Water Environment Federation
the water quality people®

FACT SHEET

Sanitary Sewer Rehabilitation

Sanitary sewer rehabilitation through repair and renewal is a common practice to reduce extraneous flow, and address structural defects. This fact sheet serves as a basic resource for practitioners providing rehabilitation information, methods and key industry references.

Introduction

Sewers are a series of connected pipes or pipelines that convey either wastewater or storm water to a designated downstream location for treatment and/or disposal. There are three different types of sewers: sanitary, storm and combined. Sanitary sewers and combined sewers convey wastewater from homes, institutions and businesses to a centralized treatment plant. Sanitary sewers carry only wastewater whereas combined sewers carry both wastewater and storm water. Wastewater conveyance and treatment are important because they help prevent waterborne illnesses and promote general sanitation before safely discharging to receiving waters. Many older sewer systems consist primarily of combined sewers in the central or older part of the city but are surrounded by sanitary sewers built in newer growth areas. Storm sewers convey snowmelt and rainwater from yards, sidewalks and roadways and route it to receiving waters directly or through best management practices and facilities to remove certain pollutants.

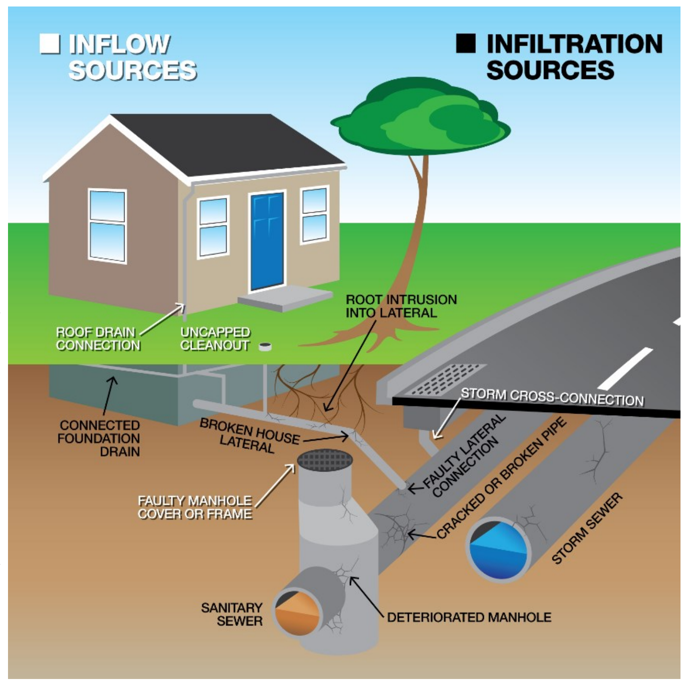

Figure 1: Typical Sources of I/I in Sanitary Sewer Systems (Image from WEF, 2017)

Sanitary and combined sewer systems usually contain private sewer laterals that connect individual buildings to main sewer pipelines. However, sanitary and combined sewers include more than just pipes. The pipes are part of an entire conveyance system that includes pump stations, force mains, manholes, storage facilities and other components. Similarly, storm sewer conveyance systems can also include pump stations, force mains, manholes and storage facilities. WEF's Sanitary Sewers fact sheet provides an overview of sanitary sewer basics, design, operation and maintenance, as well as repair / rehabilitation/ replacement issues. This fact sheet provides sanitary sewer rehabilitation information, methods and references.

The primary focus of this fact sheet is rehabilitation of the sanitary sewer mainline located in the public right-of-way or dedicated easement. In addition, it provides basic information on rehabilitation of private sewer laterals that connect homes/buildings to the sewer mains in the public right-of-way.

Sanitary Sewer Defects and Extraneous Flow

Sewers are designed to collect wastewater from intended sources and convey it downstream. However, some extraneous water may enter the pipes from unintended sources, either from surface water, groundwater through defects or direct illicit connection. Sewer defects are pipe system deficiencies resulting from system aging, structural failure, lack

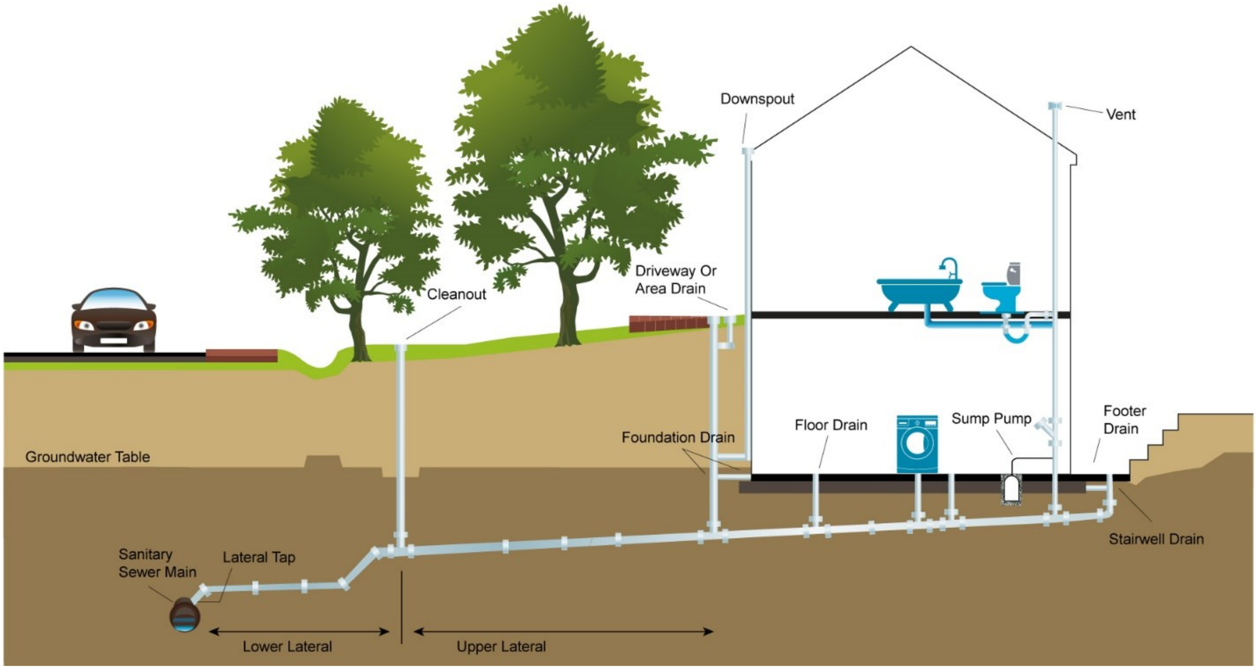

Figure 2: Example Sewer Lateral Configuration (Image from WEF, 2016)

of proper maintenance, and/or poor construction and design practices. They can include conditions such as broken pipe; leaking joints; manhole lids with holes and/or poor sealing; and root infested sewer laterals (See Figure 1). In sanitary sewers, this can lead to excessive infiltration and inflow (I/I), which can be more noticeable after precipitation conditions.

Extraneous water entering any collection system can consume some or all the available capacity as originally designed. These additional flows have a significant impact in relatively small sanitary sewers since they are sized to collect wastewater flow, not storm water. When the available capacity is reduced, or consumed, water levels rise and surcharging can occur. Surcharging, when the water level exceeds the height of the pipe, can accelerate pipe deterioration by forcing water to leave the pipe through defects into surrounding soil, and bringing in surrounding soil when the surcharge is alleviated, causing voids to form outside the pipe. Surcharging can lead to sanitary sewer overflows (SSOs) either in the street or into buildings, and surface flooding. I/I entering sanitary sewers is the highest level of concern.

Sewer laterals, which connect buildings on private properties to sewer mains, are often a significant source of I/I (See Figure 2). A comprehensive I/I reduction program requires effectively addressing private property I/I (PPII) sources. Private property laterals can account for half of the I/I entry to sanitary sewers. WEF's *Private Property Infiltration and Inflow* fact sheet outlines key considerations for municipal utilities establishing a framework for PPII mitigation activities such as program approaches, policy and legal issues, funding, public outreach, and implementation.

Sewer rehabilitation, or restoring to an improved condition, is a means to reducing the extraneous flow entering the system, which in turn lowers the potential for causing SSOs and flooding by correcting defects. Sewer defects can also be structural in nature and rehabilitation can be necessary to prevent structural failure. Increasing extraneous flow is one symptom of the poor structural condition of aging sewers in many cases. Hence, the sewer rehabilitation provides a solution to extend the useful life of the asset. Consequently, rehabilitation can result in reduction of extraneous flow which in turn reduces sewer surcharges and unintended poor system performance.

The state-of-the-art industry experiences indicate that before investing in sanitary sewer capacity improvements to handle excessive I/I, it is prudent to improve sewer system structural conditions to realize practical levels of I/I reduction first and then consider supplementing with right-sized conveyance/storage and downstream treatment systems. It has also been proven that asset management approaches to sewer system rehabilitation are effective and adding extraneous (I/I) flow reduction criteria will bring overall comprehension to prioritize public investments. Reducing I/I is a foundational step before adding additional sewer assets. Moreover, reducing PPII is critical for overall success of I/I reduction efforts. Rehabilitating the sewer system should be undertaken first to determine the magnitude of I/I reduction possible. It may be that partial or comprehensive rehabilitation of the system restores adequate levels of the conveyance capacity. Additional conveyance/storage/treatment capacity should be supplemented as needed.

Sanitary Sewer Rehabilitation

Sewer rehabilitation can be considered both repair and renewal, to reduce extraneous flow, and address structural defects. Rehabilitation is different from system replacement in that repairs selectively target I/I sources and structural defects rather than complete replacement of pipes and/or manholes. Not all sewer defects cause capacity restrictions or are considered I/I sources.

Repairs are generally made to allow the pipe to function to the end of its useful life. They can involve location specific repairs that seal the sewer pipeline and may restore the structural integrity of the pipe at that location, but does not restore the structural integrity of the entire pipe. It can include repair methods that seal the entire pipe segment but do not restore structural integrity. There are several methods of sewer rehabilitation, including internal and external point repairs, sealing joints or cracks, spray lining or applying a coating, and partial replacement.

Renewal is more comprehensive than repair, and extends the useful life of the pipe. Renewal includes techniques that renew the structural integrity of the entire sewer pipeline segment between manholes. Pipeline renewal techniques include a variety of liners, coatings, panel systems and replacing segments of pipe. Like all rehabilitation methods, eventually renewal technologies will generally decrease in effectiveness until replacement becomes the most cost-effective alternative.

Sewer rehabilitation projects can include a mixture of repairs and renewal – with a focus on both restoring structural integrity and practical reduction of I/I. Each system component is analyzed to determine where defective areas allow I/I to enter the system, and the most cost-effective repair or renewal method is applied to eliminate that source of I/I while ensuring that the extraneous water does not migrate to enter the system through a different defect. For sewer mains, a rehabilitation project may include a combination of selective sealing, point repairs, partial replacement, and lining. It is through a comprehensive analysis that the most cost-effective combination of repair, renewal, and replacement techniques are employed to meet objectives for structural condition improvements, I/I control, or both. Depending upon the size of the pipe, some methods can only be used on larger diameter pipe, while others are more universal.

Sanitary sewer conditions affecting rehabilitation

With a multitude of options available to rehabilitate sewers, the different conditions affecting the sewer should be considered before deciding on a rehabilitation method. Factors to consider when selecting a rehabilitation method include, but are not limited to the following:

- Pipe characteristics: age; diameter; shape; material; length; joint type and frequency; slope; depth; and number of service laterals connected
- Soil and groundwater conditions that effect the structural conditions and active infiltration and/or high groundwater
- Sewer location, i.e., public right-of-way or an easement or private property
- Service area characteristics: number of connections and/or tributary area; previous evaluation data such as televised inspection, smoke testing, dye water testing; maintenance history on how frequently does this sewer require cleaning or root cutting; and flow monitoring data that indicates dry weather conditions and/or wet weather response
- Installation conditions, access restrictions, and other factors to be considered during construction

Methodologies for sewer pipe rehabilitation

Sewer pipe failure is most often a result of lack of maintenance. There are 3 stages of decay that warrant definition and are a direct result of I/I (See Figure 3).

- **Stage 1**: Initial Defect allows the deterioration process to begin. Pipe remains supported by the surrounding soil.
- **Stage 2**: Structural defects continue deterioration to a point where soil around the pipe egresses into the pipe through infiltration at defects, causing a loss of supporting soils and voids to develop outside the pipe, accelerating deterioration.
- **Stage 3**: Loss of support from surrounding soil allows deformation or joint defects to degrade, leading to structural failure.

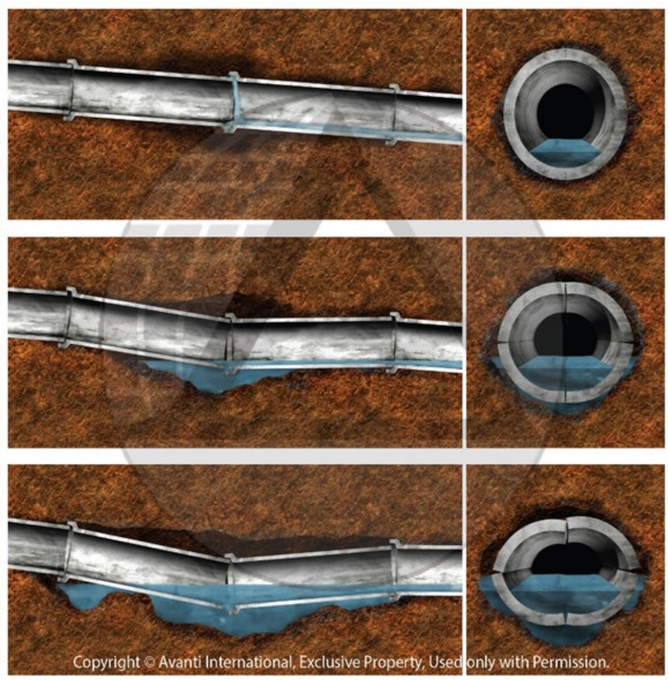

Figure 3: Process of Sewer Failure (Image from Avanti International)

Based on a thorough condition assessment, both structural and non-structural trenchless rehabilitation methodologies are proven to remediate and restore useful life of sewer pipe. The advantages of trenchless are numerous including time-to-benefit, minimal disruption to the community, and lower project costs. As opposed to defaulting to open-cut replacement methods, trenchless alternatives provide several options.

Trenchless Methodologies: Non-structural Rehabilitation

- **Injection Grouting**— Utilizing the *Test, Seal, and Validate process with Remote Packer Method*, injection grouting is a remediation method for controlling infiltration and should be performed prior to pipe degradation requiring structural repair. With the aid of closed circuit televising (CCTV), the remote packer aligns squarely with the joint, expands bladders on both sides, and performs an air test. If it does not leak air, it will not leak water. If it fails the air test, a low viscosity acrylic grout is pressure injected through the defect into the surrounding soil, and provides stabilization. A second air-test is then performed to validate the seal. Gel-times can be customized from 5 seconds to over 12 hours based on the degree of permeation required into the soil. The gel-soil matrix forms an impermeable barrier to eliminate groundwater intrusion and according to the US Department of Energy, has a 362-year half-life in the soil. It is noted there are multiple types and variations of grouts available for use, depending on the application and desired results.

Trenchless Methodologies: Structural Remediation

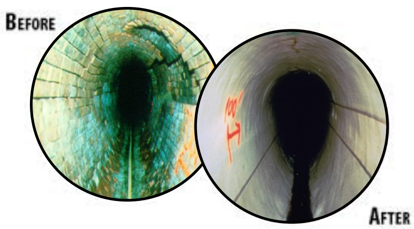

Figure 4: Sewer pipe condition, before and after CIPP (images are used courtesy of Aegion Corporation)

Pipe linings are tight fitting and installed continuously from one access point to the next. Linings provide structural renewal of the pipe barrel, improve the performance of the existing sewer, and are appropriate for various pipe sizes and shapes.

- **Cured in Place Pipe (CIPP)**— Used primarily for structural rehabilitation of sewer lines, CIPP consists of a tubular composite product composed of a reinforced mesh or felt material saturated with a thermosetting resin that cures through ambient temperatures, hot water, steam, or ultraviolet (UV) light. Before and after images of CIPP rehabilitation are shown in Figure 4. The resins are typically selected based on the CIPP performance requirements (gravity or pressure) and the nature of the wastewater (domestic or industrial).

- **Sliplining**— Used to rehabilitate deteriorating sewer pipes by inserting a smaller pipe inside the host pipe. High density polyethylene (HDPE) is a widely-used pipe material for sliplining; however, other materials such as polyvinyl chloride (PVC), fiber reinforced polymer (FRP) pipe, polymer concrete pipe and other pipe materials have been used successfully. The slipliner pipe is inserted into the existing pipe at an excavated access pit location. For small diameter pipe, a continuous pipe, often butt-fused HDPE, is typically pulled through the existing pipe by a cable from the termination location. Large diameter pipes more often are pushed, jacked or winched into place, piece-by-piece. Depending on the design conditions and pipe size, the annular space is grouted.

- **Spiral Wound Pipe**— This renewal technique is based on creating a pipe in situ by using HDPE or PVC-ribbed profiles with interlocking edges. The ribs, which may be reinforced with steel, enhance the hoop strength of the pipe. After the strips are installed, the annular space is grouted in entry size pipe. Small diameter pipe (12-inches or less) is typically not grouted except at the terminations and any side connections. Spiral wound pipe can be fitted to circular or odd-shaped pipes such as horseshoe or egg-shaped sewers.

- **Fold-and Form Pipe**— This sewer rehabilitation method inserts a folded thermoplastic pipe into the existing pipe which is expanded or re-rounded back to a circular shape through pressure, heat, or mechanical means. Fold-and-Form pipes consist of PVC or HDPE thermoplastic material folded into a cross-sectional shape that is significantly smaller than that of the pipe to be rehabilitated.

Structural and Nonstructural Spray or Spun Cast Systems

In-situ spray or spun cast coatings or structural solutions may be used to extend the life of an existing sewer by increasing its strength or protecting the existing surface from corrosion or abrasion. Coatings also may be used to improve hydraulic performance

- **Corrosion Protection** (nonstructural): Coatings for corrosion control limit or prevent damage to the pipe walls, often above the flow line in entry size sewer pipes. There are a variety of coatings available for rehabilitation applications to pipes of all diameters. Spray-on epoxy, polyurethane, polyurea and other chemical formulation coatings can be selected to match the application, pipe diameter or size and level of protection needed. Since coatings for corrosion control require a bond to the host pipe, the host pipe wall must be properly cleaned and dried.

- **Reinforced Shotcrete** (structural): Shotcrete is the application of concrete or mortar conveyed through a hose and pneumatically projected at high velocity onto the surface of the host pipe. Reinforcement in the form of wire mesh reinforcing rods can be used. Shotcrete includes both wet- and dry-mix processes, but the term *shotcrete* typically refers to the wet process: the dry-mix process typically is referred as *gunite*.

- **Centrifugally Cast Concrete (structural):** Centrifugally cast concrete pipe is used to rehabilitate culverts, storm sewers and sanitary sewers 30 to 120 inches in diameter. Once the host pipe is cleaned and prepared, the concrete is robotically spun cast onto the surface of the host pipe. Admixtures to the spun cast concrete can provide resistance to corrosion and future bacterial growth on the interior surface of the pipe.
- **Cast-in-Place Concrete (structural):** Rehabilitation with reinforced or non-reinforced concrete is an effective method for a variety of conduit shapes. The structural condition of the pipe determines if steel reinforcing is required. Slip or fixed-form construction practices are used for concrete placement typically in large diameter pipe (48 inches and greater) with adequate access for materials to be handled properly.

It is common practice for multiple technologies and more than one methodology to be deployed on a mainline sewer rehabilitation project. Most lining projects require minimal or a no infiltration environment, flow diversion and pipe cleaning. Coating projects may require flow diversion and specific surface preparation, depending on whether a bond to the host pipe or structure is required. Utilizing coating techniques requires removal of active infiltration. The underlying assumption accompanying sewer rehabilitation techniques is that they are: appropriate for the pipe condition, adequately designed and specified and installed correctly. Otherwise, the sewer rehabilitation may not be successful.

The summary matrix on page 6 is provided as an introduction to potential rehabilitation methods, type of rehabilitation, advantages and disadvantages and applicable pipe size. As noted on this matrix, not all sewer rehabilitation techniques are common to both mainline sewer and the lateral sewers connecting private homes and buildings. The summary matrix (See Page 6) should be considered as a starting point for evaluating rehabilitation alternatives and it is not intended to be comprehensive. It is advised that practitioners refer to industry references provided below and stay current with technical advancements, and continually adapt as appropriate.

Additional Resources

"Sanitary Sewers," a 2011 fact sheet developed by the WEF Collection Systems Committee
https://www.wef.org/globalassets/assets-wef/3---resources/topics/a-n/collection-systems/technical-resources/ss-fact-sheet-with-wider-margins-1.pdf

"Private Property Infiltration and Inflow" a 2015 fact sheet developed by the WEF Collection Systems Committee
https://www.wef.org/globalassets/assets-wef/3---resources/topics/a-n/collection-systems/technical-resources/ppii-fact-sheet_sep-2015.pdf

Existing Sewer Evaluation and Rehabilitation, MOP FD-6 (3rd Edition), a 2009 manual by WEF and the American Society of Civil Engineers
https://www.e-wef.org/Store/ProductDetails.aspx?productId=5302

"Private Sewer Laterals," a 2014 resource by the U.S. Environmental Protection Agency (EPA)
https://www3.epa.gov/region1/sso/pdfs/PrivateSewerLaterals.pdf

State of Technology for Rehabilitation of Wastewater Collection Systems, a 2010 EPA publication. Reference chapter 5 "Sewer Lateral Renewal Technologies."
nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P1008C45.TXT

National Database Structure for Life Cycle Performance of Assessment of Water and Wastewater Rehabilitation Technologies, EPA /600/R-14/251, January 2014
nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100LDG0.TXT

National Association of Sewer Service Companies (NASSCO). 2014. Overview Of Lateral And Main/Lateral Connection Lining And Sealing Technologies.
https://www.nassco.org/sites/default/files/lateral_rehab_white_paper.pdf

National Association of Sewer Service Companies (NASSCO). Specifications Guidelines.
https://www.nassco.org/resources/guideline-specs

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Sanitary Sewer Rehabilitation Summary Matrix

Technique	Type	Estimated Service Life (USEPA, 2014)	Advantages	Disadvantages	Potential Application, Pipe Diameter	Mainline /Lateral/ Manhole
Cementitious Coatings: Shotcrete or Gunite	Structural/ Non-Structural	20 or more years	All shapes and connections accommodated,	Address active infiltration, requires confined space entry	48" and larger	Yes / No / Yes
Spun Cast Concrete	Structural/ Non-Structural	Same as concrete pipe (Army Corps of Engineers)	Robotically applied. Antibacterial additive can be added when microbiologically induced corrosion is present.	Address active infiltrations	30 – 120"	Yes / No / No
Spray Polymer Coatings	Structural/ Non-Structural	50 years	Encapsulates sewer, can be designed for structural load, can improve flow coefficient	Sags and dips in pipe remain, service interrupted, must stop active infiltration	6" and larger as long as the host pipe wall can be properly cleaned and dried.	Yes / No / Yes
Cured-in-place-pipe (CIPP)	Structural	50 years	Prevents further degradation and collapse, improves flow coefficient	Sags and dips in pipe remain, service interrupted, infiltration may follow annular space	3" to 120"	Yes / Yes / Yes
Thermo-formed Pipe (Fold and Form)	Structural	20 or more years	Prevents further degradation and collapse, improves flow coefficient	Sags and dips in pipe remain, service interrupted, Infiltration may follow annular space	4" to 30"	Yes / Yes / Yes
Injection / Pressure Grouting	Non-structural	20-25 years	Seals leaking joints, stabilize supporting soils	Offset joints or longitudinal cracks may not seal	4"and greater	Yes / Yes / Yes
Sliplining	Structural	50 years	Quick insertion, some bends are accommodated	Circular and non -circular, loss of cross sectional area	4" to 144"	Yes / Yes / No
Spiral Wound Pipe	Structural	50 years	Prevents further degradation and collapse, improves flow coefficient	Sags and dips in pipe remain, service interrupted, Infiltration may follow annular space	6" to 144", Larger sizes on case by case basis	Yes / No / No