacity are the two most important factors which will determine the chosen rehabilitation option. Therefore, to accurately determine these factors, it is necessary to conduct an internal inspection.

Where physical entry into the pipe is possible, manual inspection is undertaken with due regard to confined space training and safety requirements (Insituform, 1996). Defects are identified and logged by certified operators who are able to classify the structural integrity of the sewer. Whereas visual
surveys will always remain the most widely used means of inspection, it has its restrictions in that it is not possible to visually inspect non man-entry sewers. Therefore, for non man-entry sewers, at present the two main internal inspection technique used (Kurtec, 1998) are the video camera or more commonly known as CCTV (Closed Circuit Television Camera) and electronic tracing equipment.

*Video Camera Inspection*

Although camera inspection is not a totally new concept, the improved techniques and advanced technology have certainly enhanced its capabilities. There is a wide range of cameras available in the market which are capable of providing perfect images of the sewer condition.

These cameras come in different shapes and sizes to suit different sewers and their varying conditions. Following is a list of different types of CCTV equipment (compiled from various CCTV brochures):

i. Pan and tilt robot tractor systems

ii. Flexiscan robot tractor systems

iii. High temperature and explosion proof vessel/tank camera systems

iv. Mini flexiprobe colour camera systems

v. Videoscope colour camera systems

vi. Flexible endoscopes (various sizes: available as small as 0.5 mm)

vii. Pan and tilt robot tractor systems

viii. Fleiscan robot tractor systems

ix. High temperature and explosion proof vessel/tank camera systems
x. Mini flexoprobe colour camera systems

xi. Videoscope colour camera systems

xii. Flexible endoscopes (various sizes: available as small as 0.5 mm)

xiii. Rigid endoscopes (various sizes: available as small as 0.5 mm)

Figure 3.1 shows two types of CCTV equipment typically used in sewers.

Figure 3.1 CCTV equipment typically used in sewers.
These camera systems have various capabilities, which include (compiled from various CCTV brochures):

i. Working in explosion proof environments

ii. Operates through 45 and 90 degree bends

iii. Inspection of horizontal and vertical sections of piping

iv. Detailed weld inspections and crack detection

v. Determining internal conditions (corrosion levels, level of deterioration)

vi. Determining discoloration

vii. Underwater operations

viii. Remote adjustable focusing

**Figure 3.2** provides an indication as to how CCTV equipment is typically set up in a sewer.

**Figure 3.2** CCTV set up in a sewer.
Electronic Tracing Equipment

The electronic tracing equipment allows for tracing of pipes or conduits, and the location of buried chambers (Insituform, 1996). The electronic tracing equipment is typically undertaken using handheld detection equipment and specialist probe systems as depicted in Figure 3.3.

Figure 3.3 Electronic tracing of sewers.
(Source: Surveys and Condition Assessment Brochure from Insituform)

3.3.1 Preparatory Works for CCTV Survey and Execution of the CCTV Survey

Before any CCTV survey can commence, it is necessary to examine the routes of the critical sewers on site and on the as built drawings. This procedure needs to be properly managed and controlled to enhance smooth CCTV survey execution. The logged data and other observations made during the physical survey (Section 3.1) are also studied prior to deciding on the sewer stretch that requires CCTV works to be conducted.
The main aim of undertaking CCTV survey is to record features, defects and the structural condition of the sewer. The most common system that may be employed is the self-propelled crawler TV camera that can be operated from a single manhole entry by skilled operators. Typically the length of survey per day is 100 m per unit (Conversation with CCTV supplier and contractor).

During execution of the CCTV survey, the health and safety procedures have to be strictly adhered to, to ensure effective and productive work is carried out. Aspects that need due consideration during the survey include traffic management, ventilation, safe parking and storage of equipment, provision of cones and adequate lighting. During the survey, the results will be recorded on screen, the computer or VCR. Data recorded include size of sewer and direction of flow, roads, chainage, manhole reference and date.

During the CCTV survey, apart from inspecting the internal condition of the existing sewer, it is also imperative to conduct manhole inspections to ensure that the manhole is in good condition, and does not allow infiltration and inflow into the sewer line. This is especially important as many trenchless rehabilitation technologies use manholes as main line access points. Typical issues with respect to manholes are buried manholes causing access problems, safety issues, jammed manhole covers, traffic problems, high flow regimes and siltation problems (Parcher, 1998).

Upon completion of the CCTV survey, a final report containing daily log sheets, video cassette recordings, off-screen photographs, computerised coding
sheets, defects coding and computerised log sheets are delivered by the appointed contractor.

3.4 Structural Performance Evaluation and Critical Sewers

After conducting the CCTV exercise, the CCTV report, video cassette recordings, photographs and log sheets need to be scrutinised to determine the structural performance of the network being studied.

The aims of carrying out this task are:

- to maintain consistency
- to follow an objective grading system
- to establish structural condition grading of 1 to 5
- to target sewer systems that require immediate rehabilitation
- to allow matching of suitable rehabilitation system to the defects at hand.

Upon receiving the final report, each length of sewer is examined and assigned a structural condition grading. This is followed by a thorough cost effective analysis.

Structural condition is concerned with defining the degree of deterioration of the overall sewer structure. The overall pipeline or sewer includes the surrounding support to the sewer as well as the sewer itself. Through research, it has been shown that the mechanism of a sewerage pipeline is a complex interaction of many variables, resulting from the external and internal
environment to the pipeline as well as the pipeline material itself (Melbourne Water, 1994). It is generally accepted that the assessment of the condition of the structure is subject to limitations and may not be terribly accurate due to the following:

- difficulties identifying the variables affecting the condition
- difficulties defining the effects of the different variable on each other
- capabilities of technology used for assessment
- accessing and sampling the structure and surrounding for assessment.

Therefore, when determining the structural condition of the sewer, interpretation of visual signs of deterioration and recorded performance data need to be relied on heavily (Melbourne Water, 1994).

The structural condition grade used by IWK has been adopted from the WRC grading system. During the research of this topic, it has been observed that the Australian sewerage industry has also adopted the WRC grading system, which is outlined in the following table.

Therefore, based on the structural performance of the sewer line, it is now possible to consider which rehabilitation method is most suitable to be used.
Table 3.1 Definition of Condition Grades

<table>
<thead>
<tr>
<th>Internal Condition Grade</th>
<th>Typical Defect Description</th>
<th>Possible Collapse</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Already collapsed; or Deformation &gt; 10% and cracked or fractured or broken; or Extensive areas of missing fabric</td>
<td>Imminent</td>
</tr>
<tr>
<td>4</td>
<td>Deformation 5 – 10% and cracked or fractured or broken; or Broken or fractured; or Serious loss of level.</td>
<td>Within 12 months</td>
</tr>
<tr>
<td>3</td>
<td>Deformation 0 – 5% and cracked; or fractured; or Longitudinal/multiple cracking; or Occasional fractures; or Severe joint defects; or Minor loss of level; or Badly made connections.</td>
<td>Within 3 years</td>
</tr>
<tr>
<td>2</td>
<td>Circumferential cracking; or Moderate joint defects.</td>
<td>Within 10 years</td>
</tr>
<tr>
<td>1</td>
<td>No structural defects</td>
<td>Unlikely</td>
</tr>
</tbody>
</table>

The structural criticality of sewers also has to be taken into consideration when choosing the most suitable rehabilitation method. IWK’s sewer refurbishment program focuses primarily on critical sewers, which are sewers that result in high post-failure costs due to the many social and commercial implications arising from its failure. Critical sewers are assumed to take upto 5% of the total length of the networks. The criteria IWK uses in determining critical sewers is as follows:

- Any sewer in good ground 6 m or deeper
- Any sewer in bad ground 5 m or deeper
- Any sewer of 600 m diameter or greater
- Any sewer under highly important traffic routes with a traffic flow of more than 7,500 vehicles per day
- Any sewer under railways, rivers, expressways, major buildings, major commercial streets, primary access to major industrial areas
• Any sewer adjacent to major hospitals, sports stadiums, exhibition centres, conference centres

• Any sewer within a local site of high tourist attraction

• Any sewer adjacent to high risk installations (electricity, oil pipelines, etc.).

The target performance standard for all critical sewers on completion of the programme is Condition Grade 3. It is important to have a target performance standard or standard of service, as this will enable IWK to measure its level of performance.

This step is also essential to narrow down the focus of the refurbishment effort in order to save time and cost, and to ensure that unnecessary works is not undertaken on non-strategic sewers.
Outline of IWK's Network Refurbishment Plan

IWK has identified the following structure for undertaking of sewer rehabilitation works. However, note that to-date, IWK has not conducted any rehabilitation works.

1. Identification of critical sewers
2. Documentation on CCTV survey
3. Preparatory works for CCTV survey
4. Pre-cleansing works
5. CCTV survey
6. Structural performance evaluation and set up database
7. Planning renovation system
8. Emergency works
9. Documentation on rehabilitation works
10. Preparatory works for rehabilitation
11. Undertake rehabilitation works

The above steps can be represented on a Refurbishment Flow Chart with regards to time (month) as depicted overpage. Should this flow chart be adhered to, it will not be surprising if refurbishment of a single sewer network will take approximately 3 years from conception to completion.