# DETERMINING TRENCHLESS RENEWAL OPTIONS USING CCTV INFORMATION

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## ABSTRACT

There are now a substantial range of trenchless renewal options available in New Zealand for the rehabilitation or replacement of deteriorated gravity pipes (Storm or Sewer). All of these options have their own set of benefits and limitations as to where they can be used. A significant challenge for designers and asset owners is determining what the available trenchless renewal options are, and therefore what the optimum option is.

The majority of sewer pre-renewal investigations involve CCTV inspections, and therefore is the primary basis for determining or designing the method of renewal. The information from the CCTV inspections provides an understanding as to how the trenchless methodologies can be applied and their limitations in that application. The key to a successful trenchless renewal project is the accurate interpretation of this CCTV information.

This paper sets out the application parameters of the various renewal options and the limitations of information available from CCTV Inspections and also identifies where further investigation may be required. The paper's conclusion will provide an independent guideline for the selection of trenchless renewal options based on the information that can be obtained from a CCTV inspection.



## KEYWORDS

Trenchless, Rehabilitation, Renewal, Replacement, CCTV Investigations, gravity pipes


## 1. INTRODUCTION

There are now a substantial range of trenchless renewal options available in New Zealand for the rehabilitation or replacement of deteriorated gravity pipes (Storm or Sewer). All of these options have their own set of benefits and limitations as to where they can be used. A significant challenge for designers and asset owners is determining what the available trenchless renewal options are, and therefore what the optimum option is.

CCTV inspections can provide the user extensive information regarding the pipeline, all of which play a vital role in determining trenchless renewal options. In some cases his information is insufficient to determine the optimum trenchless renewal option and therefore the limitations of CCTV inspections should always be considered and adequately investigated.

This paper provides a guideline which covers the process of determining trenchless renewal options from CCTV Information. This includes what information can and cannot be determined from the CCTV, and where further investigation may be required. The information from the CCTV inspections provides an understanding as to how the trenchless methodologies can be applied and any limitations in that application.

# 2. WHAT ARE THE TRENCHLESS TECHNOLOGY OPTIONS?

The main focus of this paper is on trenchless renewal options for the rehabilitation or replacement of deteriorated gravity Storm or Sewer pipes.

There are three broad categories in which Trenchless Technologies can be separated. All trenchless methodologies fall into one of the following categories; the installation of new assets; rehabilitation of existing assets and replacement of assets.

- Installation of New Assets;
  - Drilling;
  - Micro-tunnelling;
  - Auguring;
  - Thrusting;
  - Pipe Ramming;
- Rehabilitation of Existing Assets;
  - Grouting
  - CIPP Lining;
  - Fold & Form Lining;
  - Spiral Wound Lining;
  - Slip Lining;
- On-line Replacement of Existing Assets
  - Pipe Bursting/Splitting;
  - Pipe Reaming/Eating;

For this paper we shall limit, our discussion to the renewal methods (rehabilitation & replacement) to only structural renewal methods for circular gravity pipes. This is therefore excluding, all of the new installation trenchless methods and the Grouting method which is used for non-structural rehabilitation of leaky, infiltrating and exfiltrating pipes.

## 2.1. BRIEF DESCRIPTION OF THE TRENCHLESS RENEWAL OPTIONS

The available methods for the rehabilitation or replacement of deteriorated gravity pipes (Storm or Sewer) are briefly described as follows:

### 2.1.1. CURED IN PLACE PIPE (CIPP) LINING

This is a pipeline rehabilitation method that is a “close fit” lining system of resin impregnated felt. The method of CIPP Lining can offer quantifiable structural strength to a pipeline and can suit various loading conditions. It can be used for pipelines generally between 100 to 1800mm diameter and can be used for the rehabilitation of almost any shape including non-circular conduits e.g. ovoid or arch shaped cross sections.

There are three main curing methods of CIPP lining including; hot water curing, steam curing and ultra-violet curing.

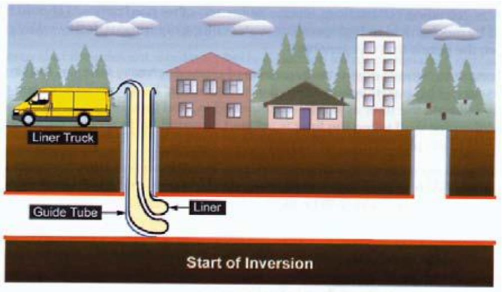



*Figure 1: CIPP Methodology Part 1*

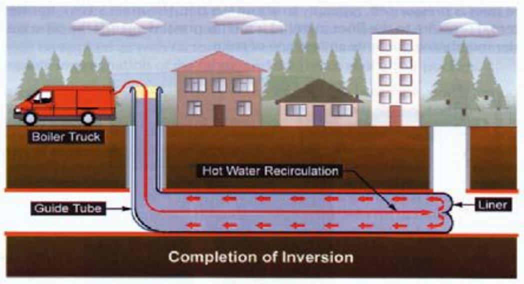



*Figure 2: CIPP Methodology Part 2*

### 2.1.2. FOLD AND FORM LINING

Fold & Form Lining is also a close fit lining system. Fold & Form lining can done using PE or PVC liner material. It is mostly limited to pipe sizes less than 540mm diameter.

*Figure 2: Fold and Form Installation*

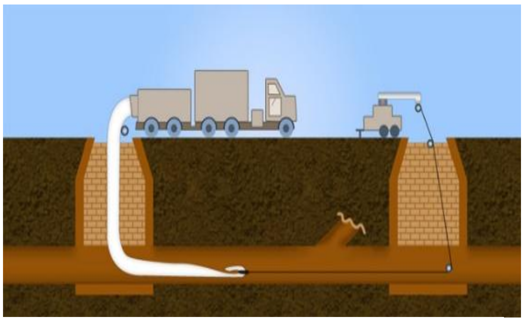


*Figure 4: Fold and Form Methodology*

The Fold and Form rehabilitation method involves deliberately deforming the PE or PVC material into a U or C shape to allow insertion into the host pipe. The liner is pulled into place generally using a winch system. The liner is then reverted back to its original circular shape using heat and pressure.

### 2.1.3. SPIRAL WOUND LINING

The liner is made of a single strip of PVC that interlocks together as it passes through a winding machine. The spiral wound liner forms a continuous liner inside the host pipe. The liner can be expanded radially to form a tight fit against the wall of the host pipe. The expanded spirally wound liner is suitable for pipes with internal diameters from 150mm to 1800mm, larger diameters are possible but not common in New Zealand. This process is different to other close fit lining systems, as it is either formed, dependent on the pipe diameter, inside the MH, or formed inside the pipe. The method does not require heating and water or steam pressure at any stage of the on-site installation process.

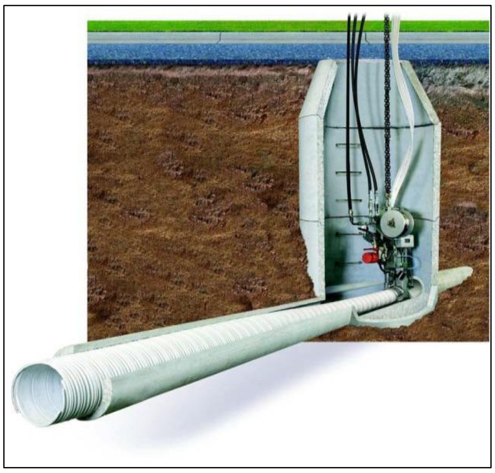


*Figure 5: Spiral Wound Installation 1*

*Figure 6: Spiral Wound Installation 2*

### 2.1.4. SLIP LINING

Slip lining is a rehabilitation method that installs a new pipe within the old host pipe. Many materials have been used in slip lining since its conception including clay, concrete FRC, Hobas (GRP) & Steel.

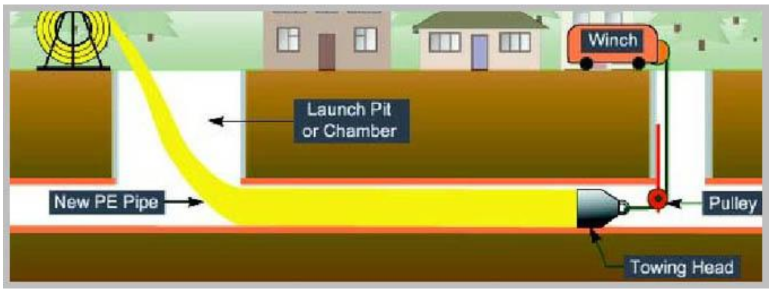


*Figure 7: Slip Lining Methodology*

The new "slip line" pipe outside dimension needs to be smaller than the host pipe's internal dimension. The slip line pipe is either pulled or pushed into the host pipe. Once in place, the annulus between the host pipe and the existing pipe is grouted. The grouting is to ensure the slip lined pipe is restrained in place and the external loads on the host pipe are transferred to the new pipe.

### 2.1.5. PIPE BURSTING/SPLITTING

The Pipe Bursting method, developed in the 1980's, involves the replacement of the host pipe by fragmenting the existing pipe and installing a new pipe of equal or larger diameter in its place.

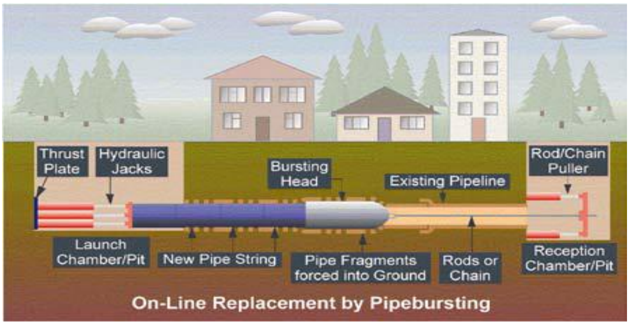


*Figure 8: Pipe Bursting Methodology*

The bursting head is pushed or pulled through the existing pipe to fragment it into the surrounding ground. The new pipe is dragged behind the bursting head.

There are several impacting factors or limitations that require consideration when carrying out Pipe bursting. These can include soil conditions; pipes with point repairs; collapsed pipes; pipes encased with concrete; entry & exit pits; depth of pipe; ground heave and the effect of Pipe bursting on adjacent structures. Pipe bursting is considered a partially trenchless method as there is some open cut work that is necessary at the entry & exit pipes and at lateral connections.

### 2.1.6. PIPE REAMING/EATING

The Pipe Reaming/Eating is another partially trenchless replacement method. It is similar to Pipe bursting in that it allows a new pipe to be installed in the same position as the existing pipe, "On-line Replacement." However, the method is slightly different in that rather than the broken pipe fragments being pushed into the surrounding soil, they are removed from the ground.

Pipe Reaming/Eating has many of the Pipe Bursting limitations as described in section 2.1.5. However, as the broken pipe fragments are removed from the ground the risk of damaging nearby utilities and the impact on the surrounding soil is reduced significantly.

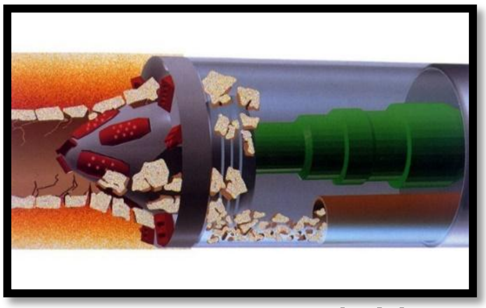


*Figure 9: Pipe Reaming Methodology*

Pipe Reaming utilizes a direction drilling machine with specialized reaming tools that grinds up the old pipe while pulling a new pipe in behind. The broken pipe fragments are suspended in drilling fluid and pass through the existing pipe to the manhole or recovery pit. Pipe Eating involves the use of a Micro-Tunnel Boring Machine (MTBM) to carry out the replacement of damaged or old sewers.

## 2.2. PIPELINE PROPERTIES THAT REQUIRE CONSIDERATION

There are many possible defects or features that may be present within existing pipelines. However, the following are critical pipeline attributes and defects that need to be considered when carrying out any renewal investigation because of the significant impact that they have on the suitability or practicality of their application:

- Pipeline Attributes:
  - Depth;
  - Pipe Length;
  - Dimension Changes;
  - Pipe Material & Material Changes;
  - Lateral Connections – Source, Status & Chainage;
  - Grade & Alignment;
- Internal Pipeline Condition:
  - General Condition (Structural & Service);
  - Pipe Deflection/Dips;
  - Pipes Holding Water i.e. Surcharged or Submerged;
  - Pipe Deformation;
- External Pipeline Condition:
  - Pipe Wall/Thickness Condition;
  - Surrounding Soil Condition;
  - Surrounding Groundwater level;

## 2.3. LIMITING FACTORS OF TRENCHLESS RENEWAL

The most suitable Renewal options will be determined based on what conditions are found from the renewal investigations. Table 1, has been adapted from ProjectMax's Trenchless Method Selection Guide, and identifies the principal limiting factors, of each methodology, against the critical pipe attributes and defects. A key benefit of trenchless technology is the elimination of the issues that arise from traditional trenched/open cut excavation. Therefore, excavation repairs, to remove limiting factors, to enable Trenchless renewal, will reduce the expected benefits of any trenchless activity.

In addition, there are other factors that may need to be considered as part of the detailed design process. The loading conditions and the hydraulic capacity (upsizing requirements) are identified as being detailed design considerations and therefore are presumed to be checked and confirmed further into the method selection process.

*Table 1: Trenchless Renewal Suitability Matrix*

| PIPELINE PROPERTIES | | CIPP LINING | FOLD & FORM LINING | SPIRAL WOUND LINING | SLIP LINING | PIPE BURSTING | PIPE REAMING/ EATING |
|---|---|---|---|---|---|---|---|
| | | TRENCHLESS RENEWAL TECHNIQUE | | | | | |
| | | REHABILITATION | | | | REPLACEMENT | |
| **DEPTH OF PIPE** | **Shallow pipe** | No particular limiting factors. Suitable for application | | | | Risk of ground heave and contact with adjacent underground structures increases with shallower depth of pipe, particularly less than 1m. | No particular limiting factors. Suitable for application |
| | **Deep pipe** | Greater depth of pipe results in increase in the loading conditions, which can impact on the liner design. | | | Greater depth of pipe results in increase in the loading conditions. Suitability is impacted on due to excavations at lateral connections and entry & exit pits. | Pipe loading considerations become more important. Suitability is impacted on due to excavations at lateral connections and entry & exit pits. | |
| **PIPE LENGTH** | **Effect of Pipe Length** | No particular limiting factors. Suitable for application. | | | | | |
| **DIMENSION** | **Applicable Size Range (dia mm)** | Greater and equal to 100mm | 150 – 540mm | Greater and equal to 150mm | Greater and equal to 100mm | 100 – 450mm (Larger diameters possible but not common in NZ) | |
| | **Effect of Small Changes in Pipe Diameter (<10%)** | Liner will follow the shape of existing pipe, i.e. there may be a step in the liner. There is a potential for minor wrinkling of the liner to occur. | Liner will follow the shape of existing defects. Smoother transition than CIPP. To change the liner profile size, excavation may need to be considered. | Spiral Wound liner can pass through a pipe diameter change, however the liner expansion will be restricted to the size of the smaller diameter pipe section. | Slip lined pipe can pass through a pipe diameter change, however it will be restricted to the size of the smaller diameter pipe section. | No particular limiting factors. Suitable for application. | |
| | **Effect of Pipe Size Change** | Not suitable for application | | | | Not suitable for application | |
| **PIPE MATERIAL** | **Effect of Pipe Material** | No particular limiting factors. Suitable for application. | | | | | |
| | **Changes to Pipe Material** | No particular limiting factors. Suitable for application. | | | | Not suitable due to needing different heads and also changes in pipe material raises the risk of external point repair clamps being present which | |
| **PIPE BENDS** | **Bends** | Liner will follow the shape of existing defects, e.g. if there is a displaced joint then there will be a step in the liner and the potential for wrinkling of the liner to occur. Sharp defects, e.g. protruding laterals should be removed as they could damage the liner during installation. | Typically bends > 11° can't be lined through | Typically bends > 11° can't be lined through | Typically bends > 11° can't be lined through | Typically bends > 11° can't be burst or reamed through | |
| **EFFECT OF EXISTING DEFECTS IN HOST PIPE** | **Displaced Joints** | | Liner will follow the shape of existing defects. Smoother transition than CIPP. | May be an issue depending on amount of displacement or deformation | Defects that reduce the diameter of the host conduit need to be removed to allow sliplining | Bursting/reaming will break away existing defects | |
| | **Pipe Deformations** | | | | | | |
| | **Obstructions & Protrusions incl (Mass root blockages & tap roots)** | | Obstructions and protruding laterals should be removed | | | | |
| | **Holes** | No particular limiting factors. Suitable for application. | | | | | |
| | **Broken & Partially to Fully Collapsed Pipe** | Can be lined through provided that there is still a clear bore. | | | | Partially collapsed pipes can be removed, although it is dependent on the level of collapse and fragility of the pipe section. If a tool finds a collapsed section of host pipe, it can be lead off track. | |
| | **Dips in Existing Pipe** | Will remain | | | | Will normally remain, but minor dips may be removed. | |
| **LATERAL CONNECTIONS** | **Effect of Lateral Connections** | No particular limiting factors. Suitable for application. | | | All lateral connections require reconnecting by excavation. | | |
| **GROUND CONDITIONS (INCL WATER TABLE)** | **Nearby Services & Structures** | No particular limiting factors. Suitable for application. | | | | Need to be considered during design. | |
| | **Concrete Encasements** | | | | | Not suitable for application | |
| | **Ground Conditions** | | | | | Must be displaceable | No particular limiting factors. Suitable for application. |
| | **Water Table** | Needs to be considered for liner design. Infiltration can afffect curing and resin washout. | | Needs to be considered for liner design. | No particular limiting factors. Suitable for application. | Need to be considered during design. | |

# 3. CCTV INFORMATION – WHAT CAN AND CANNOT BE DETERMINED?

All of the trenchless renewal options described in table 1, have method specific limitations and are not able to be applied equally across all scenarios or situations. To determine the optimum option, each method requires in-depth investigation/analysis. A CCTV inspection is widely used as the primary basis of pre-renewal investigation for determining or designing the method of renewal for deteriorated gravity pipes.

A pipeline CCTV inspection involves a camera that has a fixed or a rotating "pan & tilt" camera head. This camera is inserted through an access point to enter the pipeline, most commonly through a manhole. The camera is then pushed or driven remotely through the pipeline, during which the camera will focus on pipe features and defects. The camera lens of a pan and tilt camera, can be rotated around the cross section of the pipe. Thus, providing a 360 degree view of the pipe features and defects. The pipe features and defects should be coded on a logsheet with respect to the NZ Pipe Inspection Manual.

## 3.1. WHAT INFORMATION CAN BE DETERMINED USING CCTV?

To identify what can, or cannot be determined by CCTV, the critical pipeline attributes and defects need to be considered. The information a CCTV Inspection provides to an asset owner, or designer, includes information on the Internal Pipeline Condition, and very limited amounts of information on the external pipeline and surrounding ground condition.

There are two particular stages where information can be gathered. Firstly, there is the entry phase and then secondly the inspection phase. The entry phase, involves gathering information at the access point, i.e. measuring the depth to invert of the pipe; the pipe diameter; and the initial material/shape of the pipe. An accurate measurement of the pipe diameter often requires man entry.

For the inspection phase, most of the information is obtained from the view of the CCTV camera. When a pipe feature or defect is identified by the CCTV camera, the following information can be obtained;

- The depth to invert and the above ground location can be determined using a sonde transmitter and receiver, with an incremental accuracy loss with increasing depth.
- The chainage/distance along the pipe length can be determined using the built in distance counter;
- The internal pipe material and any material changes can be determined;
- The pipe feature or defect size (small, medium or large severities) can be interpreted qualitatively, i.e. measured only approximately in context with other pipe attributes or features, such as the pipe diameter or circumference;
- Pipes that are holding debris or holding water i.e. submerged, surcharged & dipped. The water/debris level can be identified with reference to the pipe diameter;
- Surface damage of the internal pipe surface can only be approximated visually;

## 3.2. WHAT INFORMATION CANNOT BE DETERMINED USING CCTV?

From the above details, of what can be determined from CCTV Inspections, several broad limitations of CCTV can be identified and in-turn the information that cannot be determined from CCTV Inspections, can be deduced. The limitations are as follows;

- Using a sonde unit to determine position and depth; is limited to open and accessible areas and by structures or water bodies. In addition, the signal can be interfered with by metallic pipes and electromagnetic cables, resulting in inaccurate information.
- A CCTV Inspection cannot; therefore:
    - Measuring the dimensions of a defect or pipe attribute is limited. The camera lens distorts the size of the images displayed on the screen;
    - The internal pipeline condition under the water level is generally too difficult to determine, as a result of the view being obscured;
    - No information can be determined about the outside of the pipe;
    - Loss of pipe surface or size of deformations of plastic pipes is difficult to determine;
- The accuracy of interpretation may also be limited to the training and competency of the personnel involved;
    - The interpretations of CCTV are dependent on how experienced and knowledgeable the assessor is;
    - The CCTV quality is only as good as the Operator's Inspection skills and how competent he/she may be through their experience and training;

As a result of the broad limitations above, the CCTV information is therefore qualitative not quantitative.

Table 2, summarises what information can & cannot be determined from CCTV based on the limitations of the technology. This table is designed to assist in identifying the critical attributes and defects, which can be determined using CCTV. It also identifies the further investigation techniques that may be required, when CCTV is not able to provide the information, or quantify the information sufficiently, to determine the suitable renewal options.

*Table 2 - CCTV Can & Cannot Matrix*

| Item | | INFORMATION THAT CAN BE DETERMINED FROM CCTV INSPECTIONS | INFORMATION THAT CANNOT BE DETERMINED FROM CCTV INSPECTIONS | What investigation technique can be used to gain more information? (Refer to Appendix A for more details on these techniques.) |
|---|---|---|---|---|
| Pipeline Attributes | Depth | Reduced levels to the pipe invert can be identified at the MH's or through using a sonde unit on the camera and a receiver to pick up the location. This method is limited to areas that are open and accessible. | Accurate readings of reduced levels along the pipe length where obstacles at ground level are present e.g. under buildings under vehicles. Also metallic pipe materials and other metallic services can interfere with the sonde units transmission. | Exploratory Excavations (Pot holing)<br>Ground Level<br>3D Spatial mapping tools<br>Intelligent Inspection tools |
| | Pipe Length & Chainage | Confirmation of the length & chainage of internal pipe features & defects with reference to the starting node point e.g. length of pipe material and the location of changes of pipe materials over the length. | The length & location of external pipe features &/or defects that are not visible internally e.g. external capping of the pipe. | Exploratory Excavations (Pot holing)<br>Electromagnetic Methods using Intelligent Inspection Tools |
| | Dimension & Dimension Changes | Large or sudden dimension changes can be identified - Detection is visually limited quantitatively. Dimensions can be accurately measured at the manholes | Accurate measurements of dimension changes. Changes to the effective pipe diameter can be difficult to identify visually | Man Entry Inspection<br>Laser Profiling tools |
| | Pipe Material & Pipe Material Changes | Pipe material internally can be determined using the known manufacturer's standard joint spacing and a knowledge of the internal visual appearance of the pipe. | External joint connection systems - particularly at joints where there is a material change e.g. Gibault joints for variations in the diameter pipe, and also concrete encasements around joints. | Exploratory Excavations (Pot holing)<br>Electromagnetic Methods using Intelligent Inspection Tools |
| | Lateral Connections | Confirmation of number and location of connecting laterals. Visual evidence can provide indications as to whether the lateral is live or blank. | Confirm the source or status of a lateral connection. | Dye testing<br>Smoke testing<br>Lateral CCTV |
| | Grade & Alignment | Possible to identify changes of alignment by the presence of pipe bends and offset joints. Some cameras have inclinometers to provide gradient information. Inclinometers are, however, wholly inaccurate and not reliable to provide accurate information on pipe gradient. | Subtle changes in pipe gradient will not be identified. Accurate pipe gradient information cannot be obtained other than what is available from the inclinometer. The ideal information for pipe gradient is an accurate picture of the pipe's 3D location. | 3D Spatial mapping tools |
| Internal Pipeline Condition | General Condition (Structural & Service) | For the pipeline features and defects, the structural and service condition scores of the pipe can be identfied as per the New Zealand Pipe Inspection Manual. These scores allow a structural and service grade score to be identified which indicates the overall condition of the pipe (excellent to critical). | Accurately measure the dimensions of a defect or pipe attribute due to picture distortion and magnification from the CCTV camera.<br>Accurately identify locations of | Laser Profiling tools<br>Sonar Profiling tools<br>3D Spatial Mapping Tools<br>Smoke Testing |
| | Pipe Deflection/Dips | When the pipe is not dry, ponding of sewerage is identifiable. Although limited to what can be seen visually, the severity of the deflection can be determined, based on the depth of ponding relative to the pipe diameter. The depth of flow and sediment deposits can make it difficult to assess the severity of dipping. | An accurate measurement of the pipe deflection/dip. The amount of deposits settled in a dip cannot be quantified by CCTV. | Clean out the dipped pipe section and then;<br>Re-inspect with CCTV while limiting or by-passing the flow or use;<br>3D Spatial Mapping Tools |
| | Pipe Deformation | Detection visually is limited. Deformations are more easily seen, in non plastic pipes, which are identified by 3 to 4 continuous longitudinal cracks. For plastic pipes, deformation >15% can be seen. | Accurate quantification of pipe ovality. Deformation in plastic pipes <15% cannot be determined. | Laser Profiling Tools<br>Sonar Profiling Tools |
| | Pipes Holding Water i.e. Surcharged or Submerged | A visual estimation of the water level based on how full the pipe is i.e. Percentage of pipe diameter submerged or holding water. | An accurate measurement of the water level and sediment deposits under the water level. The internal pipeline condition under the water level is generally to difficult to determine. | Laser Profiling Tools<br>Sonar Profiling Tools - Limited to pipes >450mm diameter & 1/3 full; |
| External Pipeline Condition | Pipe Wall/Thickness Condition | General condition of the pipe wall can only be identified from what is visible internally such as defects on the pipe surface or defects that have a visible pathway through the pipe wall. Erosion/corrosion on the pipe surface can be identified qualitatively, although detection is visually limited and requires evidence such as rebar/aggregate. | Identify the external condition of the pipe material or the pipe wall thickness. The condition of the pipe wall that is not visible internally. Corrosion or erosion of the pipe wall cannot be quantitatively measured. | Laser Profiling tools<br>Core sampling<br>Full Sample Removal<br>Ultrasound Testing<br>Electromagnetic Methods using Intelligent Inspection Tools |
| | Surrounding Soil | The condition of the surrounding soil can only be identified from what is visible internally such as through defects that have a large pathway through the pipe wall. These defects are cavities/offset joints/displaced lateral connections where tomos have formed. | Identify the condition of the surrounding ground. | Ground level visual inspection<br>Exploratory Excavation (Pot Holing)<br>Wave Impedance Probe<br>Ground Pentrating Radar |
| | Ground water | Active infiltration through joints, lateral connections cracks and breaks in pipe. | Identify an accurate measurement of the ground water level of the surrounding groundwater. | Flow Monitoring Devices<br>Groundwater monitoring level bores |

# 4. FLOW CHART – THE CCTV INSPECTION TO THE TRENCHLESS RENEWAL OPTION

There are two clear aspects to the information detailed in the table 2, CCTV Can & Cannot Matrix:

1. Information used in the Investigation phase which involves determining whether renewal or replacement is required;
2. Information used in the Method Selection phase which involves determining the applicable trenchless renewal methods.

CCTV is involved in both the Investigation Phase and the Method Selection Phase. To identify how the process extends from a CCTV Inspection to the trenchless renewal option, the Figure 10 (Renewal Option Selection Flow Chart), has been developed.

The flow chart details the process from CCTV Inspection to the determination of applicable Trenchless Renewal Options. The flow chart commences, with a CCTV inspection being undertaken. From there the defects/features of the pipeline are identified which determines whether or not the pipeline requires renewal/replacement. This being the investigation phase. Two scenarios can occur where there may be further investigation required, as per the flow chart, they are the following;

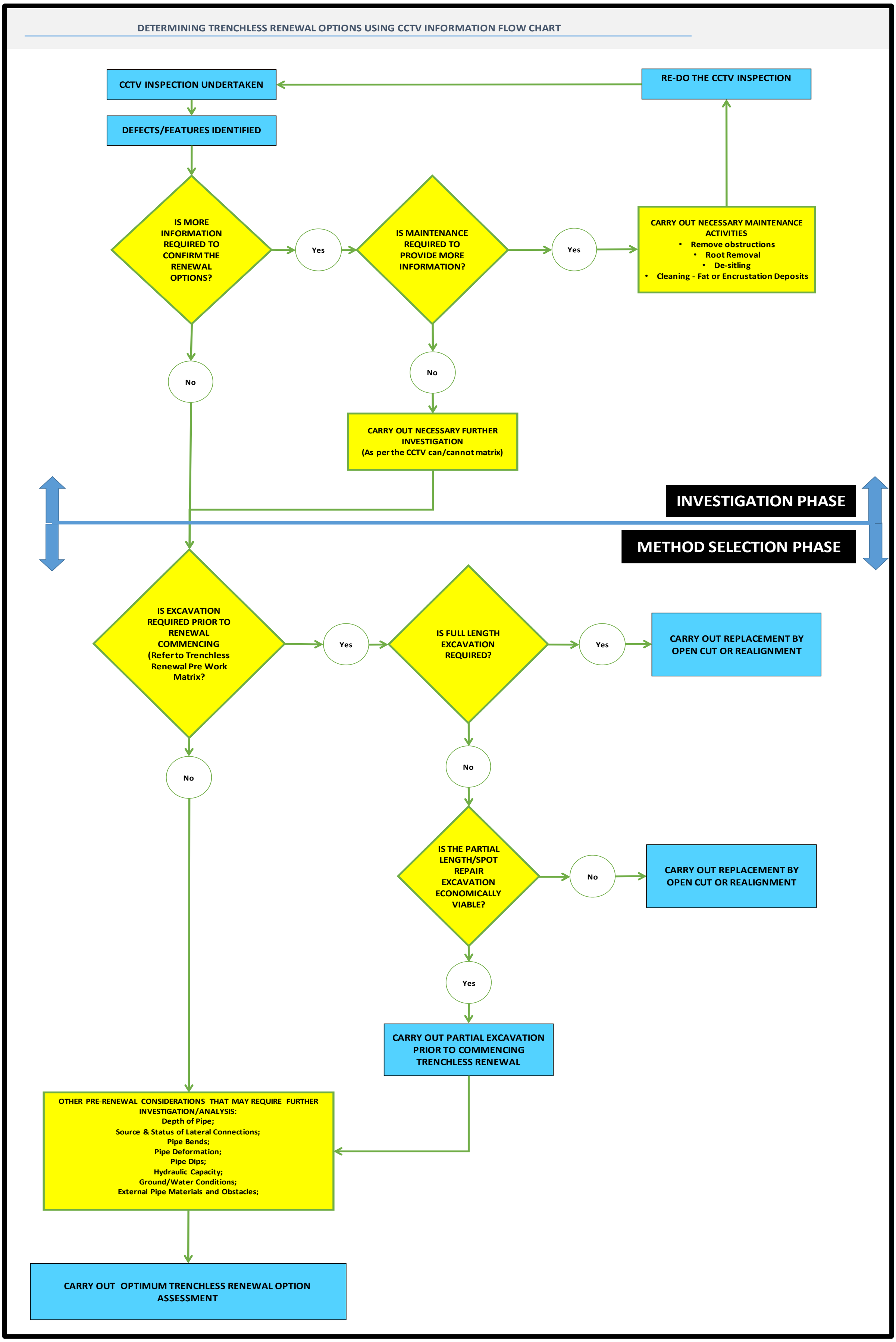
- The initial CCTV inspection could not provide enough information, due to a service issue, or;
- The initial CCTV inspection could not provide enough information, due to CCTV limitations;

If the CCTV could not provide enough information due to a service issue, then the appropriate maintenance activity needs to be carried out to allow re-inspection to be undertaken. Using table 2, any information that cannot be determined by CCTV should be determined using the further investigation techniques. Once renewal/replacement is confirmed as being required, the method selection phase can begin.

The method selection phase is where the trenchless renewal options are determined and cost benefit comparisons and risk assessments can begin. Each of the trenchless renewal options need to be compared together with all of the pre-renewal excavation activities. This is because the pre-renewal excavation activities are attributed to the specific methods. The amount or extent of excavation work determines whether trenchless renewal is optimal or not. Full length excavation immediately results in the trenchless renewal options being unfeasible, however, trenchless installation of a new asset may still be viable. This may also be the case when partial length excavation becomes less economical than the “alternate” option.

Finally, there are several other pre-renewal design considerations that may require further investigations depending on the trenchless renewal option. These other considerations, are identified in the flow chart, and include the depth of pipe, source & status of lateral connections, pipe bends, pipe deformity, pipe dips, hydraulic capacity, ground/water conditions, external pipe materials & obstacles.

*Figure 10: Renewal Option Selection Flow Chart*



# 5. SUMMARY

CCTV Inspections are vital to the determination of trenchless renewal options. Due to CCTV's ability in providing a wide range of pipeline information, it is the primary basis of pre-renewal investigation.

The process of determining a trenchless renewal option, includes the Investigation Phase and the Method Selection Phase. Using the flow chart, in conjunction with the Trenchless Renewal Matrix (Table 1) and the CCTV Can & Cannot Matrix (Table 2), allows the user to identify the level of investigation required to gain the information needed. Based on the information from the CCTV Can & Cannot Matrix (Table 2), the flow chart details where two levels of further investigation can be undertaken. The two levels of investigation include;

1. Further Investigation, to confirm the condition assessment and whether renewal/replacement is required;
2. Further investigation, to identify any other pre-renewal design considerations that were not identified completely from CCTV or at all;

External pipe condition investigations, tend to be considered sometime after the initial CCTV investigation and condition assessment. If we consider the limitations of the renewal options, and the limitations of CCTV, then necessary additional investigations could be undertaken, much sooner, as part of a more robust renewal investigation.

These further investigation techniques have been identified in the CCTV can/cannot do matrix and detailed further in the Appendix. Any decision to undertake or not, further investigation, needs be considered on a risk based analysis, with the appropriate mitigation measures in place. This work flow process ensures the user undertakes the process of determining trenchless renewal options, with all of the CCTV benefits, limitations and application parameters into consideration.

# 6. ACKNOWLEDGEMENTS

ProjectMax's Trenchless Renewal Selection Guide

An Examination Of Innovative Methods In The Investigation Wastewater Systems, WERF 2004

# 7. APPENDIX

Further investigation techniques are briefly detailed below;

**Exploratory Excavations (Pot Holing):** Is the process of digging a hole to identify details of underground services. This can be for identifying accurate measurements of the position of an underground service or it can be for locating an underground utility service that is near or within a construction projects path.

**3D Spatial Mapping Tools:** This technique involves using cutting edge technology that uses inertia gyroscopic surveying tools that can map the 3D position of a pipeline autonomously.

**Intelligent Inspection Tools (Electromagnetic Methods):** This technique involves the use of Intelligent Pigging tools or Smart Pigs in-line. Intelligent Inspection Tools use sensors to scan the inside of the pipeline and can identify spatial information of a pipeline and condition information including pipe wall loss and erosion/corrosion. The Electromagnetic Method involves inducing an electromagnetic field in the pipe wall from a transmitter and then determines the extent to which the field is changed by its passage through the pipe wall.

**Man Entry Inspection:** Man Entry Pipeline Inspection involves a person entering a large diameter pipeline to carry out a full visual inspection to assess the condition. All best practice Confined Space and Health & Safety Procedures need to be implemented when carrying out this technique.

**Laser Profiling Tools:** This inspection technique involves the use of a laser which is projected onto the pipeline creating a light ring around the cross section of the pipeline under investigation. This laser identifies the profile of the pipe and can be used with different software to provide accurate measurements of the pipe bore and the dimensions of several defects, such as cracks, deformation and pipe wall loss due to erosion/corrosion. Laser profiling tools have been combined with CCTV cameras and Sonar profiling equipment.

**Sonar Profiling Tools:** This inspection technique involves the use of high-frequency sound waves that are reflected within the pipe to identify and map the discontinuities. Sonar profiling can map the pipe wall and the sediment/water level and distribution in the pipe. Sonar profiling tools have been combined with CCTV cameras and Laser profiling equipment.

**Dye Testing:** This technique involves locating the position and source of a lateral connection within a public sewer main using dye. Dye testing is best used in conjunction with a CCTV inspection.

**Smoke Testing:** This technique involves the use of a smoke machine to confirm the connectivity of lateral connection with a mainline. This technique can be of use when a CCTV camera cannot navigate a lateral due to obstruction etc or dye cannot flow to show the connectivity.

**Lateral CCTV:** A CCTV inspection of a lateral connecting to a sewer main. In addition to the condition of the lateral, the alignment of the lateral can be identified and plotted when a sonde is in use.

**Core Sampling:** This technique involves using a core drill to obtain a sample of the pipe wall to allow examination of the type and extent of pipe wall loss.

**Full Sample Removal:** This technique involves excavating and removing a full pipe section for examination and analysis in a laboratory.

**Ultrasound Testing**: On metallic pipelines ultrasonic equipment can be used to measure the remaining wall thickness of the pipe and to some extent the amount of pitting. However, special techniques are needed with cast iron pipes due to the homogeneity of the wall, which can be rise to false internal reflections. The simple form of this technique is based on a hand held device but more sophisticated systems are available.

**Wave Impedance Probe:** This testing method was developed and patented by an Australian Company called Rock Solid Pty. The Wave Impedance testing technique is a combination of GPR and electromagnetic techniques. The method identifies the geological conditions of the soil surrounding a pipe or between a sewer and the ground surface.

**Ground Penetrating Radar**: The Ground Penetrating Radar technique is widely used in sub surface geotechnical investigation. It provides information on the location of underground services and identifies geological and manmade anomalies.

**Groundwater monitoring level bores:** Many Council's in New Zealand carry out monitoring of groundwater using monitoring sites called level bores. The data that is recorded at the monitoring sites can be obtained to identify ground water level, the physical and the chemical properties of the water.

**Flow Monitoring Analysis:** There are a wide range of flow monitoring devices and gauges that can produce information on flow rate, depth of flow, velocity, and rainfall and event interval time. Infiltration/inflow data can be obtained using flow monitoring for a specific pipeline or for an entire catchment.

**Ground Level Visual Investigation:** A ground level site investigation above the existing pipelines length is very important for any pre-renewal investigation and should be carried out at all times. However, to identify further information, in addition to a CCTV inspection, a ground level site investigation, can identify changes to the ground surface and areas where there is high groundwater. This could include sunken areas, extent of saturation to ground level, recently excavated areas and new developments built over or near the existing pipeline. All of these changes can provide clues as to what the surrounding soil conditions could be in regard to the existing pipeline. A Contractor needs to undertake their own site specific investigation prior to construction commencing.